Vulnerability Assessment of Rural Communities in Southern Saskatchewan

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Water resources in Canada are of major environmental, social and economic value. It is expected that climate change will be accompanied by more intense competition for water supply in water-stressed agricultural areas such as the southern Prairies. Beyond physical impacts, drought can be seen as a socio-economic and political problem which ultimately has implications for community-level vulnerability to climate change. This thesis presents empirical vulnerability case studies focused on the exposure-sensitivity and adaptive capacity of Coronach and Gravelbourg in southern Saskatchewan. The results illustrate the fact that farmers or ranchers are not merely passive victims of drought. They also take an active role in shaping the environment around them, thus affecting their own vulnerability to drought. Therefore, by understanding the causal linkages of the coupled social-environment system, a more comprehensive understanding of community vulnerability is achievable and informed decisions can be made based on this thorough understanding of local conditions. In the second part of this thesis, the potential of soft water path is evaluated as a possible adaptation strategy. Based on the results gathered in the first part of this thesis, adaptation measures are tailored to address specific needs of different sectors in the Town of Coronach and the Town of Gravelbourg while ensuring ecological sustainability. Examples of possible paths (adaptation measures) are suggested in order to increase community adaptive capacity to water shortages in light of future climate changes.

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Table of Contents

List of Figures

List of Tables

Chapter 1
Introduction and Overview

1.1 Introduction

Water resource scarcity is accepted as one of the world’s top resource problems. According to the United Nations World Water Development Report published by UNESCO (2006), 70 percent of the Earth's surface is covered with water. However, out of the 70 percent, only 2.5 percent is fresh water, while two thirds of this fresh water is frozen in glaciers and polar ice caps (UNESCO, 2006). There are differences in water resource availability in different parts of the world. Figure 1 shows the total renewable water resources available based on population size.

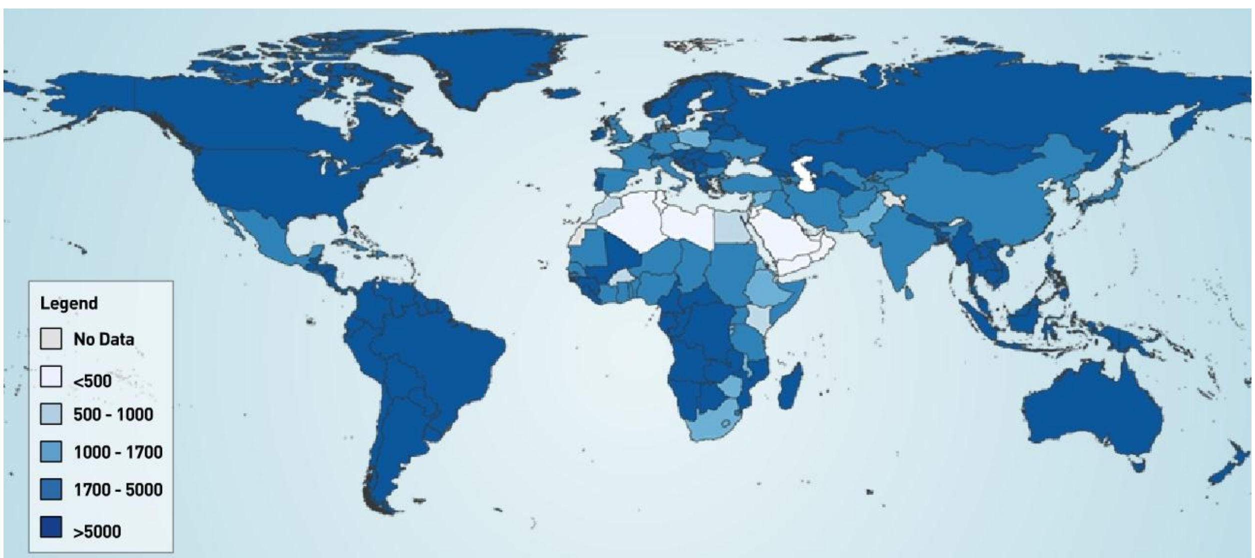


Figure 1 Renewable water resources per person (m^3/year) (Food and Agriculture Organization, 2011)

As water demand by now exceeds water supply for many places globally, it is widely recognized that sustainable water management must be undertaken to protect this precious resource. Despite the fact that 6.5% of the world’s freshwater supply is available to Canada, only one-third of that 6.5% is available to the most populated part of the country, which is the southern parts of Canada (Sprague, 2007). Recent studies show that the availability of water in the southern parts of Canada is under great pressure from various anthropogenic activities, and it is expected that our water resources are in danger of depletion in the near future (Clarke, 2004). Coupled with the impact of climate change, there is going to be an added burden to the already stressed system. Long-term changes are being ignored until they become urgent immediate threats. The industrialized and industrializing world's reliance on fossil fuels and changes in land use patterns are contributing to the accelerating rate of climate change (IPCC, 2007b). Climate change is no longer a fact that can be ignored. Scientific consensus is that climate change is happening. Out of the 30,000 available studies on climate change, almost 90 per cent of them show trends of increasing temperature and these trends are very likely to be the result of anthropogenic activities (IPCC, 2007b). The IPCC Fourth Assessment Report also concluded that the warming trend will lead an increase in the frequency and magnitude of extreme weather events, such as drought and flood (IPCC, 2007b).

Water resources in Canada are of major environmental, social and economic value. Keeping in mind that our water supply is not boundless, it is time to focus our attention on the conservation of water resources. With the accelerating rate of climate change, droughts caused by climate change are posing a major challenge to water-dependent communities and activities located in semi-arid areas. Yet, not just agricultural communities, other sectors will also be affected by the increasing impact of climate change. It is projected that by 2046, the demand for non-agricultural use of water will increase by 63 to 132 percent over present demand in the Southern Saskatchewan River Basin owing to further economic development (Lalonde and Corbett, 2004). This figure illustrates that merely focusing on the agricultural sector is no longer sufficient to cope with the upcoming changes. As drought affects all water dependent activities and not only agriculture, rural communities provide ideal case studies since they involve not only farmers and ranchers, but other non-agricultural water uses as well. Vulnerability assessment is often used as a first step to inform decision making on adaptation measures by investigating factors that contribute to the communities' susceptibility to drought and assessing their adaptive capacity to cope with changes. It highlights factors that increase the exposure and sensitivity of a community and facilitates the design and implementation of adaptation measures. Therefore, this thesis presents vulnerability assessment case studies focused on water shortages in two rural communities in southern Saskatchewan, and makes recommendations for increasing community adaptive capacity in light of climate change.

Climate change is one of the most widely studied topics in recent times. Statistical downscaling of Global Climate Models to the local scale presents a challenge; beyond this, questions of how climatic changes will affect water resource availability remain highly uncertain. Despite the increasing number of studies focusing on the impact of climate change on water resources, current climate models can only provide a suite of possible scenarios and there remain considerable uncertainties on the seasonal and geographical distribution of rainfall (Fekete et al., 2004; IPCC, 2007b; Prasanna and Yasunari, 2011). Although a reliable prediction of the changes in water resources is not available, climate and water researchers expect that climate change is going to have a significant impact on the hydrological cycle of many regions (Wood et al., 2004; Held and Soden, 2006; IPCC, 2007b). The intensification of the global hydrological cycle will increase the frequency and intensity of extreme events in this century owing to less frequent but more intense precipitation (Trenberth, et al., 2003; Millar and Yates, 2005; Held and Soden, 2006; Sauchyn and Kulshreshtha, 2008). Climate model simulations show the hydrology of arid and semiarid areas is particularly sensitive to climate variations (Frederick, 1997). Small changes in temperature and precipitation in these areas could lead to relatively large changes in runoff (Frederick, 1997). Apart from the changes in water supply, water demand is likely to increase with higher temperature. With higher temperatures and associated increased evapotranspiration translating into higher demand for irrigation and other agricultural and non-agricultural purposes, there will be more intense competition for water supply. For example, in the western United States, farmers try to cope with the increasingly drier summers by demanding more water for irrigation, which in turn leads to a conflict with the rapidly growing urban areas that demand water for household and municipal uses (Postel, 1996). Apart from sectoral conflicts, transboundary competitions also exist. For instance, the Danube is shared by 19 countries while the Nile is shared by 11 countries (Watkins, 2006). The increasing water demand by upstream countries creates constant water conflict with downstream users. As a result, water-dependent communities in arid and semiarid area will be seriously affected by the impact of changing water availability.

Water is one of the most precious assets on earth. It is not merely a physical resource that helps to sustain basic ecosystem functions. Dynamics in ecological, socio-economic and political systems are crucial for understanding environmental change and explaining human-environmental interactions. In every cultural context, water takes on different social, political, and environmental meanings, and these have a powerful effect upon patterns of water use. The study of drought may appear as a purely physical study and assessment; yet, one cannot underestimate the socio-political factors behind this issue, which have direct relationship with community’s vulnerability and their adaptive capacity.

As aforementioned, vulnerability assessment is an essential tool for drought management. It could be used to identify opportunities for adaptation strategies so as to deal with more severe and prolonged drought effectively. By looking at drought from different perspectives and from previous drought experiences of the community, information can be gained on (1) how different groups of actors in the rural communities responded to the management measures; (2) whether or not their specific needs were met; and (3) community's ability to cope with future drought. Vulnerability assessment will be able to provide information needed for planning case-specific drought adaptation strategies.

This thesis not only assesses water-related vulnerability of two rural communities in Southwestern Saskatchewan, but also provides options to avoid the adverse impact of climate-induced water shortages. Management methods for water resources tend to be in a one-size-fits-all manner as there is a false assumption of homogeneous communities (Kuehne and Bjornlund, 2007; Bennett et al., 2008). However, communities are heterogeneous. Multiple actors interact and create a unique situation for every community. Therefore, a universally applicable management method is not the panacea for drought management. With the level of uncertainty on the impact of climate change, current water management practices may not be able to deal with the situation adequately (Milly et al., 2008). As a result, management methods should be flexible and able to adjust according to changing needs.

In the face of uncertainty in water resources management, it is crucial to adopt effective measures to improve the adaptive capacity of rural communities so as to ensure they have the ability to deal with more severe climate-induced water shortages in the future. Sustainable water management could be achieved by adopting soft water path, which focuses on improving overall productivity of water rather than searching for new supplies by "complementing existing water infrastructure to limit or eliminate the need for further supply-side developments" (Rijsberman, 2006; Brandes et al., 2005). Soft water path is a planning approach that changes the concept of water demand. "Instead of viewing water as an end product, the soft path views water as the means to accomplish certain task" (Brandes and Brooks, 2007). It aims as eliminating the need of further supply-side development. As regions of Canada will face more climate-induced droughts, there is an urgent need for focusing our attention on water resource management. The current study allows rural communities in Southern Saskatchewan to showcase the feasibility in using soft water path as an effective and efficient adaptation measures to reduce the impact of drought for municipal water users. This thesis argues that by adopting soft water path; municipal water users could reduce their vulnerability to drought and future climate change.

1.2 Rationale

Canada is viewed as a country with abundant water supplies. Many people believe that water supply in this country is unlimited and water shortage will never be a problem to Canadians. However, much of the fresh water supply in Canada is from non-renewable sources. In terms of the total volume of water in Canadian lakes, Canada has approximately 20% of the water in all of the world's lakes; however, we only have around 6.5% of world's renewable water supply (Bakker, 2007). Also, most of the rivers in Canada flow to the Arctic Ocean in the north; therefore, the most populated part of Canada may not have as much water as we thought. According to Statistics Canada (2010), 98% of the population in Canada is located in the South and they have access to only 38% of the renewable water supply in Canada, which is 2.6% of the world supply (Bakker, 2007). Together with the impact of climate change, Canada is not exempt from water shortage just like other countries.

Increase in climate variability is having considerable impacts on the rural communities, especially in some areas of the Canadian Prairies where water shortage has been a serious problem throughout the years. This research is part of a SSHRC-funded project, where six communities (Coronach, Gravelbourg, Kindersley, Maidstone, Maple Creek, and Shaunavon) were selected for community-based vulnerability assessment. The two rural communities, Coronach and Gravelbourg, assessed in this thesis are located in Palliser's Triangle, which is a semi-arid area in the Prairie Provinces. It is considered the "driest region of Canada" as it is located in the rain shadow area of the Rocky Mountains (Gauthier, 2005). Over the past 100 years, over 40 droughts were recorded in this area (Marchildon, et al., 2008). Although the local communities are accustomed to the recurring droughts in this area, the increasing frequency and magnitude of droughts caused by climate change is posing a major challenge to them, especially during the summer months when dryland farmers are relying on precipitation to replenish soil moisture for the growth of crops. Drought reduces soil moisture, which leads to soil erosion and eventually a reduction in yields. Apart from biophysical impacts, drought also leads to various socio-economic impacts. The 2001–2 droughts were so serious that for the first time in 25 years, there were zero to negative net farm incomes for the Prairie Provinces and over 41,000 jobs were lost (Statistic Canada, 2003).

Surface water is the main source of water supply in southwestern Saskatchewan. Water supplies are scarce in this region because of its location and climate. The study area is categorized as a non-contributing area where evapotranspiration is higher than precipitation. Climate models have also projected that this area is going to face a greater risk of drought in this century because of the warmer and drier summers (IPCC, 2007b; Sauchyn and Kulshreshtha, 2008; Sauchyn et al., 2003). This shows that there is an urgent need for an effective planning strategy to cope with the increasing vulnerability caused by climate change. As a result, this thesis used rural communities in southern Saskatchewan as case studies to investigate the impact of drought associated with climate change and the Town of Coronach and the Town of Gravelbourg are then used as examples to explore the feasibility of soft water path as an option to reduce community vulnerabilities.

This purpose is associated with the following research questions:

1) How vulnerable are rural communities to water shortage in Southern Saskatchewan? What are the forms of exposures faced by rural communities and what are their adaptive capacities both in the present and in the future?

2) In terms of water scarcity adaptation for municipal water users, how can different sectors in the Town of Coronach and Gravelbourg increase their adaptive capacity by improving their water efficiency with existing water supplies?

In order to answer these questions and achieve the overall research purpose, two related empirical research activities were undertaken. The first one was to understand the processes that shape the impacts of drought on rural communities as well as factors that enhances or constrain their adaptive capacity to water shortage. A Community-Based Vulnerability Approach (CBVA) was used to assess drought vulnerability of two rural communities, Gravelbourg and Coronach, in southern Saskatchewan. Impacts of drought and different forms of exposure to drought on various sectors (agricultural, residential, commercial and industrial) of the two communities were examined. Adaptation measures of the two communities were investigated focusing on their ability to minimize risk associated with past and future droughts events.

The second empirical component of the study is to use the two towns as case studies to examine the practicability of soft water path in reducing their vulnerabilities by minimizing their water consumption. Despite the urgency of rural community water shortage, no soft water path analysis has been conducted in this area. As a result, communities in southern Saskatchewan can be used as case studies to assess the potential of soft water path as one of the adaptation measures. These case studies provide site-specific insight into water resources management based on the result from the vulnerability assessment. By understanding the communities' exposure-sensitivity and adaptive capacity from the first part of the study, soft path measures are suggested in hopes of contributing to the region's long term water strategy and decreasing the communities' vulnerability to future droughts.

1.3 Thesis Outline

This thesis consists of eight chapters. Chapter 1 briefly discusses the background and introduces the research questions and objectives. Chapter 2 reviews existing literature regarding the topic of vulnerability assessment as well as soft water path. Three main vulnerability assessment frameworks are reviewed. Comparisons are made among supply-side, demand-side, and soft water path regarding capacity building in the face of climate-induced water shortages. Existing knowledge gaps are identified and discussed in this chapter. Chapter 3 provides the conceptual framework used to guide the research. Chapter 4 describes the study area in terms of its biophysical and socio-economic factors. Chapter 5 explains the methodology used to collect and analyze the data gathered by interview and other secondary sources. Chapter 6 presents the results of the CBVAs for the two communities and indicates possible future vulnerabilities of the two communities. Chapter 7 discusses soft water path as a possible adaptive strategy based on the findings in the previous chapters. Chapter 8 summarizes previous findings and suggests further research opportunities. The final part of this thesis contains references and appendices.

Chapter 2
Literature Review

This chapter provides an overview of relevant research on drought and vulnerability assessment, as well as water resources management. The first section examines various definitions of drought and introduces limitations in quantitative definitions. The second section examines a number of commonly-used approaches to climate vulnerability assessment. The final section discusses different approaches for water resource management. The review presented in this chapter will contribute to the conceptual framework and the formulation of methodology presented in chapters 3 and 4 respectively.

Environmental issues do not present themselves in well-defined boxes. Instead, they are interconnected in all kinds of ways. In the traditional positivist paradigm, science is believed to be producing reliable knowledge that is technical, accurate and unbiased. As a result, most environmental management policies are informed by scientific research and the dominant research paradigm at the present time is a quantitative positivist approach. However, traditional scientific studies are limited in understanding and solving the problems of our environment (Gunderson and Holling, 2002; Berkes, 2010). Natural elements are never isolated from the social environment. They cannot be interpreted in terms of their impacts on people without taking into consideration the social and economic conditions.

Even with major improvements in forecasting technology, there is still a relatively high level of uncertainty in the scientific assessment of climate change. It is predicted that the damage caused by climate change is going to increase in the coming decades owing to the timescales of climatic processes and feedbacks (IPCC, 2007c). This illustrates a growing vulnerability of our society regardless of all the improvement in science and technology (Wilhite and Vanyarkho, 2000). Not until the IPCC third assessment report were substantial resources were dedicated to the social dimension of climate change, such as the study of how local communities can adapt to the upcoming changes. Climate change alone could not be considered as a threat or a problem unless it is coupled with humans' needs; for instance, increasing temperature affects the biological systems and changes the timing of plant growth and animal migration, which in turn affects the livelihood of farmers and hunters. Communities' responses to environmental changes are driven by the complex interactions among the environmental condition itself together with the communities' culture, values, needs, institutional structure, and other conditions external to the communities (Smit and Pilifosova, 2001; Cannon et al.,2003; Wisner et al., 2004; Downing et al., 2006; Schneiderbauer and Ehrlich, 2006). It has been demonstrated that it is crucial to understand how people both perceive and utilize the environment and natural resources. Therefore, there is an urgent need to engage in a more holistic approach in vulnerability assessment in the face of climate change.

2.1 Drought

Drought is a complex phenomenon that has been defined in multiple ways. The impact of drought can extend over a large geographical area. It is a slow-onset hazard that cannot be defined by its cause and is usually defined by its effects. Droughts are commonly perceived as extended periods with drier than normal conditions caused by a decrease in precipitation. However, studies show that drought can be divided into different categories (Dracup et al., 1980; Wilhite and Glantz, 1985; Hisdal and Tallaksen, 2003; Smith, 2006).

Traditional understanding of drought assumed that drought consists of interactions among three main components - rainfall, runoff and soil moisture. Under the traditional understanding, the first type of drought is meteorological drought, which means below normal precipitation. Changes in meteorological factors are presumed to be the main causes of drought. These early definitions of drought were based solely on a reduction in precipitation. In some regions, drought may mean any period without rain for more than one week; while in other regions, drought may be defined as one year without rain. Until the 20th century, the U.S. still identified drought as 21 or more days with rainfall 30% below normal (Kallis, 2008). This definition ignores the fact that the impact of water shortage varies throughout the year. For example, agricultural communities may value rainfall in the growing season more than the rest of the year. Another approach that is commonly used in measuring drought is the Palmer Drought Severity Index (PDSI). PDSI determines moisture availability by taking precipitation and temperature into account. It is defined by the availability of moisture relative to the normal condition. The index is a function of the length of abnormal moisture deficiency and the severity of the deficiency (Smith, 2006). Therefore, it is standardized to local climate and is able to demonstrate the condition of drought.

The second type of drought is hydrological drought. It is defined by negative impact of water resource availability caused by below normal stream flow or decrease volume of lake or groundwater. It has taken the demand of water into consideration. Hydrological drought occurs when a community receives below normal precipitation for a number of years and they no longer have access to water supplies to sustain their livelihood as their reservoirs and nearby rivers are depleted. Restriction in water use and water rationing are usually the solutions offer to deal with this type of drought.

Another type of traditionally defined drought is agricultural drought. It is identified by the deficiency in soil moisture. Agricultural drought happens when soil moisture is insufficient to support the average crop growth (Smith, 2006). It is regarded as a severe form of drought because it affects not only the farmers themselves. In countries that are highly dependent on the export of agricultural product, the national economy will be affected as well.

In addition to the above definitions of drought, there are also other unconventional definitions of drought, such as ecosystem drought, which is defined by negative impacts to natural habitats as well as ecosystem services; and economic drought that can be identified by a decrease in economic production as a result of low water supply. The different forms of drought demonstrate different types of water shortage with regards to the specified needs for water. It is believed that different types of drought happen in a sequence where precipitation is the input and soil moisture and stream flow are the output (Figure 1).

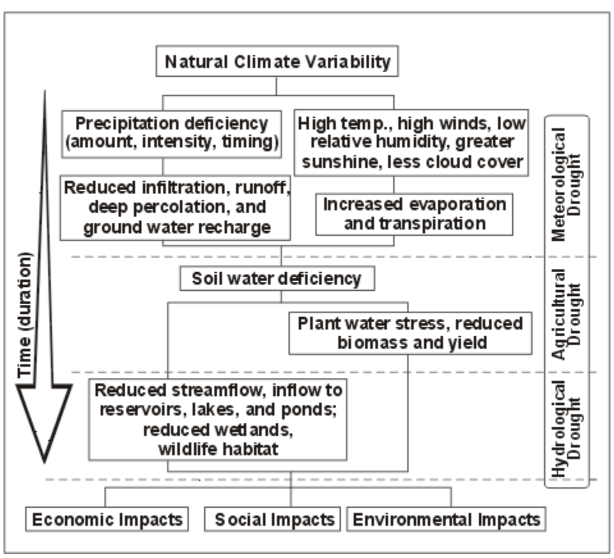


Figure 2 Sequence of different types of drought (National Drought Mitigation Centre, 2006)

With the traditional definitions in mind, where drought is merely defined by the shortage of water rather than considered with the amount of water we use, the most direct way to solve the problem of drought is through technological measures, which favor increasing water supply rather than decreasing demand or improving water use efficiency. Policy-makers and utility managers also prefer a supply-side approach because the actual amount of water supply can be calculated and the cost and benefit of infrastructure construction can be easily analyzed with a higher confidence level. However, it is increasingly recognized that this type of reductionist explanation of environmental events is too simplistic and fails to consider the complex interactions between humans and the environment. Therefore, the aforementioned unconventional definition, such as ecosystem drought and economic drought, emerged. The study of drought has to be context and user specific (Wilhite, 2000). Any discussion of drought cannot be independent of the ways human systems use water. Water is never a resource external to social relations. The severity of drought is directly related to the demand and supply relationship of water (Dracup, 1980). It is our need for water that defines water shortage. For example, 10 inches of rain per year may be enough for dryland farmers in Saskatchewan, while it could be a threat to rice farmers in southern China where they are used to having 30 inches of rain per year. Thus, both the physical and social factors have to be taken into consideration. As drought events are far too often being portrayed as environmental deficiency, we fail to deal with them efficiently and effectively (Trottier, 2008).

Unlike other natural hazards, such as earthquake or hurricane, drought can never be measured with a common metric and definition (Vogt and Somma, 2000; Wilhite and Vanyarkho, 2000). Drought is not merely an objective meteorological phenomenon but a socially-constructed anthropocentric crisis that has to be examined in a more holistic approach. This Act of Nature paradigm leads to significant amount of research on hazard analyses, which focus on the frequency, intensity, duration, and spatial extent of drought occurrence (Hayes et al., 2004); yet neglects one crucial element in the equation – the social environment. When we look at the “crisis” of drought from an ecological point of view, by taking the ecosystem’s self-regulating power into consideration, does drought still exist? As nature can never be ‘short’ of water, water shortage is a socially constructed anthropocentric crisis.

The current definition of drought, such as the PDSI which measures abnormal moisture deficiency is based on scientific ‘facts’ and it is clearly a reductionist way of thinking which fails to examine the interconnectedness between the environment and society. Disasters occur because a community is vulnerable to the changes of the environment and physical stressors (Liverman, 1994). Drought alone does not lead to vulnerability. When we conclude that drought exists in a particular region, it shows that human demand for water is not being met. The dominant discourse has led experts to overestimate the capacity of top-down approaches that portray water management as an exercise that can be based solely on scientific ‘facts’ such as the magnitude of the drought or projected changes from climate modeling. Top-down approaches suggest that scientific ‘facts’ alone are enough to guide adaptation measures. Moreover, these approaches are also driven by the assumption of homogenous community, where the degree of vulnerability is the same throughout the entire region. Yet, droughts of similar severity could affect regions and groups in a different way. Factors such as source of livelihood, cultural practices, national wealth, level of education and other socioeconomic factors contribute to these differential vulnerabilities. Therefore, solutions can be sought only on the basis of a comprehensive understanding of the root of the problem. To a large extent, drought mitigation depends on how extensively droughts are understood. It is shown that failure to develop a clear definition of drought is one of the major obstacles to effective management (Dracup et al., 1980). If drought is misunderstood, action to reduce risk may be misdirected; which may in turn increase community vulnerability owing to unnecessary resource depletion, uneven access to informational, technological, and financial resources, and inappropriate mitigation measures (Smakhtin and Schipper, 2008).

To solve the above problems, qualitative research can be used to help understand the world and explore the meanings that people attribute to different phenomena by investigating the socio-cultural, political, economic contexts in which these meanings are developed. Thus, drought is a socio-environmental phenomenon that is produced by a combination of meteorological, hydrological, political, socio-economic, and cultural factors. The study of drought should consist of three main components - ecological, socio-political, and cultural processes (Trottier, 2008).

2.2 Vulnerability Assessment

Vulnerability assessment is a transdisciplinary study that is used in different fields of study and its meaning and approach varies from field to field. It has commonly been used in various contexts, including climate change (Adger, 1999; Adger and Kelly, 1999; Leichenko and O’Brien, 2002; Adger, 2003; Ford et al., 2006; Ford et al., 2007), food scarcity (Sen, 1981; Watts and Bohle, 1993), environmental change (Liverman, 1994; Smit et al., 2005; Reid and Vogel, 2006) and natural hazards (Cutter, 1996; Enarson, 2001; Brouwer et al., 2007).

Even in the field of climate change, there are disagreements over the definition of vulnerability. One of the most popular definitions is by the IPCC, which defined vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC, 2001). Although it may seems that the IPCC definition mainly focuses on the biophysical aspect of vulnerability, some researchers argue that the determinants of vulnerability have already incorporated the social-cultural aspect of a system as the term ‘sensitivity’ is included in its definition. In short, vulnerability is a function of the “severity and probability of occurrence of the hazard and the way in which its consequences are likely to be mediated by the system itself” (Brooks N, 2003).

Similar to the definition of vulnerability, there are also various definitions of adaptation and adaptive capacity (Chiotti et al., 1997; Ilbery et al., 1997; Wheaton and McIver, 1999; Bryant et al., 2000; Smit et al., 2000; IPCC, 2001; Smithers and Blay-Palmer, 2001; Burton et al., 2002; Yohe and Tol, 2002; Fussel and Klein, 2002; Adger, 2003; Downing, 2003; Smit and Pilifosova, 2003; Bradshaw et al., 2004). Even in climate change literature, adaptation may have different meanings (Smit et al. 2000). IPCC defined adaptation as “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities” (IPCC, 2001). Watson (1996) refers to adaptation as spontaneous or planned adjustment to anticipated or actual changes. Brooks N (2003) defines adaptation as adjustments in the characteristics of a system so as to enhance its capacity to deal with a stimulus. One of the most commonly used definitions of adaptation is Smit et al’s (2000) definition, which takes multiple biophysical and socio-cultural factors as well as past and future vulnerability into account. They define adaptation as “the adjustments in ecological-social-economic systems in response to actual or expected climatic stimuli, their effects or impacts, which moderates harms or exploits beneficial opportunities” (Smit et al., 2000). To other researchers, adaptation can simply mean long-term initiatives that consider the threat of environmental changes (Cutter and Mitchell, 2001). One of the commonalities out of all the definitions is that adaptation means adjustment to stimuli, in this case climate change. It can be positive changes such as opportunities created by the stimuli, or negative change such as threats to the community. It can also be adjustment made by natural or human systems to projected or actual changes (Smit et al., 2000). Without a concrete definition, successful adaptation can hardly be achieved.

Related to the concept of adaptation, adaptive capacity is also a critical aspect in determining the impact climate change has on societies (Adger and Vincent, 2007). The idea of adaptive capacity is used differently by various scholarly communities. IPCC (2001) describes adaptive capacity as "the characteristics of communities, countries and regions that influence their propensity or ability to adapt". Adger and Vincent (2007), in the context of climate change, define adaptive capacity as "a vector of resources and assets that represent the asset base from which adaptation actions and investments can be made", while Fussel and Klein (2006) refer to adaptive capacity as "the ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences". The abovementioned definitions show that the core idea of adaptive capacity is the ability of a system to adjust its characteristics in order to cope with existing and future changes by minimizing damage or making use of the opportunities available. Although various terminologies are used in different fields, the concepts behind each categorization are similar. As Grant concludes (2000), "Let us not let terminology stand in the way of our exploration of process". In this thesis, Smit and Wandel's (2006) definition of adaptive capacity is used. Here, adaptive capacity is defined as the ability of the system to cope with and recover from stress. Despite different terminologies are used in the field of climate change; the core idea and the goal of vulnerability assessment are similar, which is to reduce vulnerability.

2.2.1 Purpose of Vulnerability Assessment

As assessing vulnerability is important for proactive planning and for allocating aid, vulnerability assessment is frequently a necessary first step in planning adaptation strategies that fit the need of the communities (Smit and Wandel, 2006). The assessment of vulnerability is highly scale-dependent. It can be used to identify the susceptibility of the community to changes as well as the complexities of differential vulnerability within a study area at scales from household to national level (Stephen and Downing, 2001). Through vulnerability assessment, the impact of environmental events on different groups of actors can be examined and other stressors that contribute to their vulnerabilities can also be identified. Furthermore, it helps to prevent hegemonic and taken-for-granted ideas or concepts from limiting what solutions are sought. Without vulnerability assessment, the assumption of homogenous community will lead to off-the-shelf solutions, which may perpetuate social inequality and increase vulnerability.

2.2.2 Existing Vulnerability Assessment Approaches

There are two generations of vulnerability assessment and adaptation research. The so-called “first generation” studies focus on biophysical vulnerability of climate change alone (Fussel and Klein, 2006). Adaptation options suggested by the first generation studies are mainly technological and engineering approaches. First generation studies rely mainly on quantitative data. This approach falls under the Act of God paradigm in which ‘nature’ and ‘society’ are two distinct entities. It targets physical condition and rarely connects to the experience of the affected community. As First generation vulnerability assessment typically stressed reducing the potential impact of climate change by controlling the emission of greenhouse gases, they usually resulted in mitigation policy at the national and international level. “Second generation” vulnerability studies focus more on the local scale and try to achieve a win-win situation by enhancing local capacity in face of the unavoidable changes. Non-climatic variables, such as socio-political and economic factors, are considered in second-generation studies. They recognize that the vulnerability of the community is based on its ability to carry out adaptation measures, but not merely on the availability of adaptation measures alone (Fussel and Klein, 2006). Therefore, it relies on qualitative studies, such as interviews with stakeholders. In the two generations of assessment, there are three main approaches used by different groups of researchers in assessing the degree of vulnerability of a community. They are end-point vs. starting point approach (Kelly and Adger, 2000); outcome vulnerability vs. contextual vulnerability approach (O’Brien et al., 2007); and impact-based vs. contextual-based (Wall et al., 2007). As different definitions of vulnerability influence the framing of the questions and the knowledge being produced, different adaptation strategies will lead to different vulnerability assessment approaches.

The impact-based approach is similar to end-point approach and outcome vulnerability approach. These are considered top-down approaches (Kelly and Adger, 2000; O’Brien et al., 2007). These approaches fall under first generation assessment and are driven from the Act of Nature paradigm in which the social environment is excluded and the assessment merely focuses on the vulnerability caused by exposure to hazard. Vulnerability is driven by the severity of the hazard, its frequency of occurrence, and the system's sensitivity to its impact (Brooks N, 2003). This type of vulnerability is also known as biophysical vulnerability, in which the indicators mainly consider the outcome of the event rather than the state of the system before hazard (Brooks N, 2003).

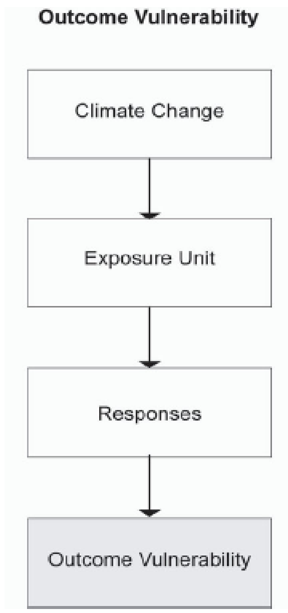


Figure 3 Impact-based vulnerability assessment (O'Brien et al., 2007)

In impact-based assessment, vulnerability is defined as the residual impact which remains after adaptations have taken place (Vulnerability = Impact – Adaptation) (O'Brien et al., 2007). As different approaches lead to different questions being asked, the questions that are asked in these approaches will be what the impacts of climate change are; what adaptation measures could address the projected impacts; and how effective the adaptation measures are (O'Brien et al., 2007). Climate models such as General Circulation Models (GCMs) and Single-Column Models (SCMs) are used to simulate the possible climate change scenarios. Biophysical impacts of climate change are estimated, and adaptation measures are suggested to limit the anticipated impacts based on a suite of possible scenarios. Impact that cannot be reduced or eliminated by adaptation measures will be considered as vulnerability. This approach is useful in providing useful background for decision making and suggesting possible adaptation measures by illustrating the general trends of climate change and the biophysical impacts. In the case of climate change, this approach will suggest that in order to reduce vulnerability, reduction in greenhouse gases should be advocated and technical adaptation measures should be adopted.

Apart from modeling, spatial and historical analogues are used to project possible climate change scenarios. Analogue scenarios are created by "identifying recorded climate regimes which may resemble the future climate in a given region" (IPCC, 2007b). For example, Atlanta may be used as a spatial analogue for New York in terms of the trend of future climate change in urban area, while the Great Plains Dust Bowl in the 1930s can be used as a temporal analogue for the impact of drought in the Prairies in the future. However, the use of analogues is often criticized as there are lacks of correspondence among important characteristics between places or periods of time (Glantz, 1988). Therefore, they may not be representative in predicting possible future scenarios.

One of the major challenges of the top-down approach is that GCMs can only provide estimates of the possible global scenarios in large grid cells and the impact of climate change at regional and local scale is uncertain. It is crucial to downscale the estimated climate change scenarios to the local scale before effective adaptation strategies can be suggested. Also, this linear model is limited in the sense that it only considers biophysical factors in the assessment and cannot represent the human component as well as its ability to adapt. Impact-based assessment frameworks also assumed that the rate of climate change will be gradual and we will be able to predict climate change accurately. For example, in the Third and Forth IPCC Report, projections of possible climate change were based on several families of the Special Report on Emissions Scenarios (SRES) that were created earlier in the century. These projections are based on future population growths, technological advances, and government political actions. All scenarios show that the rate of temperature increase will accelerate in this century. However, there is no consensus on the degree of temperature increase. In the A1B scenario, which represents a scenario with rapid economic growth, a balance of fossil and non-fossil fuel sources, with the world population peaking in mid-century and declining afterwards, the temperature is estimated to rise by an average of about 2.8^{o}C this century, but it could be as low as 1.7^{o}C or as high as 4.4^{o}C. Even various assumptions have been made; scientist still cannot precisely estimate the possible outcome.

If we could predict the impact of climate change accurately, we might be able to adapt to the changes and limit the negative impacts. However, many climate experts predict that "the abruptness of climate change is likely to limit the effectiveness of any adaptation strategies." (MacCracken et al., 2008) The ecosystem is a complex system that is subjected to multiple stressors that are constantly changing. The reductionist approach, which assumes a simple cause-and-effect relationship of our environment, is not sufficient in explaining and predicting the changing climate. Therefore, impact-based vulnerability assessment may not be the most appropriate framework to deal with the complexity and uncertainty associated with climate change.

The second vulnerability assessment framework is context-based assessment (Wall et al., 2007). It recognizes the complexity of the environment by considering multiple factors that affect adaptive capacity and is considered as second generation studies. It is similar to starting-point approach and contextual vulnerability approach (Kelly and Adger, 2000; O'Brien et al., 2007). Unlike the impact-based approach, the context-based approach argues that vulnerability is not predominantly a climate-based condition, but rather determined by a set of socio-economic and political variables, which fall under the second generation vulnerability assessment (Vasquez-Leon et al., 2003). It refers to the present inability to deal with changes by having a more multi-dimensional view of the climate-society interactions (O'Brien et al., 2007). It recognizes the complexity of the ecosystems by considering multiple factors. Rather than a linear assessment of residual impacts after adaptation measures, Second generation studies assess vulnerability in a much wider boundary that considers interactions among different dynamic processes. This approach aims at changing the context where climate change takes place (O'Brien et al., 2007). It looks at factors such as the community's physical exposure, the availability of resources, past exposures and institutional policies (Kelly and Adger, 2000; Yohe and Tol, 2002; O'Brien et al., 2004; Smit and Wandel, 2006). The questions that are asked in these approaches will be what facilitates or constrains adaptation in local communities and how can the context in which adaptation occurs be altered (O'Brien et al., 2007). In this approach, it is crucial to examine the contextual factors that constrain or facilitate adaptation strategies that limit the impacts of climate change and affect the decision making environment for effective adaptation strategies. Vulnerability can be reduced by altering contextual factors that influence the decision making environment where climate change occurs.

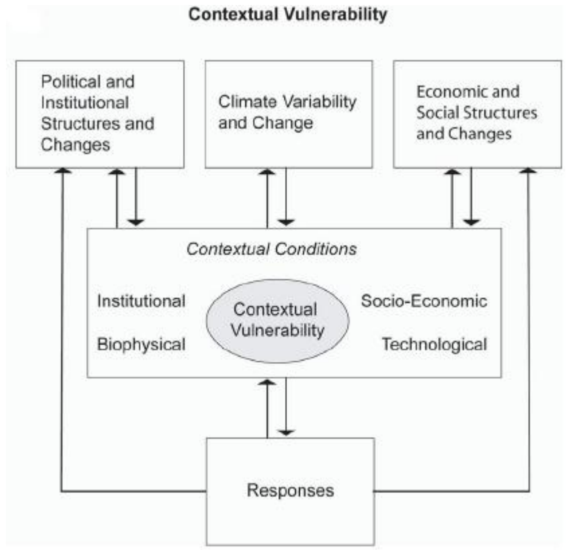


Figure 4 Context-based vulnerability assessment (O'Brien et al., 2007)

This framework is based on a risk management approach, where adaptation measures are usually integrated with existing management strategies. The risk of climate change is taken into consideration based on the local communities' past experience and is implicitly being dealt with in their decision making process and not as an isolated factor. It tries to address the issue of vulnerability in a holistic approach; yet, due to the interconnectedness of the system, it makes it difficult to define an appropriate project boundary.

Impact-based and context-based approaches represent two separate world views of climate change. They ask diverse sets of questions for vulnerability assessment; therefore, different knowledge is produced and different adaptation measures are suggested. O'Brien (2007) examines the possibility of integrating the two frameworks into one common framework. Yet, owing to the fundamental difference between the two approaches, they cannot be integrated. The two approaches involve different discourses; have different starting points and different understandings on vulnerability. For the impact-based approach, scientific studies on the identification of how the climate will change under different scenarios is crucial; while for context-based approaches, climate change is only part of the process that affects the society (O'Brien et al., 2007). As they are useful in different ways, instead of integrating the two approaches, they can complement each other and provide a complete picture in understanding the issue of climate change, which in turn leads to a variety of adaptation strategies (O'Brien et al., 2007).

This thesis looks at vulnerability through the lens of context-based approach. Through this approach, the opportunities and constraints are identified and case-specific adaptation measures can be suggested to decrease exposure and increase adaptive capacity of the rural communities in the face of climate change and other dynamic processes.

2.2.3 Operationalizing Vulnerability Assessment

The context-based approach is increasingly referred to as Community-Based Vulnerability Assessment (CBVA). Out of the two vulnerability assessment frameworks, the context-based approach is most often used in building community adaptive capacity. It recognizes the fact that knowing a community's adaptive capacity is a crucial step in implementing effective adaptation measures (Brooks and Adger, 2005). This framework defines vulnerability as a function of exposure-sensitivity and adaptive capacity. Exposure-sensitivity is the susceptibility of a system to changing condition "relative to the situational characteristics of places and people which make them sensitive to the condition" (Smit et al., 2008); while adaptive capacity as aforementioned, means the potential of the system to adjust its characteristics and cope with exposures and recover from stress (Chiotti et al., 1997; Ilbery et al., 1997; Wheaton and McIver, 1999; Bryant et al., 2000; Smit et al., 2000; Smithers and Blay-Palmer, 2001; Yohe and Tol, 2002; Fussel and Klein, 2002; Downing, 2003; Smit and Pilifosova, 2003; Bradshaw et al., 2004). As a system may not be exposed or sensitive to emerging stimuli, vulnerability does not appear whenever a stressor occurs. Questions that are being asked are when adaptation strategies take place; how effective are various adaptation measures in limiting exposure-sensitivity in local communities; and what lesson can be learned from the past that could be used to improve adaptation measures in the future (Wall et al., 2007). Adaptive capacity can be determined by a wide range of factors such as availability and distribution of resources, institutional structure, perception of risk, income diversity, geographical location, physical infrastructure, land use planning, health status and availability of technological options (Yohe and Tol, 2002; Smit and Pilifosova, 2003; Brooks and Adger., 2005)

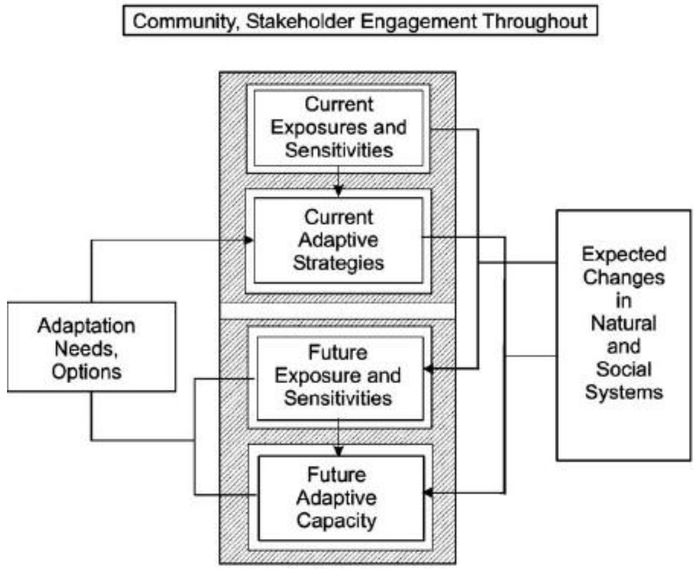


Figure 5 Community-based vulnerability assessment (Smit and Wandel, 2006)

This framework assumes that assessing past and current exposure-sensitivities, and how the community responds, will provide insights on the community's ability to cope with future changes. Adaptation measures seldom target the impact of climate change alone, but are integrated into existing actions. Instead of merely taking socio-cultural factors into account, multiple factors are considered when assessing vulnerability and how biophysical as well as socio-cultural factors affect vulnerability is examined. In this framework, past and current exposure-sensitivities, such as the stresses that have an effect on the livelihood of the community, are identified and the community's ability in adapting to the previously identified stress is studied in order to assess their vulnerability. One of the characteristics of this framework is the feedback process. It is a site-specific approach that focuses on the characteristics of the local community and tries to provide suggestions on adaptation strategies that are socially acceptable. This approach encourages public participation throughout the research process from the identification of past and current exposure-sensitivities and adaptive capacities to the identification of future exposure-sensitivities and adaptive capacities. It allows the community to make better decision on their adaptation measure as more information becomes available.

Both impact-based and context-based approaches have their own way in interpreting and assessing vulnerability. Disadvantages in one approach may be balanced by the advantages in another approach.

Although they can complement each other in understanding the issue of climate change and vulnerability, one of the challenges for all frameworks is that the degree of vulnerability is different throughout the community. Therefore, differential vulnerability has to be taken into account when designing adaptation strategies.

The study of vulnerability should not be an end in itself, but as a means to identify opportunities for adaptation strategies. The purpose of vulnerability assessment is to provide a basis for decision-making so as to improve the community's adaptive capacity by suggesting appropriate adaptation strategies to deal with future exposures. In the field of climate change, mitigation and adaption are the two main measures used to combat the impact of climate change. According to the IPCC Forth Assessment Report (2007b), even the most stringent mitigation effort cannot avoid further impacts of climate change in the next few decades. Adaptation seems to be the only way to reduce and delay the losses resulting from climate change (Smit and Pilifosova, 2001). After the communities' exposure-sensitivity and adaptive capacity are assessed from the first part of the study, the next research question that needs to be answered is how to increase the communities' adaptive capacity and consequently decrease their vulnerability to future changes.

2.3 Water Resources Management

With the emerging crisis of water shortage driven by climate change together with increases in population and urbanization, a successful water management plan is needed to achieve sustainable water conservation. If we could predict the impact of climate change on water resources perfectly, we would be able to minimize the impact or even make use of the opportunity. Yet, in the face of uncertainty and complexity, conventional management practices may not be able to deal with the more severe drought effectively; therefore, there is an increasing amount of literature that focuses on climate change and water resources management.

As mentioned earlier, there remain considerable uncertainties in the degree of climate change and the impacts associated with it. Because of the existence of time lags in our climate system, the earth is still responding to the greenhouse gases emitted to the atmosphere a long time ago. It is estimated that the impact of climate change would last for at least a few more decades. Ecosystem dynamics are complex; in another word, they are not deterministic and have a high degree of unpredictability. As

Mitchell states, resources are extremely sensitive to the complex feedback mechanisms due to the system's non-linearity (Mitchell, 2002). Cause-and-effect patterns are difficult to determine due to numerous variables and many interacting components; which means changes in one variable can have ripple effects leading to changes in other variables. The degree of complexity makes it difficult to predict what is going to happen and to manage the available resources effectively. As a result, adaptation measures should be flexible. In view of complexity and uncertainties, a long-term continuous approach that provides room for modification is necessary to achieve the best possible outcome in dealing with the dynamic vulnerability associated with climate change and to prevent maladaptation together with other social and environment externalities. With more information becomes available, adaptation measures can be improved accordingly.

The spectrum of water resources management (see Figure 6) ranges from supply management to demand management to soft path (Brandes and Brooks, 2007). Traditional response to the growing crisis of water shortage has been to "increase human control over water resources and make a larger share of the total renewable resources available for human use" (Rijsberman, 2006); in other words, humans have often resorted to increasing supplies by engineering solutions. The beginning of water resource engineering can be traced back to the earliest agricultural settlements 6000-7000 years ago (Simonovic, 2009). People tried to solve the problem of flooding while ensuring there was a secure water supply for irrigation. Floodwater was stored in dams to be used at a later time and then was distributed to the fields by irrigation canals when crops required moisture. Simonovic (2009) states that "the ideas of engineering are part of human nature and experience. By an organized, rational effort to use the material world around them, engineers responded to a myriad of problems and devised ways of providing . . . comfort and convenience for human beings". Until nowadays, supply management is still a commonly used approach for water resource management.

Figure 6 Spectrum of water resource management (Brandes and Brooks, 2007)

With current levels of technological advancement, more complex infrastructure is being built. To name a few, the construction of dams and pipelines, extraction of groundwater and even desalination of ocean water have ensured high quality drinking water flows directly to our homes (Brooks et al., 2009). However, the misconception of endless water has ended with Serageldin's (1995) comment in the World Bank report. He states that easily accessible sources of water have almost been depleted; in order to increase additional source of water supply, we have to pay a higher price, which increases every year (Sergeldin, 1995). One of the most often asked questions in the field of water resources management is whether water supply management is an effective and efficient solution to water shortage? Some groups believe "decentralized investments in capital and people cannot and will not be effective" and claim that "bigger centralized facilities are just fine and it is the best way to meet global water needs" (Wolff and Gleick, 2004). Yet, once the economies of scale of the centralized facilities have been exhausted, "the marginal cost (or cost of each additional liter) of water from piped systems will (sooner or later) become higher than the marginal cost of water conservation efforts" (Wolff and Gleick, 2004). The current extraction rate has far exceeded nature's replenishment rate. As we think we could solve the problem of water shortage by technological development and discovering new water sources, climate change is adding another level of complexity and greatly affects the availability of water resources. Traditional ways of dealing with water shortage are no longer sufficient in dealing with the more challenging situation. Although the recognition of limitations in supply-side management is improving, there is still not enough attention to demand management options, which address the ecological, social, and economic sustainability of human water use activities (Fisher, 2002; Willcocks-Musselman, 2005). This is why there is an urgent need in developing another approach to water resource management.

As humans are undeniably an inseparable part of the ecosystem, if we do not consider ourselves in our management practices, even the most technologically advanced measures will fail. In order to deal with limited water supply, more researchers have looked into the possibility of decreasing water demand. The terms "soft path" and "water demand management (WDM)" are often use interchangeably. They are similar in the sense that both of the concepts focus on "reducing the demand for a service or resource, rather than automatically supplying more of the service or resources being sought" (Brooks et al., 2009). Demand management recognizes limits to water supply and aims at improving the efficiency of water use to complete a task by posing a question of wants versus needs. Studies show that 20 to 40 percent of current urban water usage (residential, commercial, institutional and some industrial uses) can be saved by existing demand management technologies that are at a lower cost than increasing water supply (Gleick et al., 2003). The reduction in water usage can eliminate supply management projects for the next 30 to 40 years and provide "a new source of water supply" that are immediately available (Brooks, 2009). Demand management includes measures such as low-flow toilets and showerheads, drip irrigation, aerated taps, leak detection and repair, front-loading washing machines, and volume-based pricing. One of the weaknesses pointed out by Brooks et al (2009) is that demand management aims at improving water efficiency rather than water conservation. It is based on anthropocentric rather than ecological perspective, which means it focuses on short-term cost effectiveness rather than long term ecosystem sustainability (Brooks, 2009).

2.3.1 Soft Water Path

The term "soft path" was originally coined by Lovins (1976), at which time it was focused on the idea of energy efficiency and aimed at dealing with the significant increase in energy price caused by the oil crisis in the 1970s (Holtz and Brooks, 2009). In a soft water path approach, humans adjust the nature of a task and how the task should be conducted in order to use the least amount of water or water of lesser quality (e.g. reusing wastewater). Gleick (2002) describes soft path as taking a step beyond efficiency by asking some fundamental questions related to how and what humans use water for. As water is often used to perform certain services, such as removing waste and cooling, it should be treated as a means rather than an end itself. Instead of focusing on how to improve water efficiency, soft water path focuses on why water is used in the first place. The fundamental question of 'why' increases the number of potential solutions to deal with water shortage and makes "outside the box" solutions possible (Brooks et al., 2009). Soft water path "complements and works within existing water infrastructure to limit or eliminate the need for further supply-side developments" (Brandes et al., 2005). Rather than improving the existing 'hardware' to control water demand, soft water path integrates human into the solution by using social engineering to alter water consumption patterns by changing practices and behaviours (Brooks et al., 2009). De Loe and Kreutzwiser (2006) also point out the most effective solution to water shortage may be in the direction of social and institutional development rather than scientific and technological advances.

Another characteristic of soft water path is that it proclaims ecosystems to be the users of fresh water and ecological sustainability is the main consideration during decision-making (Brooks, 2003). Instead of ignoring the right of the ecosystems and merely conducting traditional cost-benefit analysis to decide on water resources management measures, soft water path recognizes the ecosystems' right to use fresh water and makes decisions that will contribute to the health of the ecosystems.

The concept of soft path largely focuses on increasing efficiency in end use and providing incentives to reduce use, while "matching supply quality and quantity with appropriate end use" (Brandes and Ferguson , 2003). Wastewater from one use may be suitable for another use. For example, grey water such as rinse water can be collected for landscape irrigation as well as toilet flushing. As high quality water is probably not required for toilet flushing, replacing fresh water with grey water can perform the same service while achieving the same result with a much lesser cost. High quality water is likely to reduce in supply and become relatively more expensive in the face of climate change. If we rethink the quality of water that is required to perform certain services, we will realize that only a small amount of high quality water is needed (Brooks et al, 2009).

Last but not least, backcasting is a crucial component of soft water path. In order to conduct an effective backcasting process, three scenarios (Business as Usual, Enhanced Efficiency and Soft Path) will be established to illustrate the potential of soft water path approach in conserving water by improving the water efficiency (Brandes and Brooks, 2007). The BAU scenario is a projection based on population and economic growth; the EE scenario is a projection based on adjustments in the "hardware" and shows the situation with the use of basic water reducing measures and techniques such as rebates for low-flow toilets and high efficiency washing machines; finally, the SP scenario includes changes in "hardware" supplemented by changes in "software", which is behavioral change such as taking shorter showers and turning the tap off when it is not in use (Brandes and Brooks, 2007). A desirable future (i.e. how much water could be used in order to guarantee a sustainable utilization of water) would be defined; then, we will work backwards to determine "feasible paths" that could connect the future to the present (Brandes and Ferguson, 2003).

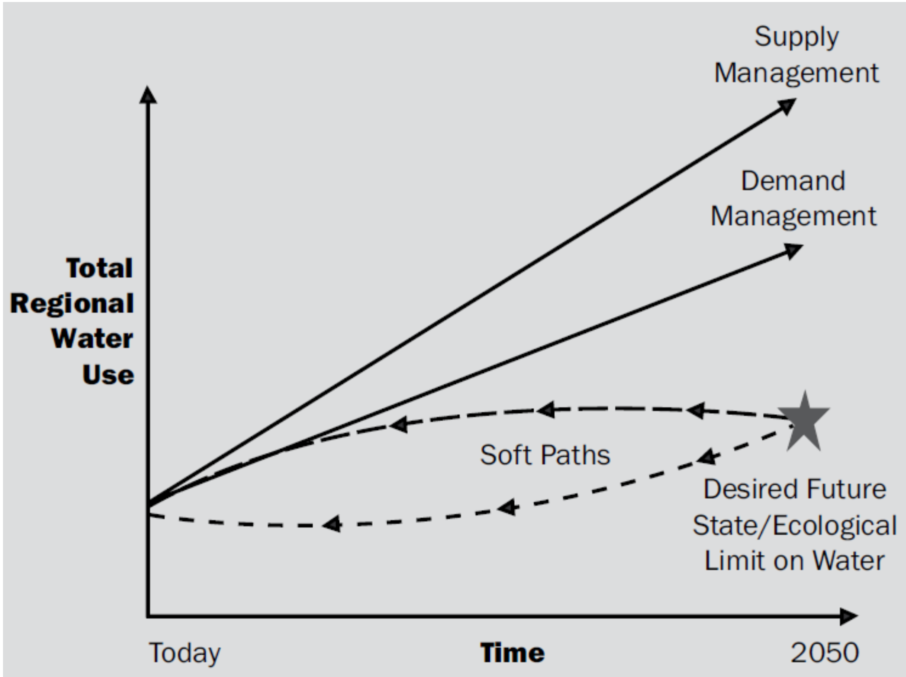


Figure 7 Soft water path – Backcasting (Brandes and Brooks, 2007)

Existing climate models can be used to help define a desirable future and allow situations such as the potential impacts of climate change to be incorporated in the planning process. It encourages stakeholder involvement in decision making in order to look for the right combination of measures to suit local needs, conditions, and preference. It is a repeating process in which adaptation strategies are being revised regularly as conditions changes, such as the change in societal values, new industries, and more information available on climate changes. Multiple feasible paths will be planned until the most cost-effective and socially acceptable one is found (Brooks et al., 2009).

2.3.1.1 Case Studies

Studies of soft water path have been done in different scales in order to discover a scale that is most suitable and effective. For example, a watershed-scale analysis was done in the Annapolis Valley, Nova Scotia (Isaacman and Daborn, 2006); a provincial-scale analysis was done in Ontario (Kay and Hendriks, 2009); while a municipal-scale analysis was done in Oliver, British Columbia (Brandes et al., 2007). As no soft path analysis has been done in rural area, the current project is a first attempt to apply this approach to rural communities. The reason of choosing such a small scale for analysis is because case studies show that soft path analysis is more effective and accurate if it is specifically tailored to each watershed (Isaacman and Daborn, 2006). As soft path requires "institutional changes, new management tools and skills, and … reliance on actions by many individual water users rather than a few engineers" (Gleick, 2002), the current study aims at overcoming barriers by carrying out the analysis in a smaller scale. Decentralized investments are highly reliable when they include adequate investment in human capital, that is, in the people who use the facilities (Brooks et al., 2007). As residents in the rural communities are going to be directly affected by the proposed changes, this makes it easier to get the communities' approval and apply aggressive water conservation measures.

A limited number of soft water path studies have been conducted in Canada. There have been only three feasibility studies (urban, watershed and provincial scales) and several supplemental studies (water use in human diets, ice rinks and golf courses) conducted in the Canadian context (Brooks et al., 2009; Brooks et al., 2007; Isaacman, and Daborn 2006). Recently, two pilot projects have been conducted in urban areas in Salt Spring Island and the City of Abbotsford (Maas et al., 2010; Maas and Porter-Bopp, 2010). Studies show that soft water path is feasible in Canada and reduction in water usage can go well beyond existing demand management methods (Maas et al., 2010).

Soft water path studies have been conducted by Brandes and Maas (2007) in proxy urban centres that are designed to be relatable to mid-size North American cities. The studies demonstrated that "urban communities can grow without expanding their local water footprints until 2050." (Brooks et al., 2009) It concludes that soft water path should not be used to 'buy time' for more supply-side projects, but to establish a "new social infrastructure", which leads to the complete transformation of the society (Brandes and Maas, 2007).

Soft water path analysis conducted at the watershed level (Annapolis Valley, Nova Scotia) shows that the watershed could sustain continued population growth and economic development while using less water than the current amount of water consumption (Isaacman and Daborn, 2006). Although the watershed scale may be an effective management unit ecologically, existing institutional and managerial barriers hinder the capacity for soft water path management. As natural resources management usually lies at the provincial level, it limits the capacity for watershed level management, and the problem is particularly evident when the watershed lies in several political jurisdictions (Isaacman and Daborn, 2006). Also, water usage is influenced by various socio-cultural factors, which may not be within the boundary of a watershed. Although metering is available for residential water use, water withdrawals by most rural communities in Canada as well as the agricultural sector from wells and surface water sources are not recorded. Accurate hydrological data are required for the soft water path analysis in order to produce an accurate water budget; therefore, it is difficult to conduct soft water path analysis at the watershed scale (Brooks et al., 2009).

Another feasibility study that has been conducted on the provincial scale (Ontario) shows that 'no new water' could be achieved in 2031 (Brooks et al., 2009). Compared with watershed scale, the provincial scale may not have the problem of institutional and managerial hindrance. However, owing to its large spatial extent, it is crucial to recognize the limitations of the lack of complete data in provincial study. Assumptions have to be made based on the best available data. "The issue for Ontario is less the ability to adopt soft path methodology than the willingness to do so" (Brooks et al., 2009). The perception of Ontario as a province with unlimited water supply leads to a lack of willingness to adopt a soft water path. Kay et al (2007) conclude that owing to the diverse conditions within the study area, the provincial scale seems to be the least appropriate for soft water path analysis (Brooks et al., 2009). Furthermore, the large spatial scale also limits the ability to conduct participatory research, which is crucial for identifying socially acceptable measures, and to implement detailed water planning strategies.

Pilot studies (Maas et al., 2010; Maas and Porter-Bopp, 2010) conducted last year in Salt Spring Island and the City of Abbotsford demonstrate that a sustainable future for water is possible by engaging the public and maintaining political support. A shift to a new way of thinking should be the starting point that is called for to gradually move the community towards to a sustainable soft water path (Brooks et al., 2009). The above case studies demonstrate that soft water path is feasible in Canada. Population growth as well as economic development can be sustained while maintaining the current amount of water usage. Case studies in different scales also show that regional and local scales may be more appropriate for soft water path. Despite three feasibility studies and two pilot studies which have been conducted in Canada, study in a rural community context is still lacking. As agriculture is one of the most water intensive industries and climate change is going to have a significant impact in this sector, research should be conducted in rural, agricultural areas in order to better equip the communities and build their adaptive capacity in the face of increasing climate variability. As a result, rural communities in Southern Saskatchewan are suitable testing ground in implementing soft water path.

The beginning of this chapter showed that vulnerability assessment is an essential tool for drought management as it can be used to identify opportunities for adaptation measures. As drought is a socio-environmental phenomenon that is produced by a combination of meteorological, hydrological, political, socio-economic and cultural factors, Community-Based Vulnerability Approach (CBVA) is successful in examining drought in its socio-cultural, political, and economic contexts. By looking at drought from different perspectives, information can be gained on how different groups of actors respond to past and current exposures. CBVA also helps to understand the opportunities and constraints that affect the adaptive capacity of the rural communities. With the completion of CBVA, adaptation measures can be tailored to the need of the communities. By understanding the complexities of differential vulnerability that varies within a study area, ways in which different water users (agricultural, residential, commercial and industrial) can undertake to reduce water consumption can be identified. The result also helps to identify potential soft water paths for each sector at the two communities which rely on municipal water. Therefore, CBVA can provide site-specific insight that can be used in soft water path for capacity building. Moreover, both CBVA and soft water path are able to deal with the increasing uncertainty posed by climate change. They do not try to predict what is going to happen but to change the context in which climate change occurs. This helps to create a bigger buffer zone to absorb shocks caused by climate change in the future. As soft water path provides room for modification in its backcasting process, it prevents maladaptation and the creation of externalities that perpetuate social inequality, which is also one of the goals of context-based vulnerability assessment. Therefore, both of the approaches are successful in complementing each other by investigating the root of the problem and proposing adaptive measures that enhance the communities' adaptive capacity in the face of more severe climatic events in the future.

Chapter 3
Conceptual Framework

This chapter outlines the guiding conceptual framework used for assessing the degree of vulnerability as well as building adaptive capacities for the two rural communities in Southern Saskatchewan.

3.1 Community-Based Vulnerability Assessment (CBVA)

The previous chapter discussed broad approaches to vulnerability assessment, and introduced CBVA as an operationalization of the context-based approach. This thesis treats the concept of vulnerability as per the IPCC definition, where it is defined as a function of exposure-sensitivity and adaptive capacity of a system (IPCC, 2001). Thus, vulnerability assessment requires understanding of both biophysical and socio-economic dynamics at the local scale. Expert from different fields, such as disaster management, social sciences, political science, and economics, are required to work together in order to provide meaningful assessment (Brooks, 2003).

In the field of vulnerability assessment, there has always been interest in indicator-based assessments. Indicators that are used to assess vulnerability include GDP, social equality, food availability, water resource sensitivity, health and education status, physical and institutional infrastructure, access to natural resources and technology (Moss et al., 2001; Boruff et al., 2005; Birkmann, 2007; Eriksen and Kelly, 2007; Metzger et al., 2008; Fussel, 2010). With the use of indicators, comparisons between different cases are made possible. However, another school of thoughts suggest that there is no universally applicable measurement for vulnerability. The same indicator may not necessarily be used to answer the same research questions in different places (Schroter et al., 2005). For example in a community that depends on specific ecosystem services for survival, GDP may not be a meaningful measurement for the well-being of the community (Luers et al., 2003). Qualitative studies acknowledge the existence of heterogeneous communities and are able to capture the place-specific vulnerabilities of different communities. Therefore, an indicator approach is not used in this study. As concluded by Adger and Vincent (2007), "the use of indicators and indices is one means of quantifying adaptive capacity for the use of policy-makers. However, the process of identifying and deriving accurate indicators is fraught with uncertainties. Indicators can be controversial, as in trying to encapsulate a complex reality they run the risk of oversimplifying or inaccurately representing the intended condition or process".

Apart from indicator-based vulnerability assessment, there are also different place-specific vulnerability assessment approaches. Schroter et al (2005) have suggested an overarching methodological framework in assessing vulnerability to global changes. They proposed an eight-step approach that can satisfy the criteria that guide global change vulnerability assessment. Schroter et al (2005) commented that in order to assess the coupled human-environment systems, it is necessary to have collaboration between an interdisciplinary research team and the stakeholders. It starts with the community of interest and responds to the need of the stakeholders. This approach recognizes differential vulnerability within the community, considers multiple factors that may amplify the level of vulnerability and is aware of the importance of both historical and projected components.

The guiding conceptual framework for CBVA used in this thesis is similar to the framework suggested by Schroter et al and is outlined and developed in Smit and Pilifosova (2001), Ford and Smit (2004), Smit and Wandel (2006) and Young et al (2010). The framework selected in this study assumes that assessing past and current exposure-sensitivities, and the community's responds together with future climate conditions, it will provide insights on the community's future exposure-sensitivities and their ability to cope with future changes (refer to Figure 5). CBVA defines vulnerability as a function of exposure-sensitivity and adaptive capacity. As aforementioned, exposure-sensitivity is the susceptibility of a system to changing conditions; while adaptive capacity means the ability of the system to adjust its characteristics to cope with exposures and recover from stress. Questions that need to be answered in CBVA are how and when adaptation takes place; what are the stresses that have an effect on the livelihood of the community; how effective are various adaptation measures in limiting exposure-sensitivity in local communities in the past and currently; and what lesson can be learned from the past that can be used to improve adaptation measures in the future (Wall et al., 2007). Similar to other CBVA approaches, the ultimate goal is to inform stakeholders of their adaptation options and facilitate decision-making process.

In this study, two rural communities in southern Saskatchewan are studied and compared against each other. As the degree of vulnerability is different between or even throughout the community, what makes one community vulnerable may not make the other vulnerable as well. It cannot simply be assumed that because of the communities' similarity in geographical location or their sizes, they will be equally susceptible. Even within a community, the degree of one's exposure-sensitivity is affected by many external factors, such as their social and economic situation or even their perception of risk. Thus, it is crucial to select people that are representative of the different groups of actors within the community. CBVA focuses on the characteristics of local community and tries to provide suggestions on adaptation strategies that are socially acceptable. It incorporates human dimensions into the assessment process by involving the local community throughout the entire process, from the identification of past and current exposure-sensitivities and adaptive capacities to the identification of future exposure-sensitivities and adaptive capacities. As a result, exposure-sensitivity and adaptive capacity of the community can be accurately portrayed and better assessed.

In the current case, past exposures such as droughts in the late 1980s and 2001–2 are studied, stresses from non-climate-related sources such as socio-political and environmental conditions were investigated and the effectiveness of previous adaptation strategies were also examined. Adaptive capacity was assessed by a wide range of factors, such as the availability and distribution of resources, institutional structure, perception of risk, income diversity, geographical location, physical infrastructure to the availability of technological options (Yohe and Tol, 2002; Smit and Pilifosova, 2003; Brooks and Adger, 2005). Then, future exposure-sensitivities were estimated by projections from climate models, existing scientific knowledge, and inputs from respondents. Finally, future exposure-sensitivities were considered with factors that either facilitate or constrain adaptations so as to assess the degree of vulnerability of the communities in the future. Climate model simulations show that the hydrology of semiarid areas is particularly sensitive to climate variations (Frederick, 1997); therefore, there is a high likelihood that Palliser's Triangle is going to experience more intense drought and there is an urgent need to build adaptive capacity in those communities.

3.2 Soft Water Path

As the intensification of the hydrological cycle is going to lead to more frequent and extreme droughts and floods in the future, there is a need for building greater adaptive capacity if vulnerability is to be reduced. This thesis explores soft water path as a potential means of achieving this goal for a subset of stakeholders. Soft water path analysis was conducted in the study area as case studies in order to test its feasibility to increase the adaptive capacity of the municipal water uses in the two towns. By adopting soft water path, major water users (residential, industrial, commercial and institutional) in the Town of Coronach and the Town of Gravelbourg will have greater adaptive capacity by reducing their water usage and better adapt to the more severe climate-induced water shortages in the future. As discussed in the previous chapter, soft water path is a planning approach that changes the concept of water demand. "Instead of viewing water as an end product, the soft path views water as the means to accomplish certain task", which eliminates the need of further supply-side development (Brandes and Brooks, 2007). As a result, sustainable water management can be achieved by soft water path as it "[complements] existing water infrastructure to limit or eliminate the need for further supply-side developments" (Rijsberman, 2006; Brandes et al., 2005).

3.2.1 Water Audit

The first step to assess the potential of soft water path was to conduct water audit to find out water usage patterns for different sectors (residential, agricultural, industrial, commercial and institutional). The main steps of the water audit are as follows:

- Definition of the water system in each sector
- Description of water use operation and processes

Definition of the water system

A survey of water-using equipment, which includes both direct and indirect consumption, was conducted by interview, direct observation, and literature review. A list was compiled for different water usage in each sector.

Description of water use operation and processes

This step involved studying the water-using units in the list and then determining how much water is used. In order to make sure the information from the interviews was reliable, direct observation of water-using equipment was also used to determine the type of appliance the respondents use and the amount of water used.

3.2.2 Backcasting

Unlike traditional planning approaches, soft water path planning first defines a sustainable and desirable future in water usage and works backwards to discover ways that connect the future to the present (Brandes and Brooks, 2007). Thorough assessment of the available information was conducted and locally knowledgeable experts were consulted for characterizing and quantifying current and potential future water availability and demand.

The process of backcasting used in this project was based on the water reduction scenario assumptions in *Urban Water Soft Path – 'Back of the Envelope' Backcasting Framework* (Brandes and Maas, 2007). According to Brandes and Maas (2007), in order to achieve the desired future, soft path scenario must go further by involving "changes to individual behaviour and perceptions, laws and regulations, and in some cases, to water management institutions themselves". In order to conduct an effective backcasting process, three scenarios were established to illustrate the potential of soft water path approach in conserving water by improving the water efficiency. The three scenarios were Business as Usual (BAU), Enhanced Efficiency (EE) and Soft Path (SP). The BAU scenario was a projection based on population and economic growth; the EE scenario was a projection that includes adjustments in the "hardware" and shows the situation with the use of basic water reducing measures and techniques such as rebates for low-flow toilets and high efficiency washing machines; finally, the SP scenario includes changes in "hardware" supplemented by changes in "software", which is behavioral change, such as taking shorter showers and turning the tap off when it is not in use. It backcasts from a desirable future (i.e. "no new water") that reflected local conditions and incorporated all the measures in the EE scenario as well as the adoption of more advanced technologies that required changes in individual behavior (Brandes and Brooks, 2007). The amount of water saved in each scenario was calculated by the water efficiency factors and it showed the amount of water that can be saved by each technology in the study area.

3.2.3 Possible Solutions

After projection of future water usage was established, possible solutions were assessed for the scenarios where soft water path was applied. With the aim of identifying the potential for improving water-use efficiency, a number of questions were asked (Wolff and Gleick, 2002):

- Why do we need the water?
    - What are the goals and purposes that we want to achieve?
- What kind of water is required to meet the goals and purposes mentioned above?
    - How much water of a particular quality is needed in reality to meet any given goal?

The above questions helped to challenge the water consumption pattern that we have been using for a long time. “By focusing on ‘why’ the soft path greatly increases the number of possible solutions” (Brandes and Brooks, 2007). The ability to provide answers the above questions led us one step closer to soft water path.

Soft water path is not limited to changes in hardware. It requires a certain degree of social acceptability to achieve maximum efficiency and “cooperative arrangements are needed for the maximum cost-effective water savings to become reality” (Wolff and Gleick, 2002). As soft water path approach aims at delivering diverse water services that match the users’ needs, public participation is a major part in practicing soft water path. Without the public’s opinion and support, water conservation measures will not be able to develop fully and effectively. Therefore, interviews were conducted to gather public opinion as study shows that “decentralized investments are highly reliable when they include adequate investment in human capital, that is, in the people who use the facilities” (Wolff and Gleick, 2002).

Based on the above analyses, feasible solutions were identified and recommendations were provided to ensure that water resources in the community are better managed. It is hoped that after demonstrating the values of undertaking the proposed changes, some of the proposed paths will be incorporated into the community’s water management plan.

As CBVA was successful in examining drought in different contexts and providing information on how different groups of actor responded to past and current exposures, opportunities and constraints that affect the adaptive capacity of the communities were identified and adaptation measures can be tailored to the need of the communities. The result from CBVA was used to define feasible adaptation measures that can increase the communities’ adaptive capacities and allow them to be better equipped in face of future environmental changes.

Chapter 4

Background of Study Area

This chapter provides a description of the two study sites located in Southern Saskatchewan – The Rural Municipality of Gravelbourg (including the Town of Gravelbourg) and The Rural Municipality of Hart Butte (including the Town of Coronach). By understanding the characteristics of the study sites, a more thorough assessment of their vulnerabilities can be achieved. The current conditions of the two communities were assessed in terms of their biophysical as well as socio-cultural aspects. The biophysical aspect includes climate, source of water supply, soil type, and general topography (natural drainage); while the socio-cultural aspect includes political system, economic activity, socio-cultural factors and demographic information.

The two study communities are located in the Palliser's Triangle. It is a triangular-shaped semi-arid area located in the Prairie Provinces in Western Canada. The rain shadow area of the Rocky Mountains makes Palliser's Triangle the driest region in Canada (Gauthier, 2005).

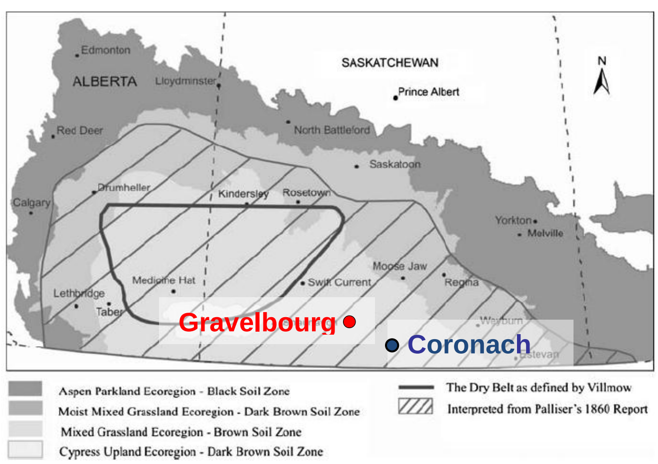


Figure 8 Map of Palliser's Triangle (Marchildon, et al., 2008)

Palliser's Triangle is named after Captain John Palliser, who viewed this region in the nineteenth century and concluded that it had low agricultural potential. However, other botanists and naturalists explored the same area and asserted that the area would be a successful area to grow wheat despite the absence of trees, which could potentially mean soil deficiency. In the end, the British government agreed with those botanists and thought that the lack of trees made clearing the land for farming easy.

Therefore, the British government encouraged agriculture in that area regardless of Palliser's report. The fields were productive when they began; however, after a short period of above-normal precipitation and some recurring droughts, one of the most significant droughts in recent Canadian history occurred in the 1930s. As previously mentioned, drought is a slow onset disaster that may spread over a large spatial area. When the impacts of drought become obvious, it is already too late to implement measures to return to the previous state within a short period of time. The drought in the 1930s lasted from 1929 to 1937 and caused tens of thousands of farms to be abandoned. It had serious impacts on agriculture, such as physiological effects on the crops, increased grasshoppers and soil degradation from which the area took decades to recover. The drought in the 1930s led to severe hardship for the farmers with its large spatial impact over a prolonged period. In Saskatchewan, per capita income decreased for 72%; from $478 in 1928 to $135 in 1933 (Marchildon, et al., 2008). Almost $4 billion (constant dollars) of relief fund was distributed to farmers in the Prairie Provinces in the 1930s (Marchildon, et al., 2008). As mentioned in the introduction, over the past century, widespread droughts (e.g. 1920s, 1930s, 1960s, 1980s and early 21st century) with increasing magnitude has occurred almost every decade since the West was settled. The most recent significant drought happened in 2001–2. It had a great spatial impact that spanned from Eastern to Western Canada (Marchildon et al., 2008). Climatic data show that the drought in 2001–2, with its major impact being found in the agricultural communities in Saskatchewan and Alberta, had a larger spatial extent than the drought in the 1930s (Wheaton et al. 2005). The 2001–2 drought even led to a "negative or zero net farm income for several provinces, for the first time in 25 years" and the GDP decreased by $5.8 billion (Statistic Canada, 2003).

Palliser's Triangle experiences climate extremes with temperatures ranging from -40^{o}C to +40^{o}C and moisture conditions vary from severe droughts to floods. This mixed grassland eco-region has an annual water deficit of less than 300mm with most annual precipitation occurring in the growing season from May to early July (Sauchyn et al., 2009). Agriculture is not just affected by moisture deficiency; the timing and forms of moisture are also crucial in determining productivity. Palliser's Triangle is considered a non-contributing region in which precipitation does not contribute to stream flow because of high evapotranspiration and poorly developed natural drainage system (Fang et al., 2007). There is limited surface runoff in the summer owing to the short duration of rainfall and the characteristic of the soil (sandy soil), which is usually unsaturated at the surface (Sauchyn et al., 2009). Owing to evaporation, much of the water is exhausted before infiltration can occur. Therefore, water resources are limited and this makes this region sensitive to changes in climate.

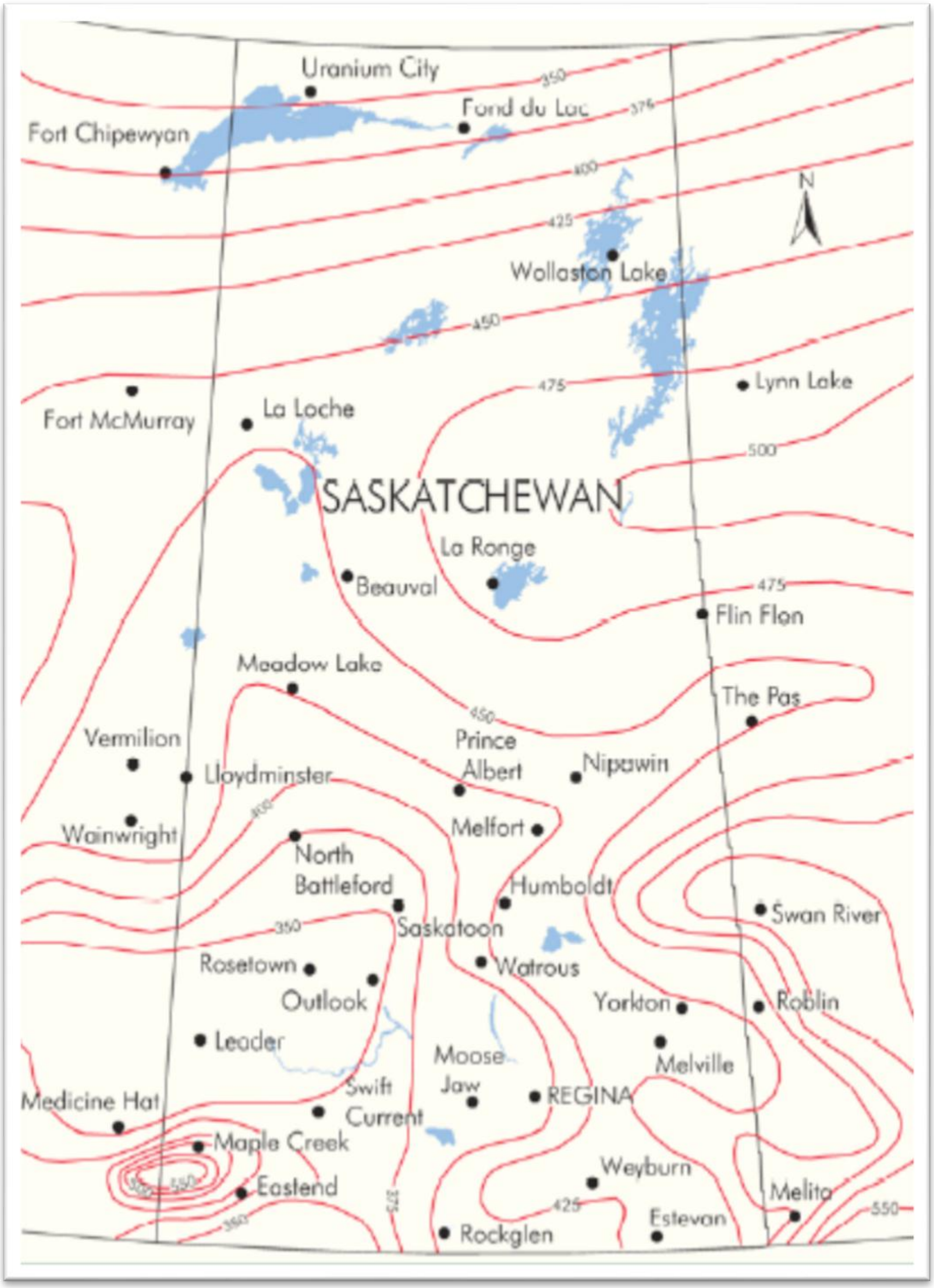


Figure 9 Mean annual precipitation in Saskatchewan (Canadian Plains Research Center, 2006)

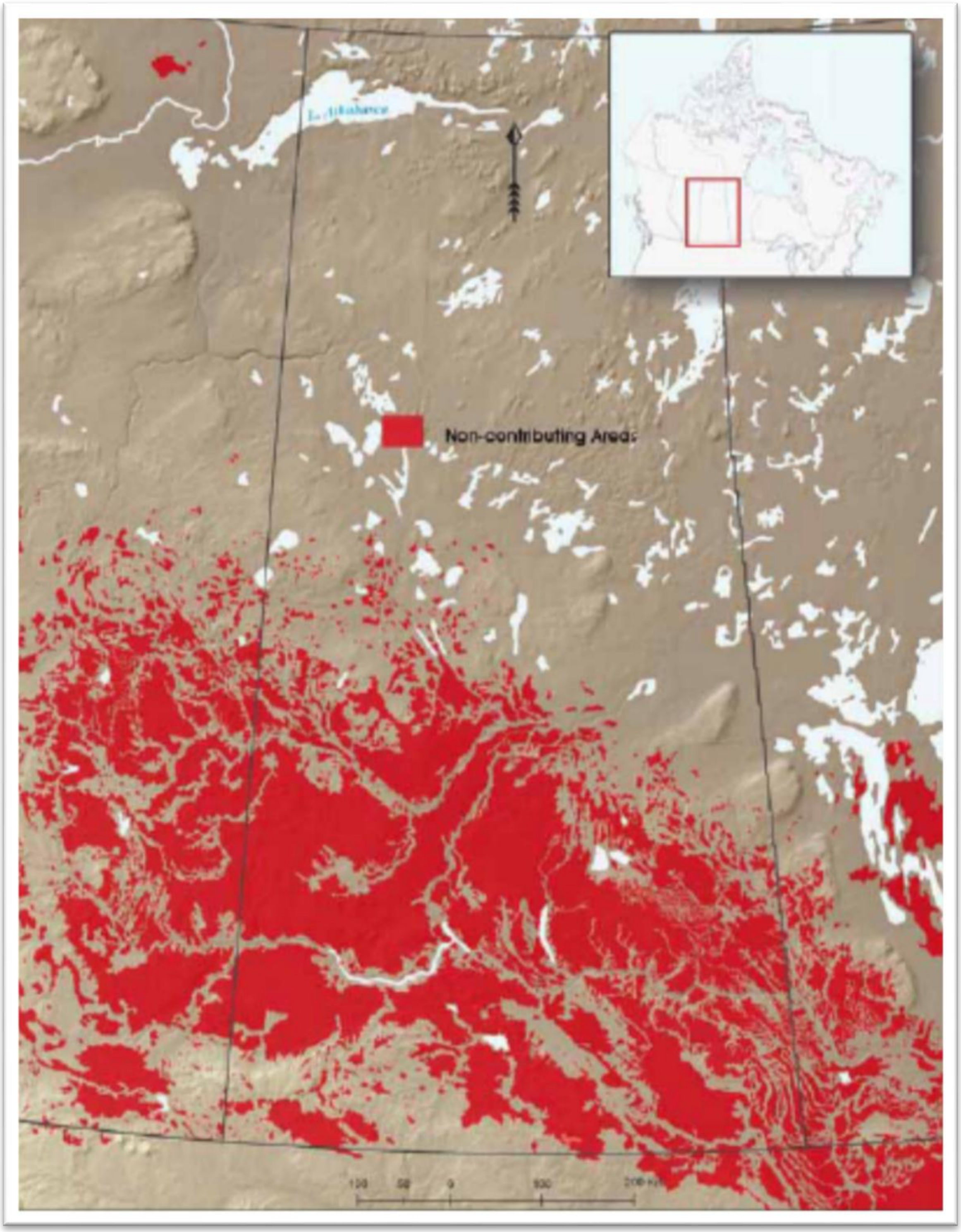


Figure 10 Non-contributing area defined by PFRA (Pomeroy et al., 2007)

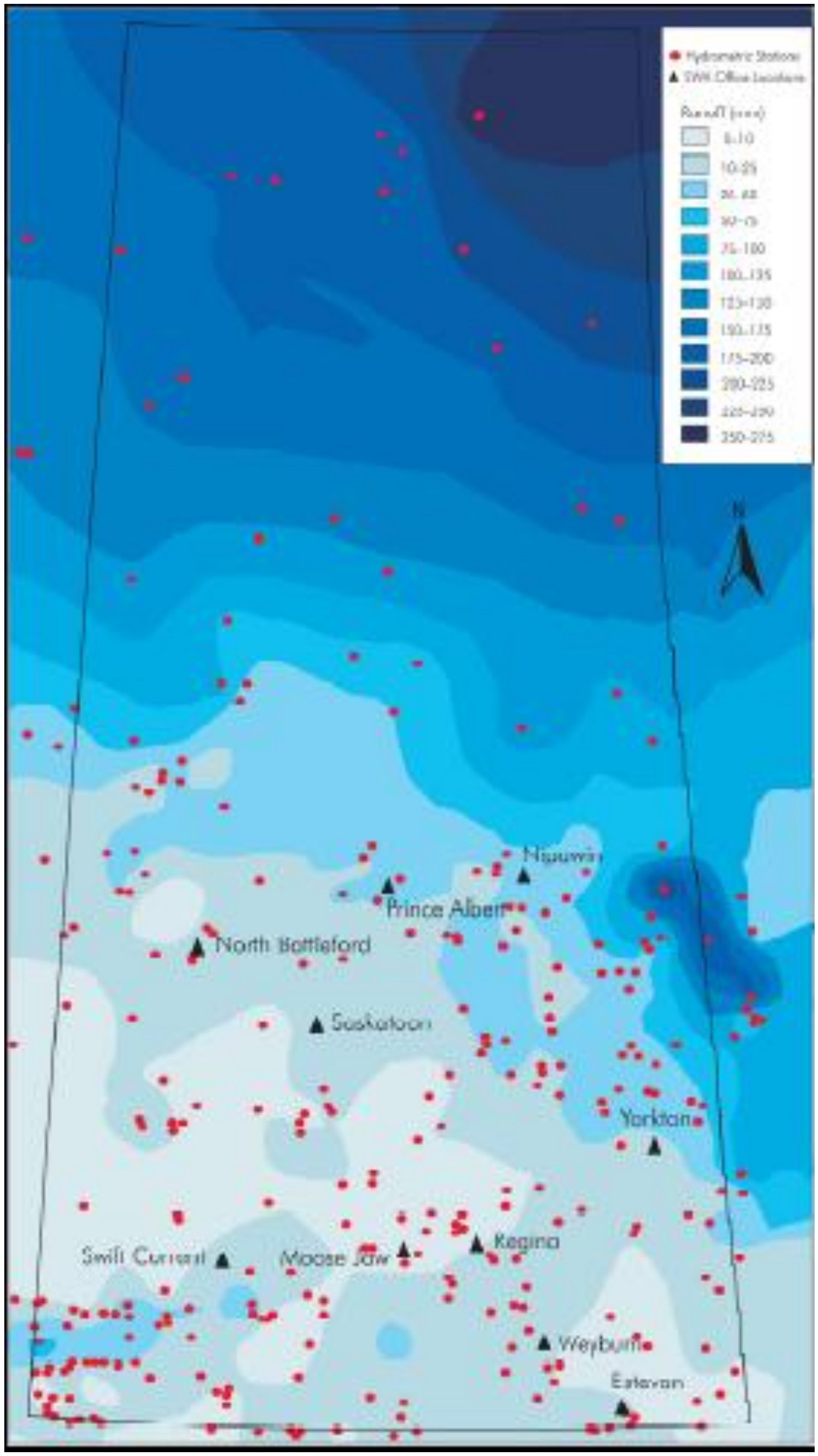


Figure 11 Mean annual runoff (Canadian Plains Research Center, 2006)

The two study areas in this thesis are located in the Missouri River Basin (MRB). Gravelbourg is in the Old Wives Lake Watershed (OWLW) while Coronach is in the Poplar River Watershed (PRW). Although the OWLW is internally drained and water mainly leaves the system through evaporation, the Saskatchewan Watershed Authority (SWA) still designate the OWLW as part of the MRB.

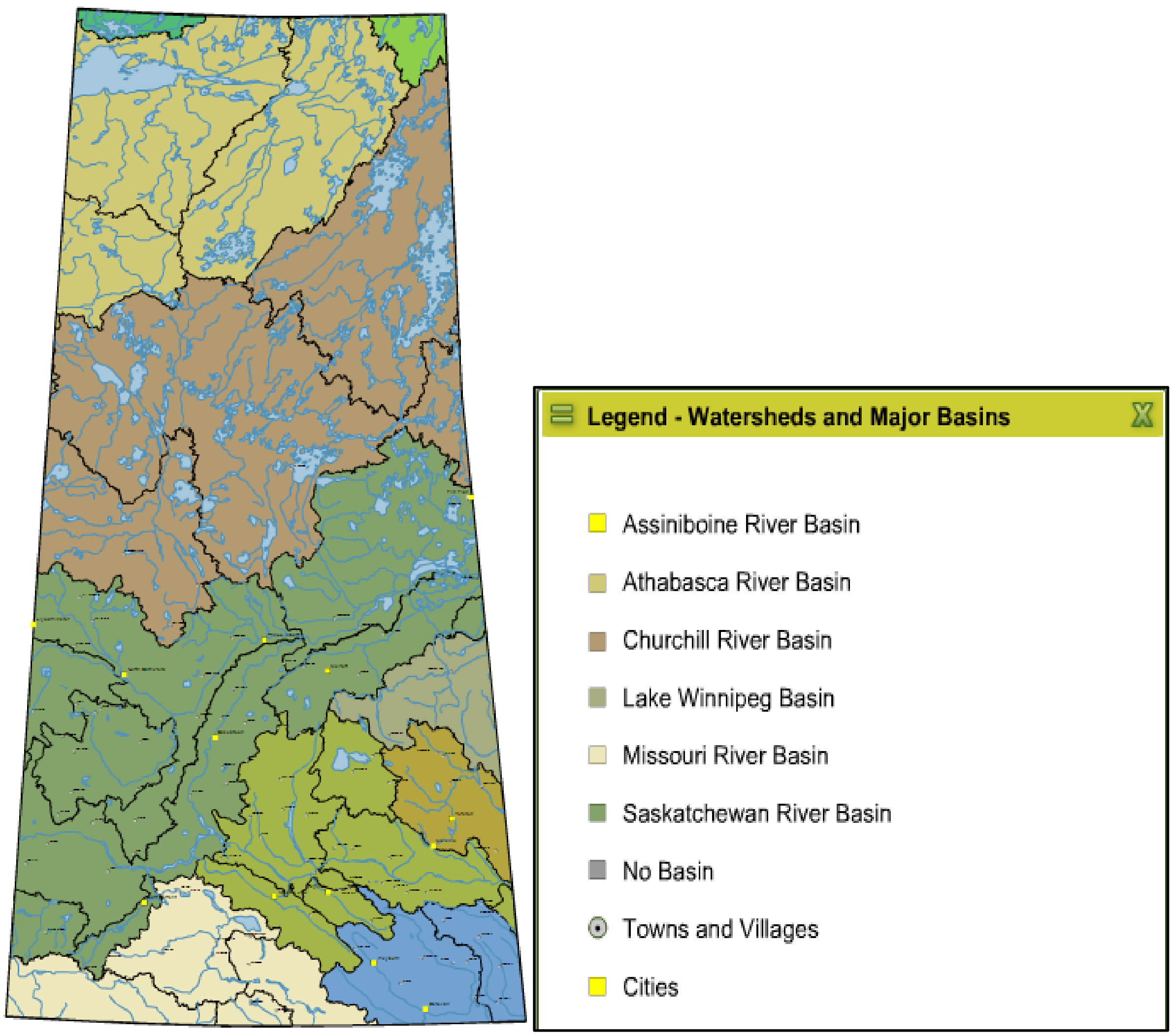
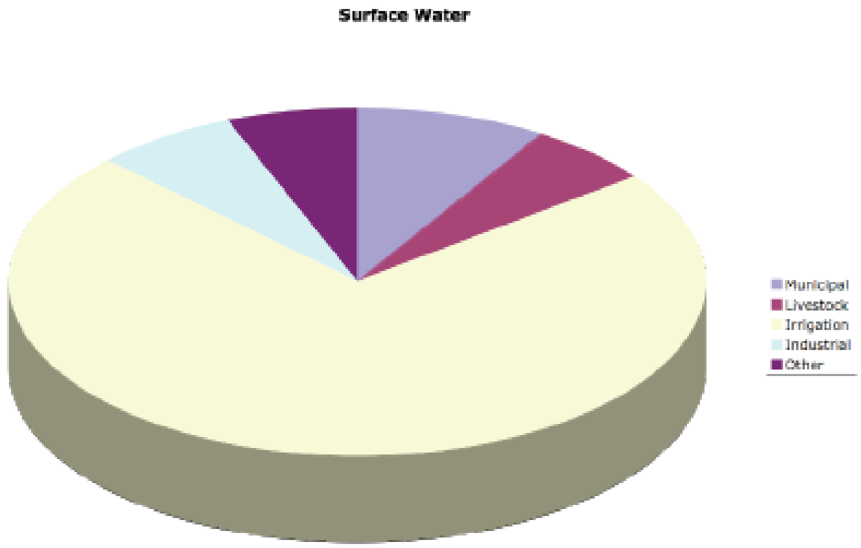


Figure 12 Watersheds in Saskatchewan (Saskatchewan Watershed Authority, 2011)

The MRB covers an area of approximately 1,371,000km^2 of the Eastern Rocky Mountains and the Prairies (Missouri River Natural Resources Committee, n.d.). It spans across two provinces (Alberta and Saskatchewan) in Canada and nine states (Colorado, Iowa, Kansas, Minnesota, Missouri, Montana, North Dakota, South Dakota, and Wyoming) in the United States with a totally population of around 10 million people living in this basin (Missouri River Natural Resources Committee, n.d.). The Canadian part of the basin consists of a number of rivers, which are the Frenchman River, Battle Creek, Lodge Creek, Poplar River and the Big Muddy Creek. These rivers flow to the United States and then join the Missouri River which ends at the Gulf of Mexico (Halliday and Associates 2009). The average flow of the Missouri River is about 0.0045m^3/s, which is relatively low compared to other rivers of similar size (Missouri River Natural Resources Committee, n.d.). However, the amount of water licenses issued for the entire basin in the United States has exceed the median natural flow of the streams, with irrigation as the largest surface water user while industrial use as the largest groundwater user.



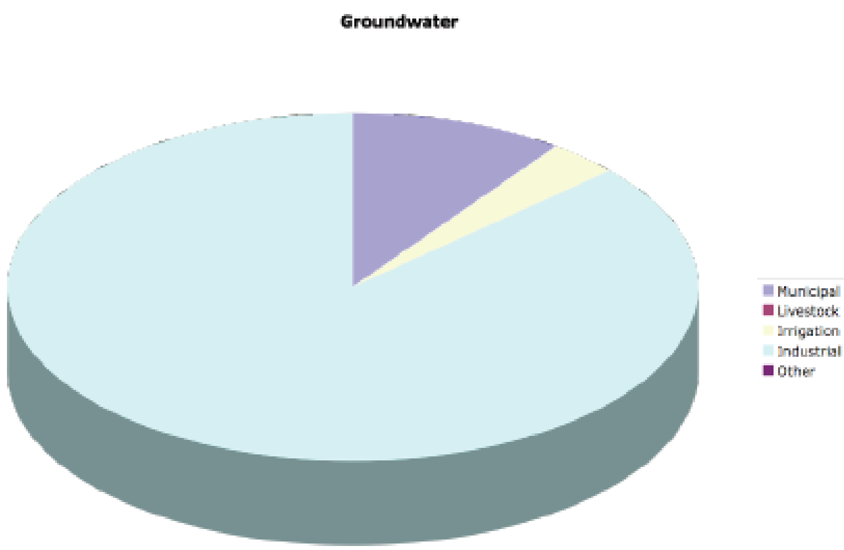


Figure 13 Surface and groundwater allocation for MRB (Halliday and Associates, 2009)

In response to widespread soil degradation and water shortage in this region, the Prairie Farm Rehabilitation Administration (now known as the Agri-Environment Services Branch of Agriculture and Agri-Food Canada (AAFC)) was established in 1935. Since then it has provided support for agricultural communities in the Prairie Provinces. This support has involved programs such as building windbreaks, subsidizing the construction of dugouts, and organizing seminars of new farming techniques for soil conservation. With the support of AAFC, farming techniques have changed in the Palliser's Triangle with more farmers adapting to the changing environment by using techniques such as direct seeding, leaving crop residues on the field to trap snow, and crop diversification.

Figure 14 Windbreaks

Figure 15 Dugout

Major industries in the Palliser's Triangle include farming and cattle ranching. Despite Palliser's comments on the unfavourable condition for farming, with recent technological advancements and increasing research conducted on agriculture, the adoption of new farming techniques helps to sustain the livelihood of agricultural producers in this region. To adapt to the changing climate, the type of crops grown by the farmers changed from wheat only to a variety of crops (lentils, peas, mustards, etc). Farmers also try to increase the competitiveness of the region by looking into value-added industries such as the production of processed mustard.

As most of the catchment areas are internally drained, water resources are limited and dryland farming is the dominant form of farming in this area. Dryland farming means growing crops without the help of irrigation systems and relies solely on precipitation. It is commonly practiced in arid and semi-arid areas where there is limited rainfall and it is a form of adaptation to moisture deficiency. In terms of cattle ranching, climate in the Palliser's Triangle supports the growth of grass, which makes ranching another dominant form of primary industry in this region. Despite the aridity and highly variable climate, Palliser's Triangle produces more than half of Canada's agricultural output (Lemmen and Warren, 2004). As concluded by Bonikowsky (2011), "Mother nature definitely holds the upper hand in Palliser's Triangle, but adapting to the environment and learning from experience has ensured that Macoun's (a botanist that supported agricultural activities in the 19^{th} century) prediction of a successful wheat-growing region would come true – with or without drought". Finally, with the rapid development of oil and gas industry in Alberta, oil and gas companies start to search for oil in Palliser's Triangle with more exploration studies being done on farmlands.

4.1 Rural Municipality of Gravelbourg – Town of Gravelbourg

Gravelbourg is located around 196km southwest of Regina and 120km north of the United States border. The Town of Gravelbourg was founded by the family of Father Pierre Gravel with other French-Canadian settlers from Quebec. It has a total area of $3.23km^2$ and it is known as the 'Cultural Gem of Saskatchewan' with its rich European influence and bilingual heritage (Statistics Canada, 2007a).

Figure 16 Town of Gravelbourg

4.1.1 Biophysical Factors

4.1.1.1 Climate

As aforementioned, Gravelbourg is situated in the Palliser's Triangle, which is under the influence of semi-arid continental climate. One of the characteristics of this type of climate is that there are large variations in temperature and precipitation annually. The average annual temperature is $4.2^{o}C$ and the highest temperature mainly occurs in July and August and the lowest temperature occurs in December and January. The total amount of precipitation is 381.9mm with the wettest months being June and July and the driest months being October and November (Environment Canada, 2011a). Northwest winds are common in the Town of Gravelbourg as well as it vicinity with an average wind speed that reaches 15 to 19km/hour (Town of Gravelbourg, 2010).

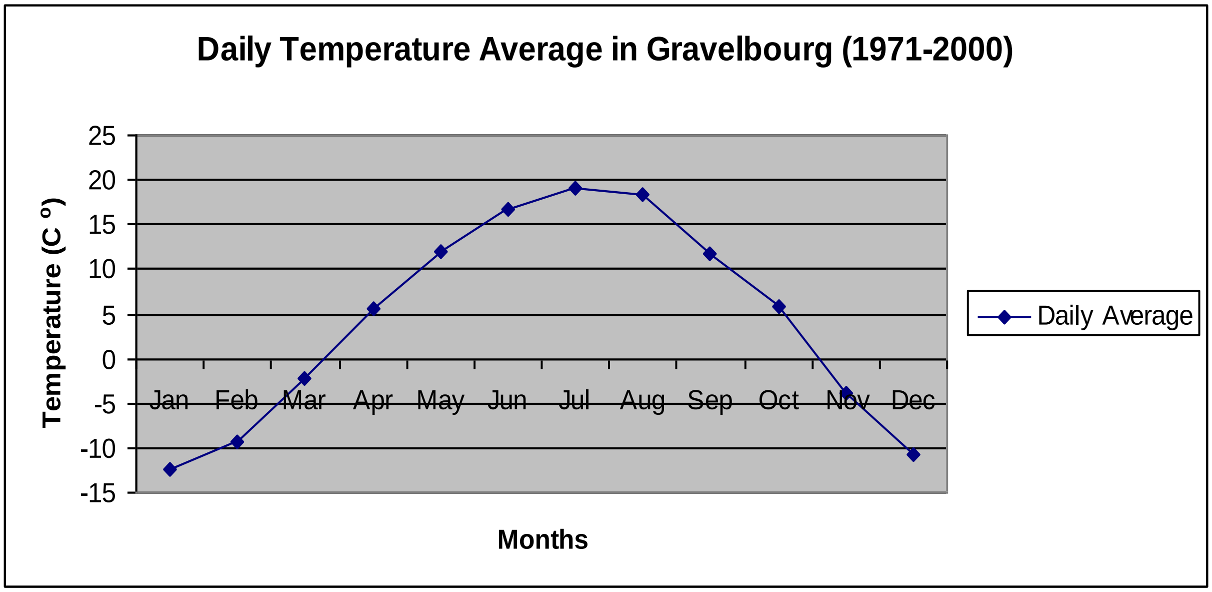


Figure 17 Daily temperature average in the Town of Gravelbourg

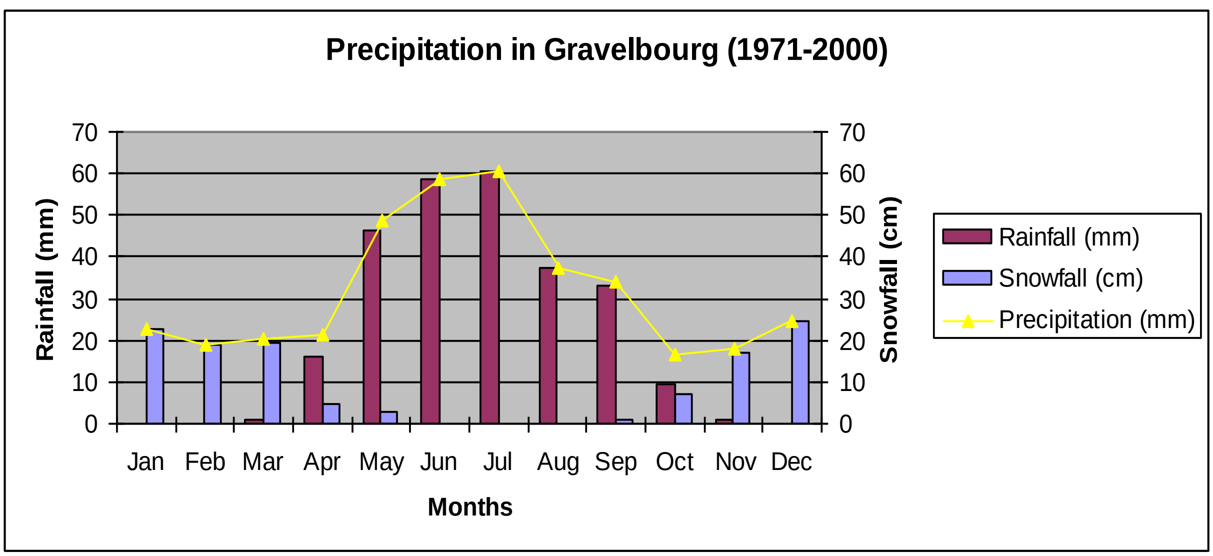


Figure 18 Precipitation in the Town of Gravelbourg

4.1.1.2 Source of Water Supply and Sewage System

The primary water source for Gravelbourg is Thomson Lake, which is 6 miles south of the town. The total storage capacity of the reservoir is 300,000 gallons. Together with the 60,000 gallons of water stores in the water tower on the southern side of the town, the total amount of water available to the town is 360,000 gallons (GB 6). The water treatment plant is owned and operated by SaskWater while the distribution is managed by the Town Foreman. Water is chlorinated and then pumped to 535 services in town (GB 6). Sewage is managed by the town and is pumped into a two cell lagoon, which is ¼ mile east of town, and is released back to the Wood River twice a year (GB 6).

Figure 19 Thomson Lake (Lafleche Dam)

Figure 20 Water tower in the Town of Gravelbourg

4.1.1.3 Vegetation and Soil Type

This part of Southern Saskatchewan falls under the category of short grass prairie with Brown Chernozemic soil. This type of soil indicates that moisture deficit is high and soil organic matter is relatively low in this region. It is susceptible to soil erosion owing to high average wind speed. This area is abundant with grasses. With its semi-arid climate, silver sagebrush, and cactus are common.

4.1.2 Socio-Economic and Cultural Factors

4.1.2.1 Political System

The local government of Gravelbourg consists of an elected Town Council with six Aldermen and a Mayor. The positions are filled by election and they serve for three-year terms. Under the Council, there are five working subcommittees (Economic Development Committee, Public Services Committee, Finance Committee, Recreation Board, and the Aquaplex Committee & Beautification Committee). The town also employs a Town Administrator, an Assistant Administrator, a Town Foreman, and an Economic Development Officer to manage daily affairs, public works and economic affairs (Town of Gravelbourg, 2010).

All levels of government (federal, provincial, and municipal) are involved in governing the community. The Agri-Environment Services Branch (AESB), formerly known as the Prairie Farm Rehabilitation Administration (PFRA), is responsible for promoting sustainable development in terms of environmental stewardship on the agricultural areas of Alberta, Saskatchewan and Manitoba (the Prairie Provinces). Regarding the provincial government, the Local Government of Gravelbourg follows the acts of the Government of Saskatchewan; while the municipality has authority over police and fire department, water and sewers as well as parks and recreation (Town of Gravelbourg, 2010).

4.1.2.2 Economic Activities

The Chamber of Commerce in Gravelbourg aims at maintaining a "prosperous and viable business sector in the community" by supporting the opening of businesses (Town of Gravelbourg, 2010). The town has more than 100 businesses and services. With its numerous agricultural businesses, the Town of Gravelbourg serves as an important regional service centre of the surrounding Prairie farming community, which produces staple crops such as wheat and barley as well as pulse crops such as peas and lentils.

With the effort of the economic development committee, more value-added agricultural and small manufacturing operations are starting in this town. The headquarters of Saskatchewan's leading manufacturer of light commercial trailers – Trailtech, as well as Mustard Capital Inc. and other mustard production plants are also located in Gravelbourg. They employ more than 150 individuals and help to sustain the economic viability of the town.

Tourism is one of the major industries in Gravelbourg. The town is a center for the Roman Catholic Church in Western Canada. Its religious importance is shown in the construction of Gravelbourg Religious Complex. Apart from that, Our Lady of the Assumption Roman Catholic Cathedral, the

Convent of Jesus and Mary, and the old Canadian National Railway Station are well-preserved and are popular tourist attractions in the Province of Saskatchewan.

Figure 21 Our Lady of the Assumption Roman Catholic Cathedral

4.1.2.3 Cultural Activities

Gravelbourg tries to preserve the French language and culture by maintaining the only French-language residential school operating in Western Canada - Collège Mathieu – and providing French immersion programs in both the elementary and high schools. A French cultural centre was also built to promote French culture within the community by organizing a diversity of cultural activities. There is also a French resource centre, Le Lien, which provides cultural resources to Francophone schools and cultural organizations (Town of Gravelbourg, 2010).

Figure 22 Gravelbourg High School

4.1.2.4 Demographic Information

The Town of Gravelbourg had a population of 1089 in 2006, with a 8.3% decrease since 2001 (Statistics Canada, 2007a). The median age of the population is 48.2 while the median age of Saskatchewan is 38.7 (Statistics Canada, 2007a). In terms of male to female ratio, it is 1: 1.16 in Gravelbourg compared to 1:1.04 in Saskatchewan. The majority of the population (~70%) stayed in town for more than five years. In the range of 15 years old and over, 47% of them have postsecondary certificate, diploma or degree (Statistics Canada, 2007a). The major fields of study are architecture, engineering, health, parks, recreation and fitness (Statistics Canada, 2007a). The majority of the labour force (55.4% of the population) works in sales and service as well as trades, transport, equipment operations and related occupations (Statistics Canada, 2007a). The median income after tax (persons 15 years old and over) is $24,271 (Statistics Canada, 2007a).

The Rural Municipality of Gravelbourg had a population of 329 in 2006, with a 19.6% decrease since 2001 (Statistics Canada, 2007b). The median age of the population is 43.5 and its male to female ratio is 1: 0:78 (Statistics Canada, 2007b). The majority of the population (~96%) stayed in the RM for more than five years. In the range of 15 years old and over, 36% of them have postsecondary certificate, diploma or degree (Statistics Canada, 2007b). The major fields of study are architecture, engineering, education, business and public administration (Statistics Canada, 2007b). The majority of the labour force (90% of the population) works in primary industry such as farming and ranching (Statistics Canada, 2007b). The median income after tax (persons 15 years old and over) is $ 19,640 (Statistics Canada, 2007b).

4.1.2.5 Infrastructure

Gravelbourg is accessible by two major highways in Saskatchewan, Highway #43 and Highway # 58. The general road condition is acceptable, although some of the roads need major repair. The town is also accessible by air. The Gravelbourg Airport is located close to town with a capacity of servicing light aircraft. A rail line owned by the Canadian Pacific Railway passes through the Town of Gravelbourg for the transportation of agricultural products from a local grain elevator operated by Pioneer Grain Company. Daily freight service is available to and from Regina and Moose Jaw. The Saskatchewan Transportation Company also provides bus services four times a week travelling to major cities such as Regina, Moose Jaw and Shaunavon (Town of Gravelbourg, 2010).

There are three schools in Gravelbourg that offer education in both English and French from kindergarten to grade 12. In terms of the adult education, the Great Plains College and Le Service Fransaskois de Formation aux Adultes offer different training programs and remote courses that can be transferred as university credits (Town of Gravelbourg, 2010).

The town has its own hospital, St. Joseph’s Hospital, which provides 24 hour emergency service with 2 ambulances that operate within a 60-km radius of town (Town of Gravelbourg, 2010). Apart from the hospital, there are also three doctors, one dentist and two public health nurses working in Gravelbourg. Two pharmacies are located in the town to provide services six days a week. The town is protected by the local RCMP detachment, which employs three police officers, as well as a volunteer Fire Department, which consists of a Fire Chief and twenty-one volunteer firefighters (Town of Gravelbourg, 2010).

Recreational facilities allow all-season activities such as swimming, hockey and bowling. The town also owns one of the last remaining movie theatres in rural southern Saskatchewan, which attracts people from nearby communities to town every week. Each summer, the community organizes the Solstice Festival, which celebrates the uniqueness of the community's culture and "reinforces the spirit of southern Saskatchewan" (Town of Gravelbourg, 2010). The town is also surrounded by numerous recreational sites and tourist attractions, for instance, Thomson Lake Regional Park, Shamrock Regional Park, Wood Mountain Ranch & Rodeo Museum, Old Wives Lake National Bird Sanctuary, to name a few.

4.2 Rural Municipality of Hart Butte – Town of Coronach

Coronach is located 145 km southwest of Regina and 13 km north of the United States border. This town was created around 1927 when the Canadian Pacific Railway started to serve this particular location. It is named after a horse named Coronach after the horse won the Epsom Derby, which is a horse-racing competition in England. The town has a total area of 2.33 km^2 (Statistics Canada, 2007c). One of the most distinguishing features of Coronach is its rolling hills of ranchland and its large extent of farmland.

Figure 23 Town of Coronach

4.2.1 Biophysical Factors

4.2.1.1 Climate

Like Gravelbourg, Coronach is located in the Palliser's Triangle, which is characterized by its hot and dry climate. The average temperature is 3.8^{o}C and the highest temperature mainly occurs in July and August and the lowest temperature occurs in December and January; the total amount of precipitation is 414.1mm with the wettest month being May and June and the driest month being January and February (Environment Canada, 2011b). Northwest winds are also common in this region.

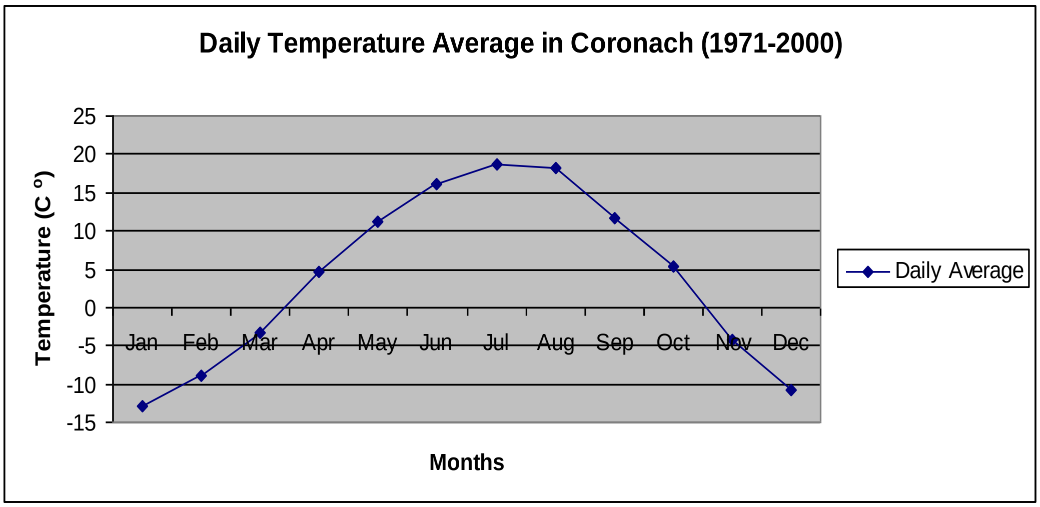


Figure 24 Daily temperature average in the Town of Coronach

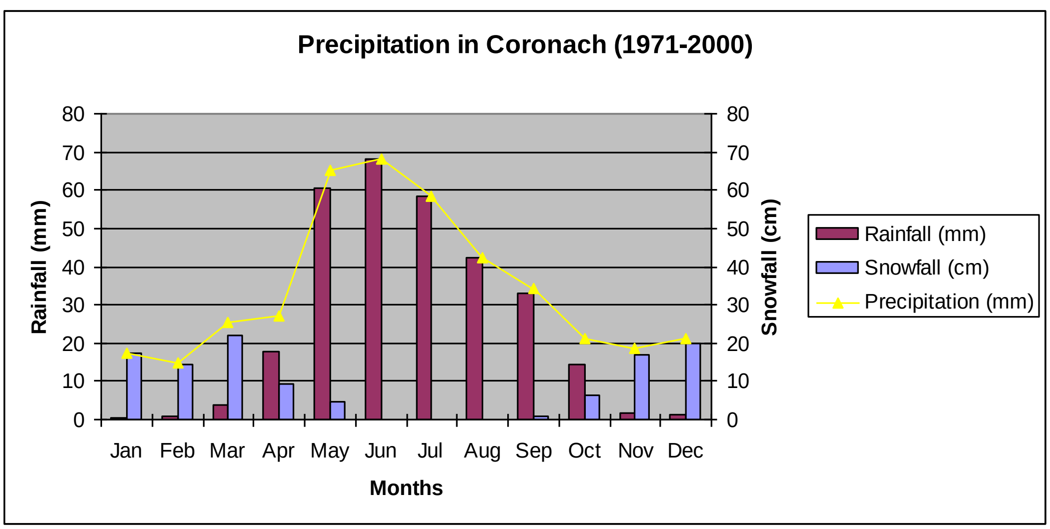


Figure 25 Precipitation in the Town of Coronach

4.2.1.2 Source of Water Supply and Sewage System

Coronach and the surrounding area mainly rely on groundwater from two wells. The town owns a 60ft well that supplies ¼ of the town water; while the rest of the town water comes from a dewatering line from SaskPower. As the coal seam in this region is covered by groundwater, dewatering is required to lower the water table for coal excavation. The water pumped out from the ground is then connected to the dewatering lines that support nearby population. Town water is treated by green sand filter, which is backwashed every second day. The water treatment plant is owned and operated by the town. The total storage capacity of town water is 600,000 gallons and it supplies around 350 houses and stores in town. Sewage is managed by the town and is pumped into a two cell lagoon, which is ½ mile east of town. The treated sewage is then pumped to nearby fields for irrigation of forage crops (Town of Coronach, 2010).

Figure 26 Two cell sewage lagoon in Coronach

4.2.1.3 Vegetation and Soil Type

Coronach also falls under the category of short grass prairie with Brown Chernozemic soil. As moisture levels and soil organic matter are low in this region, grasses are dominant in this region and ranching is one of the major activities in this rural municipality.

4.2.2 Socio-Economic and Cultural Factors

4.2.2.1 Political System

The local government of Coronach consists of a Town Council and a Mayor. They serve on a four-year term and they are responsible for various town issues. The town also employed a Town Administrator, an Assistant Administrator, a Town Foreman, and an Economic Development Officer (Town of Coronach, 2010).

All levels of government are involved in governing the community just like Gravelbourg. Although the AESB does not have an office in Coronach, they are also responsible for agricultural matters in this region, such as management of community pasture and provision of funding and educational seminars/workshops for farmers and ranchers. The Local Government follows the rules and regulations of the Provincial Government; while the Municipal Government is responsible for the police and fire department, water and sewer as well as parks and recreation.

4.2.2.2 Economic Activities

The Town of Coronach has more than 25 businesses and services (Town of Coronach, 2010). However, the town is mainly driven by two major industries, the Sherritt's Coal Poplar River Mine as well as the SaskPower Generation Plant. Under the rolling hills, there are considerable amounts of lignite coal deposits in this region. Therefore, the town is the home to Sherritt Coal's Poplar River Mine (Figure 27), which specializes in surface strip-mining with two of the biggest draglines in North America. This mine serves SaskPower Generation Plant that generates power for approximately 1/3 of the Province. The mine and the power plant together employ around 300 individuals, which is more than 1/3 of the town's population. According to the report of Saskatchewan Environmental Society (Halliday and Associates , 2009), cooling is the most significant industrial use of groundwater next to the oil and gas industry in the Province. For SaskPower Generation Plant, groundwater has been used to supplement the decreased surface water for cooling during drought years and the use of groundwater in most years is limited (Halliday and Associates, 2009). One of the major concerns regarding mining is land reclamation. Each year, the amount of land that is disturbed by mining is equal to that reclaimed to its natural state (CN 34). Land reclamation in this area has been successful in leveling the spoil piles and saving topsoil for agricultural use. After the land is reclaimed, the mine will keep the land for a few years and grow forage crops to make sure the reclaimed land is suitable for farming. Farming is another major industry in this region; farmers produce crops such as wheat, lentils and peas while ranchers mainly focus on cattle.

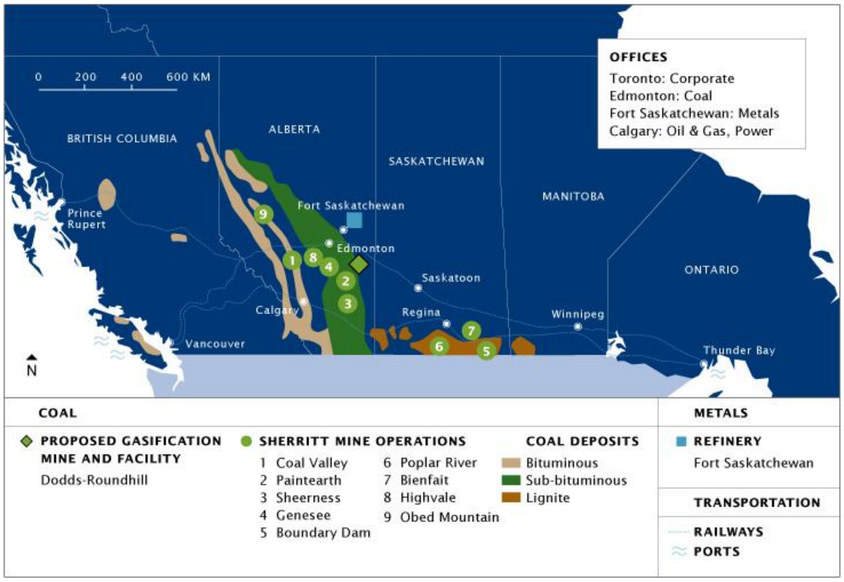


Figure 27 Sherritt's Coal - Prairie Operations (Sherritt International, 2010)

Figure 28 Sherritt Coal with previously reclaimed land in the background

Figure 29 Largest Dragline in North America

Figure 30 SaskPower Poplar River Power Station

Figure 31 Inside Poplar River Power Station

4.2.2.3 Cultural Activities

Like in Gravelbourg, tourism is one of the major industries in this region. Tourist attractions around this area are mainly related to local culture/history and the natural landscape, such as the Outlaw Trails, Sam Kelly's Outlaw Caves, North West Mounted Police Site, Castle Butte, the Turtle and Buffalo Effigy, the ceremonial rings, and the Big Muddy Valleys, which is a badland area that showcased some of the most interesting geological features in the area. Each summer, the community organizes the Outlaw Days Festival, which celebrates the past and present of this region and attracts a large number of tourists to this town (Town of Coronach, 2010).

Figure 32 Castle Butte

Figure 33 Big Muddy Valleys

4.2.2.4 Demographic Information

The population of the Town of Coronach in 2006 was 770 with a 6.3% decrease since 2001 (Statistics Canada, 2007c). The median age of the population is 41.1 while the median age of Saskatchewan is 38.7 (Statistics Canada, 2007c). In terms of male to female ratio, it is 1: 0.95 in Coronach compared to 1:1.04 in Saskatchewan (Statistics Canada, 2007c). The majority of the population (~64%) stayed in the town for more than 5 years (Statistics Canada, 2007c). In the range of 15 years old and over, 56% of them have postsecondary certificate, diploma or degree (Statistics Canada, 2007c). The major fields of study are architecture, engineering, business, management and public administration (Statistics Canada, 2007c). Approximately 67 % of the population (over 15 years old) is in the labour force (Statistics Canada, 2007c). Similar to the Town of Gravelbourg, the majority of them work in sales and service, trades, transport, equipment operations and related occupations (Statistics Canada, 2007c). The median income after tax is $ 25,308 (Statistics Canada, 2007c).

For the Rural Municipality of Hart Butte, the population in 2006 was 272 with a 12.5% decrease since 2001 (Statistics Canada, 2007d). The median age of the population is 41.1 while the median age of Saskatchewan is 39.2 (Statistics Canada, 2007d). In terms of male to female ratio, it is 1: 0.77 in the RM of Hart Butte (Statistics Canada, 2007d). The majority of the population (~78%) stayed in town for more than 5 years (Statistics Canada, 2007d). In the range of 15 years old and over, 26% of them have a postsecondary certificate, diploma or degree (Statistics Canada, 2007d). The majors field of study are business, management and public administration (Statistics Canada, 2007d). Approximately 87 % of the population (over 15 years old) is in the labour force and most of them work in primary industry such as farming and ranching (Statistics Canada, 2007d). Owing to the limited size of the population, the median income after tax is not available.

4.2.2.5 Infrastructure

Coronach is accessible by two major highways in Saskatchewan, Highway #18 and Highway # 36. A rail line owned by the Canadian Pacific Railway also passes through the Town of Coronach for the transportation of agricultural products from two local grain elevators owned and operated by Pioneer Grain Company. Another short rail line is owned by Sherritt’s Coal. It is the longest privately owned rail line in Canada. It is used to transport coal to the coal fired power plant approximately 20km away.

There is a school in Coronach that offers education from kindergarten to grade 12. The need for early childhood development is served by the Coronach Early Learning Literacy Centre; while adult education is provided by South East Regional College in Assiniboia, which is one hour away from Coronach (Town of Coronach, 2010). Remote courses are also offered by universities and colleges.

The town has a health centre, which has 12 long-term care beds and 4 multi-purpose beds with an x-ray lab (Town of Coronach, 2010). The Coronach ambulance has six Emergency Medical Technicians (EMTs) and an ambulance is available whenever a patient needs to be sent to a hospital outside of Coronach (Town of Coronach, 2010). For the past few years, there has been no doctor in town and the nearest doctor is located in Assiniboia. This town is protected by the local RCMP detachment which consists of a corporal and two constables. There is also a volunteer Fire Department, which consists of a Fire Chief and fifteen volunteer firefighters (Town of Coronach, 2010). A number of recreational facilities are available in town, such as a nine-hole golf-course, ice-rink, horse track, curling rinks, swimming pool, and gymnasium. Recreational activities such as boating and swimming are also allowed in the Cookson Reservoir east of town.

Chapter 5
Methodology

5.1 Data Needs

In order to identify ways in which the communities can increase their adaptive capacity to drought, this project employed a variety of research methods and they are described in the following sections.

5.1.1 Community-Based Vulnerability Assessment

The CBVA conducted in this research followed the conceptual model outlined in Chapter 3. Given the socially defined nature of drought (see Chapter 2), it is crucial to examine the diverse cultural understandings of drought, the communities' everyday water usage practices and habits, and the processes that reinforce or change them. In light of this, qualitative research methods are needed in order to understand the multi-dimensional nature of drought. As mentioned in the conceptual framework chapter, CBVA assumes that assessing past and current exposure-sensitivities, and how the community responds (adaptation strategies) will provide insights on the community's future exposure-sensitivities and their ability to cope with future changes. Semi-structured interviews and participant observation were used to explore past and current exposure-sensitivity (stresses that have an effect on the livelihood of the community) as well as their adaptive capacity (ability to adjust their practices to cope with exposures and recover from stress). Secondary data such as literature reviews as well as websites of Prairie Adaptation Research Collaborative and other relevant organization were used to provide information on the droughts in the late 1980s and the droughts in 2001–2. Regarding future exposure-sensitivity and adaptive capacity, climate predictions from literature review as well as prediction made by informants were used. By conducting semi-structured interviews, information that helps to define differential vulnerability within the communities can be collected. The result from CBVA is then used to define adaptation measures can be tailored to the need of the communities while increasing their adaptive capacity.

5.1.2 Soft Water Path

The case study for soft water path analysis consists of two main parts. The first part includes water auditing in the two municipalities so as to assess the potential of soft water path. Data on water usage patterns for different sectors were collected by semi-structured interviews supplemented by literature review. Town foremen were interviewed for background information of water usage in the towns. Direct observation was used to help eliminate bias from the interviews. In the second part, literature review and interviews with knowledgeable experts helped to define a sustainable and desirable future by characterizing and quantifying potential future water availability and demand. The process of backcasting was based on the book - *Urban Water Soft Path – 'Back of the Envelope' Backcasting Framework* (Brandes and Maas, 2007). Finally, a list of feasible paths was identified and recommended to the communities.

To conclude, primary data was collected through methods such as semi-structured interviews and direct observation. Secondary data, for instance climatic data, government reports and web resources, were used to provide background information for the project, to supplement information provided by informants, and to guide the research design. Finally, communication with professionals and experts yielded up-to-date information and guidance.

5.2 Case Study Research

Case study research was practiced through a comprehensive investigation of two rural communities in Saskatchewan. Case study research enables researchers to "understand the complex real-life activities in which multiple sources of evidence were used" (Noor, 2008). The primary and secondary data collected in this study mainly focused on the two major droughts – the droughts in late 1980s and 2001–2. As aforementioned, this research was part of a SSHRC-funded project, where six communities (Coronach, Gravelbourg, Kindersley, Maidstone, Maple Creek, and Shaunavon) were selected in total. The chosen communities were based on their size, drought experience, types of water sources, availability of weather monitoring stations, and their location within the drought-prone Southern Saskatchewan. First of all, they had to be agriculturally-based communities that had a variety of economic activities that sustained them. They needed to have a population of at least 500 people with basic infrastructure that proved that they were viable. The communities selected have a variety of water sources, such as surface water, groundwater and pipelines. They experienced drought in the past that led to crop failure and they also had their own water-related problems that added stress to their water supplies. Finally, the availability of weather monitoring stations also helped to assess the communities' exposure-sensitivity and adaptive capacity in the face of drought.

Rather than focusing on a set of strictly defined indicators, the general contextual factors were studied so as to ensure a more holistic approach in gaining understanding of the communities' exposure-sensitivity and adaptive capacity. Through this method, the suggested CBVA framework was applied and more in-depth studies on specific components were suggested for future research. The case studies on the two communities helped to provide a general idea on the level of vulnerability of rural communities in the face of climate-induced drought.

5.3 Semi-Structured Interviews

There are three different types of interview - structured, semi-structured and unstructured. The structured interview focuses on questions where interviewer has to be especially familiar with the subject of interest so as to formulate questions in advance; in unstructured interview, conversation focuses on the participants and the flow of the interview is directed by them instead of the researcher. Semi-structured interviews are situated at the middle of the continuum. Semi-structured interviews were chosen in this project as they are more flexible and allow researchers to bring up new questions in response to the participants' comments. Non-verbal gestures are also observed in a semi-structured interview to supplement information provided verbally. This format helps interviewers to prompt questions for more in-depth answers. Probing allows researchers to clarify concerns and issues raised by the participants (Hutchinson and Skodal-Wilson, 1992), provides opportunities to examine sensitive issues (Hay, 2008; Nay-Brock, 1984), helps participant to recall information, and facilitates a sense of rapport between the researcher and the participant so that socially desired answer could be reduced (Patton, 1990). Instead of allowing the conversation to flow freely, an interview guide with a few questions of the general topics and themes is prepared in advance to guide the flow of the interview.

The goal of the interviews was to identify stresses that were important to the interviewee and the community. The first step of conducting the interviews was to establish a list of key informants to be interviewed. The snowball sampling method was used to extend the network in order to gather more informants for interviews. A wide range of informants was ensured by starting multiple snowball chains in each community. One of the advantages was that, as the communities were relatively small in size and almost everyone knew each other, people were able to suggest other informants that faced different problems regarding climate change and water issues. Also, when people knew that someone referred them, they were more likely to participate in the study. Regarding the issue of bias, non-discriminative snowball sampling was used in this study. Because of the size of the community, informants were encouraged to nominate people that can provide different perspectives on the issue. As a result, the problem of bias was minimized.

Many people are more willing to express their opinion in detail by verbal communication. Especially in the rural communities where people grew up in farms and work as ranchers or farmers for their entire lives, they may find interviews more preferable to other research instruments. Participants in semi-structured interviews may have a greater sense of empowerment as it encourages participants to involve actively. Unlike direct observation, semi-structured interviews allow researchers to collect information with relevant actors from the main stakeholder groups.

Owing to the complexity of environmental issues, the discussion questions themselves may not be straightforward and easily understood by everyone. Semi-structured interviews allow researchers to clarify unclear questions. Not just gaining information in the participants' own words, the researcher also evaluated the validity of the participants' answers by observing their non-verbal gestures. In self-administered questionnaires, unclear questions will not have a chance to be clarified. Participants may simply choose an answer arbitrarily from the list of choices, which will affect the accuracy of the study. Moreover, standardized questions may not be able to explore the complexity of the issue. By conducting semi-structured interviews, researchers can prompt questions according to the response of the participants. Also, the selected methods can overcome the weaknesses of poor response rate as well as unanswered questions in questionnaires.

An interview guide was followed in this project (Appendix C). All of the questions were open-ended in order to obtain in-depth thoughts on people's opinion on their vulnerability to water shortages. It obtained questions regarding people's opinion on environmental issues they thought are relevant to them, issues that made them vulnerable, how those issues affected their livelihood, how they dealt with those issues, and whether their solutions were effective. The final part of the interview contained questions on soft water path, such as how people felt they used water within their household and whether they thought it was possible to conserve water in different ways. Scenario-based questions were asked in order to gather information to supplement data collected from climate models as well as literature review on future exposure sensitivity and adaptive capacity. The participants were encouraged to elaborate on their answers in order to obtain as much information as possible. After the interview, a review was conducted on all the interviews to see if any issues arose and a summary which contained key points from the interviews was prepared.

5.4 Participation Observation

Sometimes people do not behave the way they say they do. Participant observations allow the researcher to observe what is actually happening on the ground. It is used to generate reliable results and verify information provided by informants. Values, structures and social dynamic of community members can be observed through this research method. It assists in the investigation of the social meaning of natural phenomena and is often used as triangulation in combination with semi-structured interviews and literature review to answers the question of 'how' and 'why'. Therefore, in the specific topic of drought vulnerability assessment, overt participant observation can help to identify the multiple stresses and adaptation strategies of different community members.

5.5 Sampling Strategies and Sample Size

Seventy-five interviews (37 interviews in Gravelbourg and 38 interviews in Coronach) were conducted in a ten-week period in the summer of 2010 from June 7 to August 13 (See Figure 34a and b). Sample sizes were determined in the field when the point of data saturation was achieved and no new insights emerged from the data. All the interviews were approximately 60 minutes in length (For the interview information sheet and consent form, see Appendix A and Appendix B). Throughout the field season, trust is developed through informal interaction and conversation with community members, living with a local family, and frequent visitation of public space such as local coffee shops and grocery stores. Multiple snowballs were started by making initial contacts with the RM Reeve, Town Administrator, local PFRA officers (only in Gravelbourg), economic development officers and church pastors. Further participants were suggested by key informants and the sample contains a mixture of different genders and socioeconomic backgrounds in order to get a representative sample of the community. Participant observation is used to improved interview questions so as to make them more relevant and context-specific. It also helped to identify appropriate informants for later interviews. Another advantage of participant observation is that by immersing oneself in the community, the researcher's experience can assist in understanding and enriching the data collected through other methods.

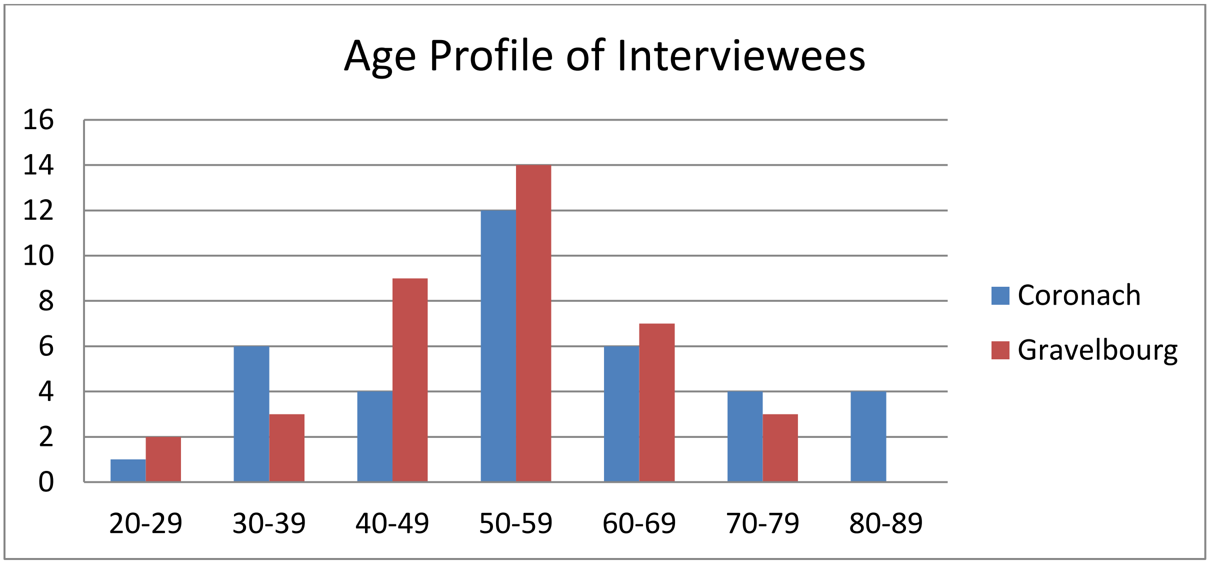


Figure 34a Age profiles for interviewees in Coronach and Gravelbourg

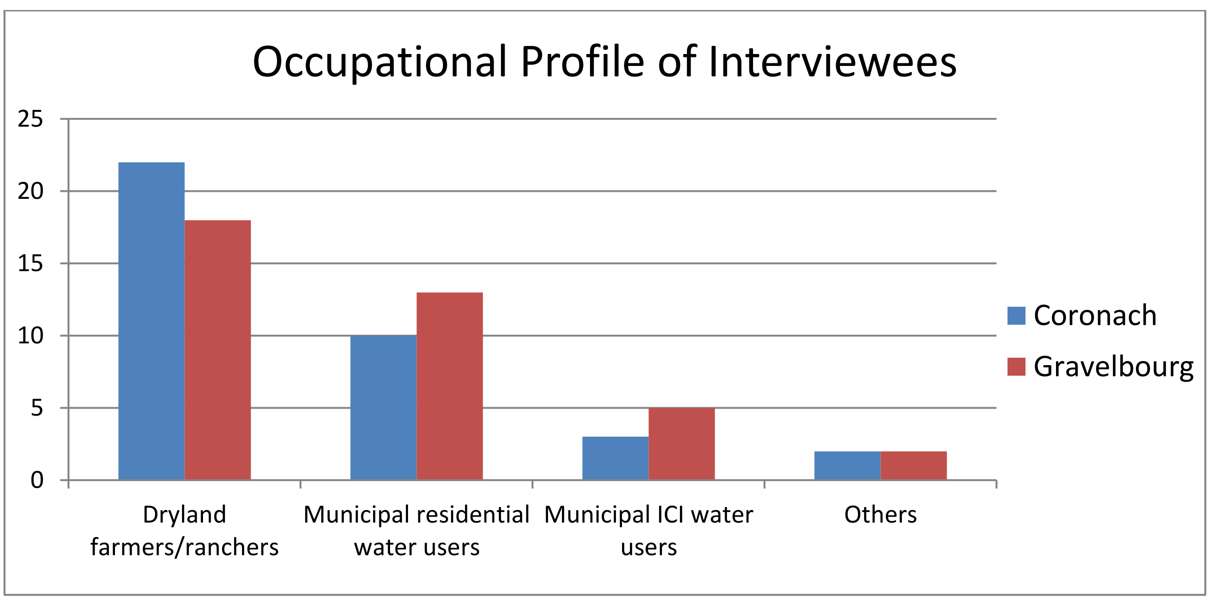


Figure 35b Occupational profiles for interviewees in Coronach and Gravelbourg

5.6 Data Interpretation and Analysis

All the interviews and focus groups were recorded and transcribed in word processor files. The data were analyzed with a qualitative data analysis software program - NVivo 9, which is capable of organizing large amounts of textual data. Nodes were used to classify different concepts and themes. Free nodes were created based on major ideas mentioned by the informants. When more than one informant brought out the same idea, a free node was turned into a tree node so that the connections between different concepts or themes can be drawn and analyzed. The tree codes used in this study were livelihoods, water use, climate exposures and sensitivities, adaptive strategies, and adaptive capacity. Free nodes included barriers to adaptive capacity, improving institutional support, future resilience, gender roles, water financial management, and other issues. The same nodes were used throughout the entire study in different communities for comparison purpose. For further information regarding the coding scheme, please refer to Appendix D.

5.7 Research Ethics

This study has been approved by the Office of Research Ethics (ORE), University of Waterloo. In order to ensure the safety and well-being of the participants and the communities, the ethics clearance process is to make sure that the study conforms to the Guidelines for Research with Human Participants of the ORE and the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans. The information letter (refer to Appendix A) and consent form (refer to Appendix B) were given to each participant so as to provide them with the background of` this study and inform them what was expected from them. In the information letter, it was stated that participation was voluntary and that they can choose to withdraw from the study at any time. Utmost care was undertaken to conduct this study to the best of the researcher’s ability. Interviews, recordings, and transcripts were labeled with project codes to ensure anonymity of the informants. A report will be sent to the communities for their feedback and reference in hopes of bringing benefits to the communities by helping them to better prepare for future climate-related events.

Chapter 6

Results – Community-Based Vulnerability Assessment

Vulnerabilities of the two communities are not merely dependent on the magnitude of droughts and the social systems separately, but on the interactions between the two (Bankoff et al., 2004; Smit et al., 2005). As Holling (2001) identified in his paper, the natural and human systems are intertwined and they should be considered as coupled social-ecological systems. Small farmers or ranchers are not merely passive victims of drought. They also take an active role in shaping the environment around them; thus, affecting their own vulnerability towards drought. Therefore, vulnerability assessment has to be context-specific and address issues that affect the communities at different scales. This chapter discusses the current exposure-sensitivity of Coronach and Gravelbourg with respect to experience from past drought events, i.e. droughts in the 1980s and 2001–2. Adaptation strategies adopted by the communities to cope with the drought events are described and assessed.

In this analysis, exposure-sensitivity is divided into two main categories – the biophysical aspect and the socio-economic aspect. Owing to the geographical proximity of the two study communities, which are less than 115km apart, the biophysical attributes of the two communities are similar. Regarding the socio-economic aspect, as vulnerability varies across different groups of actors (i.e. based on their livelihood), the analysis is presented with respect to different types of livelihood instead of their geographical location. The main types of agricultural operation in the two communities are dryland farming, mixed farming, and ranching. Dryland farming means crop production without relying on irrigation. This type of agricultural operation is supported by precipitation in the forms of rain and snow only. Dryland farmers aim at retaining the maximum amount of moisture available by practices such as minimizing soil disturbance and growing crops that are drought tolerant. With the limited amount of precipitation in this region, water resources are scare and irrigation is not practiced. Ranching is commonly practiced in an area near Coronach where the topography is more suitable for grazing livestock. Beef cattle are the most popular form of livestock and most of the ranchers practice cow-calf operation in this area; therefore, this paper mainly focused on this type of operation instead of other forms of livestock. Finally, mixed farming is also practiced in this area. It is a combination of farming and ranching. Most producers practice mixed farming to ensure that they have a secure source of income, as income from crops can supplement income from cattle. In terms of the analysis of adaptive capacity, it analyzed the resources that are available to the respondents that enhance their resilience to drought. It is divided into five main categories – farming practices, information and education, financial resources, social network and others. Despite the fact that the result is organized and presented in subcategories under exposure-sensitivity and adaptive capacity, site-specific characteristics of each community are presented and discussed in each subcategory.

Summary tables (see Table 3 and 4) are used to conclude this chapter and the tables should be viewed as a guide to design future adaptation strategies but not an exhaustive list of the vulnerabilities of the two study areas. As previously mentioned, vulnerability has to be site-specific and context-specific; this study is by no means a generalization of the vulnerability faced by all the rural communities in southern Saskatchewan.

6.1.1 Current Exposure-Sensitivity

6.1.1.1 Biophysical factors

"After 'hello' people talk about the weather next. Usually, like if it's summer, winter, whatever, that is part of the farmer's conversation is the weather" (GB 15)

As weather plays an important part in agriculture, this section explores the biophysical exposure-sensitivity in the two study communities. Before specific climatic events are examined, the optimal range of weather that the respondents prefer is discussed for contrasting purposes for the following subsections.

Timely rain is a crucial element in ensuring good crops. Many producers pointed out that they do not need a lot of moisture to grow a decent crop. Some of them claimed that they can get 30 bushels an acre on just four inches of rain. This indicates that they simply need timely moisture at the critical stages of the growing season. Although crops require different amount of moisture to grow, the general ideal situation will be having a sufficient amount of moisture from snowmelt to get the crops started in April. Once the crops are in and have established their root systems fairly well, the producers need a shower in middle of May and a rain in the beginning of June to keep the crops growing, another rain in July and some showers in early August. According to the producers, this will almost guarantee a decent crop. Once the harvesting period is over at the end of September, the farmers said they can get as much rain as nature offers. Rain and snow in the fall after harvest is important because moisture will not be lost through evaporation after it gets cold or the ground freezes. In addition to precipitation, the producers also need a certain amount of heat to encourage crops to grow. Some producers prefer a temperature that is not too high and not too low; while others are more specific and prefer the temperature to be 10°C by the last week in April, around 27 °C in June, 33 °C in early July and then to cool off a little bit in the middle of July, so that crops can finish without the heat. Usually it is the wind that dries out the moisture out of the stems or the soil, so strong wind is not preferred. A producer said he prefers harsh winters because if there is moisture in the ground, it will freeze and crack up the ground. When spring comes, the ground that was loosened in winter will soak up the water. (CN23)

Similar to grain producers, ranchers believed that early rain is important to get the grass and hay growing. After that, a little moisture is sufficient to keep the grass growing, but they can also take in all the moisture they can get. In the haying season, dry weather is preferred as moisture encourages the growth of mold in the bales. The cattle prefer weather that is not to hot and not too cold. Therefore, weather extremes can stress the cattle. For example, temperature that reaches 35°C may be too hot for black cows. Also, if it is too hot, there will be more flies and that bothers the cattle as well. Ranchers prefer warm and open winter time when there is not a lot of snow, so that they can practice winter grazing to reduce the cost for feed by letting the cattle stay on the pasture and graze. In colder weather, cattle consume more feed and bad winter storms are not good for the cattle either. Therefore, ranchers prefer a mild winter.

6.1.1.1.1 Drought

"Even this spring, when it was raining and raining and raining, you're wishing quietly that it would stop so you could get the crop in but you never really wish that out loud because, you know, that tap is going to shut off some time…We're only one rain away from a drought" (CN6)

By analyzing people's definition of drought, researchers can understand how the respondents define a problem based on what is relevant to them. Therefore, suggestions offered can correspond with the way drought is defined. Drought is defined by town residents as "a lack of sufficient water to sustain normal practices" (CN2); although some of them defined by the visual aspect, which is when everything turns brown because of the lack of moisture (GB36). As town residents do no depend on weather for their livelihood, they are less likely to be aware of and be affected by drought.

Figure 36 Dried lake near Coronach

Figure 37 Dried lake bed with salt sediment

In contrast, producers are more specific on the definition of drought. Some producers claimed they know that there is a drought when the crops in the lower spots of the fields are taller and greener than those at the top of the hills (CN8). However, most of them focused on the timing of the lack of moisture. They defined drought as a lower than average rainfall during the growing season. There is not enough rain to saturate the soil, with a combination of wind and heat (CN3, 8, 10, 20, 22, 23, 35, GB18, 26). However, only a few producers related drought to the lack of moisture in both winter and summer. They know that if they do not see a lot of snow, they are more susceptible to drought (CN19). Therefore, they may change their crop and livestock management plan if they see a dry winter. (CN12, GB35). Experienced farmers defined drought as three years of minimal run-off and low rainfall together with high temperature, because crops will still grow when the temperature is cool and the rainfall is low (CN29). Younger farmers may define drought as "three or four months without rain" and a few young producers even think that they have a drought all the time (CN6, 7). Some of them related drought to crop failure and defined it from their past experience, such as the droughts in late 1980s when they had significantly less than average moisture that was not enough to germinate their crops (CN 5, 14, 15, 21, 31, 33, 34, 36, 37, GB27, 30, 37). A few producers associated drought with grasshoppers, gophers or dust storms (CN19, 24, 33, GB23); while the rest of the producers characterized it based on what they have to do, such as buying extra feed, renting more grass, culling the herd, etc. From the result of the interviews, most producers thought that the most obvious characteristics of drought are the lack of runoff that leads to dry dugouts and lowered water levels in the lakes and rivers.

Although town residents may not be able to provide a detailed definition on drought, they are able to identify drought based on town water usage. In the summer of 2007, water usage in Coronach went up to 250,000 units a day while only two respondents in Coronach identified 2007 as a drought year (CN18). The increase in town water usage not just represents increased water demand of residents, but also the increased demand by agricultural producers in the nearby area. As the towns offer load out stations for producers to fill up their tanks, many producers haul water from town during the dry years. For example, in Gravelbourg, it costs around two dollars for two hundred and eighty gallons of treated water and around one dollar for two hundred gallons of untreated water. Since town water supplies have been consistent and dependable during dry years, most town residents commented that they had never experienced drought. However, they are also indirectly affected by the impact of drought. Local businesses are affected as producers spend less money in town. For mustard producing companies in Gravelbourg, drought not only affects the quantity of mustard seed, but the quality as well. As the companies want high quality mustard seed, they need to go further for higher quality mustard seed if drought occurs. This increases their production costs depends on the distance they have to go.

In Coronach, the power plant is also affected by the impact of drought. As cooling is a major process, they rely on a reservoir to supply water for cooling. As the watershed in this area is rather small, the power plant needs to have a lot of snow or a lot of rain to fill up the reservoir. In the drought years when there was limited runoff, the water level of the reservoir went down and that affected the efficiency of the power plant because they had to shut down one unit in the plant. For the mine, they rely on runoff to fill the settling pond for dust suppression. Therefore, if there is not enough snow in the winter, there will not be a big runoff that fills the pond by the end of the year and it will increase their costs for dust control.

Figure 38 Haul road in the coal mine

Figure 39 Settling pond for dust suppression

When producers were asked to recall specific years of drought, they were able to identify 1961, 1987-9 and 2005-7 as drought years. Out of all the droughts, the drought in the '80s was the most memorable to the respondents. Forty-eight respondents identified the multi-year drought in 1987 as the last drought they had experienced. They remembered it as a drought that lasted for two to three years with dust flying and grasshoppers all over the highway. Most of them thought they had not seen any bad drought since the late '80s. Out of 75 respondents, only seven thought that they were affected by the drought in 2001–2. Although the drought in 2001–2 received much attention across Canada, compared to other drought events, such as late 1980s and 1960s, the drought in 2001–2 was not memorable to the respondents in this area. Some people thought that as producers were used to farming in dry condition, they may not have noticed this drought. Past droughts put some farmers out of business whereas in 2001–2 producers were still making enough money to stay in this industry. When producers looked at their weather record, one of them identified 2001 as a dry year where they only received a few inches of rain till the 9th of June; while in 2002, they had a lot of snow in May, but other than that, there was no significant amount of precipitation. Some producers also suggested that changes in farming practices may have made this drought more manageable than the past droughts. Many producers made comments similar to this: "if we were farming the same in 2001 and

2002 as we were back in '80s, we probably would have had a disaster. But our farming practices have changed that we don't notice it so much" (CN3). Producers are not as worried about drought as they were before. Many producers recognized that with better farming practices (such as minimum tillage and crop rotation) and better machinery, producers have reduced their exposure and sensitivity to drought significantly. With changing farming practices, producers do not need the moisture that they needed before. For instance, when they do not have enough moisture in spring, they will seed more acres in drought–resistant crops. This example demonstrates that their experience and knowledge help them to manage the changing condition better. For town residents, as the town was not affected and water supply was consistent in 2001–2, no one identified 2001–2 as drought years.

In order to compare the severity of the drought in 1988 and 2001–2, Table 1 shows the monthly temperature and precipitation of Coronach and Gravelbourg (with the growing season highlighted). During the growing season in 1988, the average temperature for Coronach and Gravelbourg was 17.3°C and 17.4°C respectively; while the total precipitation was 193mm and 172mm. During the growing season in 2001–2, the average temperature for Coronach and Gravelbourg was 15.7°C and 15.3°C respectively; while the totally precipitation was 296mm and 331mm. This shows that the drought in 1988 was more severe in terms temperature and precipitation compared with the drought in 2001–2.

Table 1 Monthly temperature and precipitation of the Town of Coronach

1988	Temperature (°C)	Precipitation (mm)	2001–2	Temperature (°C)	Precipitation (mm)
Jan	-12.7	9	Jan	-8.8	20.5
Feb	-10	13	Feb	-11.1	9
Mar	-1.1	13	Mar	-7.2	17.5
Apr	5.9	13	Apr	3.2	15
May	14.9	41	May	10.1	34.6
Jun	22	85	Jun	16.1	98.4
Jul	19.6	38	Jul	20.2	63.8
Aug	18.6	16	Aug	18.2	29
Sep	11.3	13	Sep	14	43.3
Oct	5.5	8	Oct	1.9	18.3
Nov	-4.3	15	Nov	-0.2	7
Dec	-9.6	30	Dec	-7.8	4

Table 2 Monthly temperature and precipitation of the Town of Gravelbourg

1988	Temperature (°C)	Precipitation (mm)	2001–2	Temperature (°C)	Precipitation (mm)
Jan	-14.4	7	Jan	-9.4	12
Feb	-10.4	14	Feb	-11.3	4.5
Mar	-0.8	17.1	Mar	-7.9	19.5
Apr	5.1	0	Apr	-2.8	14.8
May	15.3	9.4	May	10.4	33.8
Jun	22.3	83.1	Jun	15.6	86.8
Jul	20	32	Jul	19.6	66.4
Aug	17.8	32.1	Aug	17.7	101.5
Sep	11.4	15.3	Sep	13	42.2
Oct	5.3	5.2	Oct	1.2	16.7
Nov	-4.3	14	Nov	-3	5
Dec	-10.9	27	Dec	-8.8	7.5

Spotty rain is another crucial factor that affects crop productivity. Producers claimed that if they can get a few timely rains, they can get a decent crop; but if they are outside the raining area, they may have a disaster. During the drought in the late ‘80s, some farmers were only able to get less than five bushels of crops; while in normal conditions they can get around thirty bushels of crops on average. Even if they had a good start in spring, the heat and the lack of moisture in the later part of the growing season can also lead to crop failure. Sometimes, when the cost of harvesting the crops was higher than the total value of crops that were in the field, producers with livestock will just graze the cattle and let them clear up the field instead of combining the crops. For dryland farmers without livestock, some of them expressed that they will leave the crops in the field without combining. A number of producers even identified Russian thistles as being the only plant that grew, and everything else just died during that year. There was no profit for them at all and some families had to sell their cattle to buy feed.

In some dry years when the grass never turned green, some of the ranchers had to feed their cattle into the growing season when the hay should have been growing. When the cattle need to graze on grasses that are too short because of the lack of moisture, it will wear down their teeth and they cannot live as long. Therefore, cattle may get weak and die in a prolonged drought. A drought in one area also means ranchers need to go to other places to buy hay. The further they go, the more expensive the hay because of the trucking costs. Moreover, producers have to be extra careful when they are harvesting because it only takes a spark to start a fire when the crops are extremely dry and fire spreads really fast in the prairies (CN17).

Some younger farmers thought that the last drought they had experienced was in 2008 and they have not seen good crops in the last few years (CN14). For experienced farmers, they claimed that in the past 30 years the only drought that they had experienced was the one in late 1980s. There might be a few dry years, but they were not serious droughts that the producers will comment on. As more producers are having off-farm jobs to supplement their farm income, the economic impact of drought is greatly reduced.

6.1.1.1.2 Excessive Moisture

"It is a matter of timing and you cross your fingers you get some moisture at the right times in order to grow a decent crop" (GB 19)

Some producers think that excessive moisture is never a concern in the Prairies as excessive moisture can replenish dugouts and increase groundwater levels that may be beneficial in future droughts. When the interviews took place, the communities had an abnormally cool and wet spring. Many producers thought that it was an unusual year with a significant amount of rainfall during the seeding time. During excessive moisture, many producers delayed seeding because the soil was so wet that they could not get into the field. Some of the producers had to change their plans a number of times and seed different crops depending on the time they could start seeding. For producers that seeded their crops before the excessive moisture, their seed may rot in the ground or may not be able to germinate. If it had germinated, it may also have been drowned and may not have survived. Moreover, if the soil is too wet, the roots of the crops will remain at the soil surface to take advantage of the moisture available without utilizing the moisture reserved underneath. Most of the producers think that excessive moisture is not what causes the biggest problem to the crops, but the heat that follows it. With roots that are exposed at the soil surface, the crops will dry up when the heat comes. For organic farmers, they get more weeds because they may not have a chance to pre-work the soil before seeding it.

Excessive moisture hurts both organic and conventional producers during harvest time as well. When the producers cannot get their crops off, it will have a serious impact to their income. As seeding is delayed in the situation of excessive moisture, the crops are more susceptible to frost damage that will downgrade their crops. Indeterminate crops like chickpeas will continue to grow as long as there is moisture, so excessive moisture at the end of the growing season will prevent the chickpeas from maturing. Green peas and lentils are also very sensitive to moisture at harvest. Once they are in the last week before harvest, the weather should be as dry as possible so as to keep the color on them. Some producers expressed that it is hard to keep damp grain in the bin and the quality of grain will drop if it is harvested at a high moisture level. Excessive moisture can also affect the protein level of crops and create problems of sprouting and bleaching that will downgrade the crops and affect their price.

Figure 40 Excessive moisture in 2010

Figure 41 Slough created by excessive moisture

As for ranchers, excessive moisture means a good year for hay. Hay crops thrive in high moisture condition and many ranchers will have an abundance of hay that they can sell to earn some extra income. In some areas, if the grass is growing too fast, the nutrients in it may not be as good, but that is not a common problem in the area. If the ranchers start to bale hay when the moisture level is high, cattle may get sick and die from moldy feed. Also, if the land has good drainage, excessive moisture will not be a problem. If not, the cattle may get foot rot, which is a bacterial infection of soft tissue between the cattle’s claws. Cattle that suffer from foot rot will lose a considerable amount of weight and this affects overall productivity. If excessive moisture happens during calving and the calves are exposed to cold and wet condition, this will increase the probability of calf death because of hypothermia.

Excessive moisture may also affect the town if the town is not well-prepared. In the spring of 2011, high levels of spring runoff affected the water quality of the Thomson Lake Reservoir. The turbidity and manganese level of water increased and there was a concern for potential contamination. Therefore, the Ministry of Environment issued a Precautionary Drinking Water Advisory on the Gravelbourg Potable Water Supply System. Similar events had also happened in the past. In the spring of 1998, a large amount of snow melted in a short period of time and the water did not have enough time to soak in. That early spring melts led to a serious flood that almost inundated the town. For mustard manufacturing companies, the effect of excessive moisture depends on the total acreage that cannot be seeded. As excessive moisture may lower the quality of mustard seed, this may affect mustard production. Chemical companies are also being affected because they will not be able to sell as much chemical if less acreage is being seeded. For the coal mine in Coronach, excessive moisture stops the haulers from entering the pits and the production is slowed down if the weather is bad.

6.1.1.1.3 Other Climatic Events

Besides drought and excessive moisture, Coronach and Gravelbourg are also affected by harsh winters. Residents in rural communities may be snow-bound for three to four days and some of them go to other places for vacation before growing season begins. In Coronach, there was a massive blizzard that lasted for three days in 2010. Houses had no electricity and hot water. Students had to take the ambulance to go home from school. Some of the people had to live at neighbour's house with back-up generators. In the mine, it takes a lot of time and energy to thaw the draglines in wintertime. If there is heavy fog with low visibility, the draglines need to be shut down. However, there are also some respondents who thought that the winter was not as harsh and they did not have as much snow as before. Although frost damage is not common in this region, some producers experienced early frost in the past and had to sell their crops as feed because the frost downgraded them.

Figure 42 Hailstones from the storm in July 2010

Figure 43 A field of Kamut hit by the hailstorm in July 2010

Figure 44 Crops affected by hailstorm

For summer, serious rainstorms and hailstorms are common in this region. The general rains, where almost everyone gets it in a large area, usually occur in June (CN8). General rains turn into showers in July and August and the spottiness of the rain affects the producers. They can get thunderstorm in one area and no rain at all five miles away. Moreover, timely rain is crucial for crop production. If there is a lot of moisture in the early months and it starts to be dry in July and August, the quality of crops will deteriorate quickly. That is why producers usually buy lands that are spread out. Although organic producers select their crop varieties based on disease resistance, weather that is too warm and moist will create disease problems and being organic they cannot spray for diseases. Therefore, warm and humid weather may affect their yields. One producer commented on the fluctuation in moisture conditions in the Prairies "You know, with not very much precipitation and then another cycle, there's lots of precipitation. So that's one thing about this part of the country. If you don't like the weather you wait a half an hour" (CN17). In terms of hailstorm, a field can be hailed out 100% in just one night. A farmer claimed that he has lost about $200,000 worth of crop in a day with a hail storm that went through his field. Although a hailstorm is an isolated event that is restricted to a specific area, many farmers have experienced hailstorm in the past and reported that this decreased their yields significantly. Lightning is another climatic exposure in the Prairies. Owing to the relatively flat landscape, producers may lose cattle because the lightning strike and some houses were burned down because of that as well. In addition to agricultural impacts, heavy rain also influences social activities and make road conditions more dangerous in rural communities.

6.1.1.2 Socio-Economic and Cultural Factors

Demographic trends of the two communities place them in a vulnerable position. As aforementioned, both communities have a problem of depopulation. Owing to the lack of employment opportunities, people that are moving out are likely to be between the ages of 18 to 40. As soon as the younger population finished high school, they will leave the town and pursue higher education or get a job in the city. This trend is supported by the median ages of the population in both communities, as they are higher than the median age in the province of Saskatchewan. Aging population in the two communities leads to a decline in demographic resources to sustain economic activities and increases their vulnerabilities in face of extreme events, such as drought. With the commonly identified problem of the lack of health care services in the community, some elderly left Coronach and moved to bigger cities for better medical care. Therefore, depopulation reduced local economic activity significantly.

The livelihoods of local business owners are highly susceptible to the well-being of the town in general. If the town is growing, there will be a positive feedback that will encourage the development of more local businesses. On the other hand, if the town is declining, more businesses will be closed down owing to the lack of customers. Especially in rural communities like Coronach and Gravelbourg, which rely basically on agriculture. When the producers have less money, they will spend less money in town. For example, when there is excessive moisture, the farmers do not buy as much chemicals or fertilizers because of the decreased acreage of seeded land. Also, farmers may use bin-run seed for a few years instead of buying new seed every year if their farm income is low. Therefore, it will affect other sectors of the community.

The livelihood of local business owners is also affected by leakages to larger centres. As local stores do not have as much to offer the consumers compared to big city centers, many people shop in places such as Moose Jaw or Regina when they have to leave the town for different reasons. This hurts the local economy and causes a vicious cycle that contributes to the decline of local businesses. For example, although Saskatchewan's third-largest power plant is located in Coronach, a lot of people are commuting to work back and forth during the week and go back to the city on the weekends. So the number of workers in the power plant and mine does not help the community's economic growth necessarily. One of the challenges mentioned by the respondents in Coronach is the lack of a doctor in the community. They had several major accidents in the past and the victims had to be sent to Regina, which is more than 200km away. They only have an EMS team and if they need immediate medical attention, the closest doctor is an hour away. Therefore, geographical isolation contributes to the decline in this aging community. In Gravelbourg, they have a hospital, a nursing home and three doctors in town; therefore, they are not as vulnerable as Coronach.

With the decreasing size of community population, agricultural producers have to do everything by themselves and there is a shortage of manpower. They do not have any employees and they cannot complete their tasks in the time because they are on their own and they can only finish everything by themselves. As producers are getting older, they may not have the same amount of energy and efficiency to deal with the work they have to do. Therefore, it affects their productivity and they become less competitive against larger producers.

The decrease in farm income owing to high input cost and low commodity prices causes many producers to have off-farm jobs to support their expenses. Some producers complained that if they were paid in an hourly rate on the farm, they could retire at a much younger age with the hours they put in every day. However, with the low commodity prices and high input costs, they feel that they are underpaid. Some mixed farmers and ranchers expressed their concern that it is hard for them to have an off-farm jobs because they need to take care of their cattle every day. If they have an off-farm job, something may get neglected on the farm or ranch. Therefore, when the number of cattle or the size of their land is sufficient for them to make a viable income, most of them will quit their off-farm job and focus on farming and ranching.

Figure 45 Land for sale near Coronach

With the combination of low farm income and high interest rate, a number of producers even needed to declare bankruptcy because they could not pay their bills. Some producers returned their equipment to the finance company because they could not make payments. That is why a number of ranchers do not own any haying equipment and they hire someone else to do that for them or sell it to someone else and let others do it. In the past, a producer could sell a bin of wheat and buy a tractor. Older farmers claimed that they have never had off-farm job mainly because they did not spend as much money as today's farmers. They did not borrow money and they paid for their machines all the time. Now some of them said that they do not have enough bins on the farm to buy a tractor because the cost has gone up so much higher.

Several people went into mixed farming because they think usually if the price of grain goes up, the price for cattle goes down or it is the other way around, so having both grain and cattle dampens the effect of price fluctuation of the market. However, there are cases in which mixed farmers gave up their cattle and went into custom grazing because the price of cattle has been low since the Bovine Spongiform Encephalopathy (BSE) hit in 2003. Some producers noticed that big multi-national companies control the prices and small producers are forced to take what they are offered. Together with the rising price of inputs, they figured that the costs of keeping the cattle, buying hay, raising their own hay are so high that they will be better off selling the cattle and custom grazing. That way their financial situation can be improved from custom grazing, selling hay and not buying feed for their cattle (CN7). On the other hand, some farmers think the fact that they have to put in a lot of money in the beginning of the year and not knowing what to expect makes it hard for them to budget. As a producer mentioned "farming nowadays appears to be much more of a gamble than it used to be in the past. So that there's more at stake, because the costs are a lot higher" (GB22). If the crop does not pay out at the end of the year, they will be in trouble. Therefore, some of them try to grow crops that are worth more money.

Farmers' livelihood is also affected by weeds, pest and insects. Gophers and grasshoppers are major issues to this area. Many farmers that were interviewed reported that they lost a lot of crops in the past because of gophers and grasshoppers. Therefore, they spent a lot of money in controlling pests. As for ranchers, diseases such as the BSE have given them a hard time in selling their cattle. After the BSE hit, the price of cattle has dropped and some of the ranchers had to keep their older cows in the herd and hope the prices will come up in the future. However, the price remained low for the last few years. Ranchers recalled that before BSE they were getting $800.00 for a calf in the fall; while for the past few years, they were selling calf for $550.00 (GB19). When the $300.00 difference is multiplied by 300, that makes a big difference in their income.

While their input costs keeps going up and the prices of grains remain low, producers cannot get ahead on farming. The fluctuations in product prices also get producers in trouble because of the difficulty in budgeting. When the prices of grain go up, many producers start to borrow money and buy new equipment. When the prices go down again because of overproduction, many producers are in debt and that causes them more financial difficulties. Others are in debt because they want to achieve the economies of scale by expanding the size of their farm. As the cattle industry is easily affected by the economies of scale, more ranchers are expanding their enterprises so as to maintain their livelihood. Some producers pointed out that the middlemen are making more than the producers do because, although the prices of food have been increasing, the prices of their grain are relatively stable over time.

Some producers raised a concern about their competitiveness against other producers in Canada. As the study communities are located in a semi-arid area, given that the input costs and the prices of product are the same across Canada, they are still in a disadvantaged position as producers in other area can harvest a 40 bushel crop per acre while they can only harvest a 30 bushel crop because of the climate (CN8). As there is nothing they can do to change the climate, they do not assume they are going to get a good crop every year and they can only try to spend accordingly.

Producers are also sensitive to the international market. If there are good crops in other countries, such as Argentina, Australia, Pakistan and China, it will affect the markets. As the prices of grain are driven by world market, producers do not have a say in the price of their own product and they can only play a passive role in ensuring that they are not overproducing. The international exchange rate is another determining factor for the price of product. If the value of Canadian dollar changes, it will affect the competitiveness of the agricultural products. When the Canadian dollar appreciates, it makes our grain more expensive compared with grains from other countries and the demand for Canadian grains decreases. This once again places Canadian producers in a passive position and one of the producers said "I know everybody's got to make money but it just doesn't make sense when my cost, my markets are dictated by world costs and I have no control over the margins of what I sell my products for" (CN 7). That is why the number of farmers is decreasing over the years.

Marketing is another major issue faced by producers. As the number of elevators is decreasing, producers have to haul their grain for a greater distance. Together with the increasing transportation costs caused by more expensive fuel, producers are trying to market grains that are worth hauling. Many organic producers also have a hard time marketing their grain because the buyers think that the price of organic product is going down and they do not want to buy organic product right now. That is why a lot of bins are full with organic products. As some organic farmers cannot afford to hold their crop until the prices go up, they have to sell their grains in conventional market because they needed the money immediately. The price of organic grain used to be much more than conventional grain, but the price of organic grain has dropped close to the conventional rates in the last few years and their livelihood is seriously affected by the low prices. They said that they only want a reasonable price for their product that can at least cover their cost of production, but it is getting harder nowadays.

6.1.2 Current Adaptive Capacity

6.1.2.1 Economic and Financial Resources

Access to economic and financial resources is a crucial factor in contributing to the adaptive capacity of the community. For producers, low crop prices reduce their farm income. Some of the producers cannot make payments to the finance company and they have to sell their equipment to pay off debts. As the costs of machinery are rising, some producers cannot afford to upgrade their equipment. They had to change their operation by finding a way to farm without some of the equipment that they used to have, which makes their operation less productive. The topography and the change of elevation in the badlands also restricted the range of technologies that can be used. Cattle producers have to pay more for technologies that can be used in the specific conditions. Therefore, it affects their ability to purchase new technologies that can improve their adaptive capacity.

Owing to financial difficulties, some producers cannot pay the premiums of crop insurance and have to farm without any form of insurance. Programs such as crop and hail insurance can only help producers to adapt in the short-term. In order to maintain their livelihood, more than 60% of the producers that are still actively farming or ranching have other sources of income. For mixed farmers, most of them expressed that they did not have time to have an off-farm job and mixed farming itself helped them to diversify the risk of grain production alone. With less room for error, farmers that cannot subsidize their input costs are forced to stay away from new technologies and reduce their insurance coverage, which make them more vulnerable to drought in the long term. A grain producer commented “it’s hard to go forward because every drought or a little bit of crop failure takes away from your income and it’s hard to move forward” (CN14). With all the little costs that add up throughout the year, many producers can only live on a day-to-day basis. If they do not have a good crop, they cannot afford to pay for insurance next year, which is why they tend to deal with changes in a reactionary manner owing to low farm income. As the expense of farming is rising, some conventional farmers have switched to organic farming because the prices for organic products are higher than conventional products and the expense is lower as well. Although they know that cultivation may lead to soil erosion, they cannot change their practices because they simply cannot afford the chemical bill.

During drought years, some ranchers had to buy hay of lower quality (such as oat straw, slough hay or oats that had baled up late in the season) because of the increase in the price of hay. Some ranchers could not afford hay and shipping costs were forced to cull their herd. Financial issues tend to be in a vicious cycle. When cattle producers sell their cows owing to financial difficulties, they are giving up the income that they can earn from the calves next year. That way their income generating capacity is decreased, so as their adaptive capacity to future changes.

Although financial assistance is available to producers, some of them are still restricted by the lack of financial resources. Some producers have identified things that they could do to make them more adaptable to drought; however, financial issues restricted them to carry out their plans. Irrigation is often identified as an effective adaptive strategy to cope with drought in agricultural communities. However, with the increasing cost of irrigation equipment and the cost of drilling a deep well to ensure a reliable source of water, a few producers said that the cost of irrigation has restrained them from practicing irrigation. Some producers have discovered wet areas that they can make use of by digging dugouts or enlarging their original dugouts to capture snow water that melts in spring; yet, they do not have sufficient financial resources to do it. For instance, a rancher (CN29) planned to build a pipeline in 2003. When the BSE hit, the cattle market was so bad that he had to cancel the pipeline project. Even though the government covered two-thirds of the cost, he could not afford his portion of the project. Moreover, new technologies may not be accessible to the producers owing to financial difficulties. Some producers show interest in new technologies, such as auto-steer, but the potential cost of maintenance with the amount of electronics available in new machineries prevented them from investing in new models. Therefore, they have to wait till the technology is more affordable after a few years. In order to minimize the cost required to obtain new technologies, as aforementioned, some producers formed farm clubs to share the cost of machineries, which makes new technologies more accessible to them. Therefore, it shows that the lack of financial resources has hold producers back in investing in capacity building infrastructures.

For other businesses, such as Sherrit Coal, their adaptation measures are restricted by cost. As identified by a respondent, the scale of the coal mine operation makes adaptation strategies more expensive. When they have to cope with water shortages, their options are restricted by cost. One of the examples given by the respondent is that salt was used to replace water for dust control in previous drought years as that was the only affordable solution that could be identified by the company. Although there are other methods for dust control, cost has limited their options. In terms of the schools, as water conservation is "not a huge budgetary item", adaptation measures are not being carried out unless government provides financial incentives (GB7).

6.1.2.1.1 Availability of Financial Resources

As drought is a recurring event in the Prairies, the government has developed financial programs to assist municipalities and producers to improve their adaptive capacity by helping them to drill wells and dig dugouts. For example the provincial government has a Farm and Ranch Water Infrastructure Program for producers in drier area. Many producers have made use of the grant provided by the program to ensure water availabilities in the future. Fifteen producers claimed that they have made use of government financial support such as the Farm and Ranch Water Infrastructure Program to increase their sources of water supply. In order to ensure sufficient water supply, some producers even drilled a 1,400 feet well down to the Judith River Aquifer with the help of the government. The government programs also subsidize measures for the protection of water quality, such as fences and solar pumps, so that cattle will not pollute the water source. However, some of the programs are capped and government only provides producers with funding up to a maximum amount depending on the project. Also, with government financial support some of the workers raise their price for well-drilling, so it dampened the effectiveness of government grants.

Figure 46 Cattle drinking directly from a dugout

Other cost-sharing programs are also available to producers, such as the Canada-Saskatchewan Farm Stewardship Program, which promotes beneficial management practices for agricultural production. Projects funded in this program include seeding grass in the riparian area, building of remote water systems, measures to protect existing wells, and farmyard run-off control etc. This financial support makes conservation measures more appealing to the producers and promotes long-term adaptive capacity in agricultural production.

Some producers have their own insurance programs to protect themselves financially. When dealing with creditors, some producers try to put clauses in the contract, so that they could skip a payment if they had a bad drought. Several of them keep this year's crop in the bin and sell last year's crop (CN 30). Thus, if there is a crop failure this year, they still have some income to support themselves by selling last year's crop. As producers will never know whether they hit the right price when they sell their product, some of them try to market their crops a little bit each quarter so that they will hit some of the highs and some of the lows. If the price of a certain crop is really low, some producer will simply keep it and sell it next year when the price comes up.

Not just the producers, other sectors also took advantage of the government funding. The RM of Hart Butte (Coronach) utilizes the government funding to build community wells. “The primary reason (for building community wells) was because the government provided 85% of the funding, so we’re only spending 15% to develop the program…that’s the biggest driving factor” (CN12). Results of the interviews show that government financial support encourages proactive measures in drought-prone area. In the RM of Gravelbourg, government grants facilitated the construction of a pipeline project, which provides water to almost 70 percent of every farm yard. A respondent stated that without financial support from the government, this project would never have been feasible for the RM (GB 3). With the pipeline, producers have another source of water supply, which greatly improves their adaptive capacity. The RM also works together with the town, so as to bring more cash into the town to carry out projects that were too costly for them at one time. In terms of households, $50 rebates are provided by the provincial government for installing water-efficient toilets. The rebate program encourages reduction in water demand, which helps to household to improve its adaptive capacity in the long run.

6.1.2.2 Institutional Support

In terms of institutional support, different levels of government play crucial roles in helping the communities to deal with issues that make the residents vulnerable by enhancing their adaptive capacity.

6.1.2.2.1 Federal Government

As Canada is an exporting nation and deals with different countries, the federal government needs to be involved in regulations and foreign relations. The federal government plays an essential role in supporting research conducted on enhancing the adaptive capacity of farm and ranch operations in rural communities. Federal statistics on overproducing or under producing are valuable to producers for future planning.

To prepare the producers for potential drought, Agriculture and Agri-Food Canada (AAFC) has a drought watch website that shows the impact of climate change on water availability and provides an overview of drought risk in different areas of Canada. This information helps producers to improve their adaptive capacity by planning ahead and helps the provincial and local governments in planning drought programs according to their local condition.

PFRA community pastures are a resource provided by the federal government to help the ranchers. Ranchers can send a certain amount of cattle to graze in the community pasture. This program has a formula that is specially designed to help the small producers. According to the AAFC website, around 3,000 producers utilize the community pastures each summer and approximately 222,000 head of livestock are being grazed in all community pastures (Agriculture and Agri-Food Canada, 2011a). The community pasture promotes sustainable land use practices and contributes to soil conservation in the Prairies. As the pastures are being managed carefully, some ranchers claimed that they had good grass even in past dry years.

AgriInvest is a program that assists producers in the situation of small income declines. Producers make annual deposits in an account, then, for every dollar the producer puts in, the government will match it and the interest of the producer's and the government's money will be given to the producer. If the producers need the money, they can withdraw their money anytime from the program. This program helps producers to put away money in good years and they can collect it whenever they need it later on. Most producers agree that this program is designed for big farmers, because for farmers with extra money in the bank, they can make use of this program and further improve their financial situation. Small farmers that need help are neglected as they cannot afford to put money into this program owing to limited financial resources and the government does not seem to be able to make it more equitable. As most people that need the help cannot afford to put any money into the account, it is the big farmers that are getting the benefit and they are getting bigger and bigger (CN15). Older farmers also expressed that they do not participate in AgriInvest because they are retiring soon and will not depend on the money in the account.

One of the most discussed topics among the farmers is the Canadian Wheat Board (CWB). The purpose of the CWB is to help farmers to get the best price possible for their grains. Producers will then receive interim payment on their grain throughout the crop year as the price of grain on the world market improves. At the end of the year, a final payment with the total value of sales minus the operating cost is given to the producers. There are diverse opinions on whether the CWB should continue to have a monopoly on wheat products. As Coronach is close to the American border, producers with land next to the border often compare Canadian policies with American policies.

Because of the CWB, producers cannot take their wheat across the border when the price of wheat per bushel was 5 dollars higher. With the CWB, they have to wait until the end of the year to get the full payment and they cannot get the money for immediate use. As a producer concluded “last year, we could have shipped $100,000 worth of product to the States as seed. Because I’m a wheat grower, we couldn’t do that. That hurts. We’re only 10 miles from the U.S. …I know a lot people across the line that I have grown up with them. Why is that border so important between us?”(CN16). In addition, as grain elevators are getting further and further away, producers have to haul their grain a greater distance; therefore, this has a significant impact on their livelihood. However, some producers also mentioned about the difficulties in marketing their own grain without safety nets and ad hoc programs. As a load of grain can be given a different price depending on the broker, once the cheque is signed, they are on their own. The Wheat Board can make sure producers are getting a fair grading of their crops and everything is dealt with fairly. This makes the producer less vulnerable to the fluctuation of grain prices. However for big farmers, they are able to market their crops at a better price with their bargaining power; therefore, most of the big farms do not support the Wheat Board.

6.1.2.2.2 Provincial Government

Most of the producers claim that they prefer help from the provincial government instead of the federal government. The reason behind this is that usually the provincial government has programs that are gauged to the specific condition of the province; while the federal government tries to design programs that work across the country but end up not benefiting the people that needed the help.

One of the most well-known programs provided by the provincial government is the Crop insurance program. It is a government program that helps producers to manage the risk of farming. It is a federal-provincial cost shared program where the producers only pay 40 percent of the premium and the remaining 60 percent is shared between the federal and provincial governments. Producers can select coverage at 50, 60, 70 and 80 percent of their average yield based on their need (Saskatchewan Crop Insurance Corporation, 2011). More than 20 of 35 interviewed farmers carry crop insurance. One of the main reasons farmers carry crop insurance is because they have debts to pay off and the insurance can protect them by minimizing the risk of farming. However, not all the farmers are satisfied with the program.

A number of producers dropped crop insurance because they thought that the premium was too high and the pay-off could barely cover their expenses. Some of them said that they never collected any money even in the major drought in 1988. A producer questioned the usefulness of crop insurance and said, "in order to have crop insurance be good for your financial situation you had to plan around it. You had to farm the program. And I didn't come here to do that. I came here to farm…crop insurance to me is not the answer. You know, there are guys that did well with it because they knew how to milk the system" (CN7). Those producers thought that the yield average was so low that they have never had a situation where they needed to make major claims, and they will be better-off saving their money in the bank. If the producers collect crop insurance for two or three years in a row, their premiums will go up and their coverage will go down. So if a producer has hailstorm for two years and a drought for the next year, they are not going to get enough money to cover the cost of the inputs. Especially with the increasing intensity and frequency of drought events, the premium required will increase and make agricultural producers more vulnerable. For organic farmers, the price it takes to insure organic product is so high and the number of bushels guarantee so low that a number of organic producers claimed that unless they had a complete disaster, they would not be able to collect anything. Therefore, it is hard to justify spending money on crop insurance and almost half of the organic farmers do not take crop insurance. Producers with large farms tend not to carry crop insurance because it is too expensive to insure the area their farm covers. For most years, farmers do not have a claim, so that will be a large expense for bigger farms. For younger farmers, if they have just started, they have to pay the top premium but are guaranteed the lowest bushel. As they are also buying land and machinery, it can be particularly hard for them to maintain their livelihood. Many of them are forced to take off-farm jobs to subsidize the expenses in farming. During the year when the interviews took place, the government has extended the seeding deadline for crop insurance because of the excessive moisture in spring. However, a number of producers pointed out that by the time of the deadline, it was already too late to be seeding in that part of the country and the chance of getting good quality crop is poor because they need a certain period of frost-free weather for crop growth. Therefore, the program has to be designed based on the characteristic of the specific location.

Crop insurance is one of the proposed methods to reduce farmers' vulnerability; yet, it has been demonstrated that the insufficiency of crop insurance returns and coverage contributes to social vulnerability. For example, insurance provided by Saskatchewan Crop Insurance Corporation is just enough for the subsistence of the farm with minimal returns as the rules imposed by the insurance companies restrict their claim of insurance. If agricultural producers use crop insurance, their premium for the following year will increase.

AgriStability is a relatively new provincial government program that aims at protecting farm operations against large declines in the producers' income. Producers receive payment when their income falls below 85% of their income from previous reference years (Agriculture and Agri-Food Canada, 2011b). This program provides producers with a safety net when an unfavourable condition occurs. For instance, for grain producers that have had some good years to build up the reference margin, AgriStability insures them well for a bad year. A producer gave an example of how he can benefit from the program with the type of crops that he grows. As chickpea is a high-value, high-input crop, crop failure can be disastrous because of the high inputs. So if he has several good years before and then a bad year hits, he will get paid really well in that disaster year (GB15).

Similar to crop insurance, there are also different pitfalls in this program. As the government uses previous years as reference margin, some ranchers are concerned that after BSE hit, everyone's income was at the bottom of their entire farming career, which means they may not able to collect anything unless the price of cattle drop further down. Also, with the low cattle prices, they never had the big years to establish the baseline data. So although their livelihood has been seriously affected, they are not protected by the program. A producer also mentioned that, in 2004, his income had dropped by 40%, but because his neighbour gave him three to four hundred bales of frozen field peas and that was counted towards his income, the program did not kick in for him. At other times, even when the producers did not expect a payout, they would get a cheque unexpectedly. Some producers also had problems with the way the program calculates allowable income and allowable expenses. As one of the non-allowable expenses is land payment, this program may not be beneficial to young farmers who are trying to expand their farms. An accountant also stated that half of her clients dropped out last year because the paperwork was too complicated and they were not getting the support that they wanted. Many people think that the AgriStability program is not fair. They think that if they have someone "knowledgeable" (someone who knows the system) to fill out the forms, they will get paid fairly well (CN5); whereas small farmers that cannot afford to hire someone to do their forms may not be able to get the payments like others. Moreover, for producers to participate in AgriStability and AgriInvest, they have to carry crop insurance, so they have a heavier financial burden in paying for crop insurance in order to participate in other programs. With many costs being added up throughout the year, some people decided that it is just another bill that they don't need (GB25).

The provincial government has an Agriculture Knowledge Centre for the producers to ask questions. They have people who specialize in different areas of agriculture to provide advice to farmers on various topics, such as the type and amount of fertilizer that they should be using on their land based on their soil sample.

The Saskatchewan Watershed Authority manages water resources in the province by monitoring the quantity and quality of surface water as well as groundwater. They conduct research on the current condition of water in Saskatchewan and promote water conservation initiatives by communicating with local communities. In the local Agri-Environment Services Branch (AESB), officers meet up with clients in the field and help them with their problems as well as to educate them about soil conservation and water development projects. AESB also helps to maintain the Thompson reservoir and monitors its water level. During the late 1980s, Old Wives Lake went dry because of drought. As it is a saline lake, the salt left behind after evaporation blew onto the adjacent land and made the land unproductive. The farmers were concerned about this situation as year after year they were losing more land to salinization. The former PFRA (now AESB) helped the community to adapt to this situation by developing a saline resistant grass that can hold the salt down and survive in saline condition. Therefore, the farmers can continue to farm in this area. Apart from financial and technical support, the provincial government also provides emotional support with their farm stress line. It provides counselling service to producers that are under stress and helps the producers by improving their emotional adaptive capacity towards changes.

In other circumstances, the provincial government has supported ranchers by subsidizing twenty-five dollars for a ton of hay that they had to buy for their cattle during a drought. However, as soon as the government made the announcement, the price of trucking and the price of hay went up. In the end, the trucker and the people selling hay were making more money and the ranchers that needed the money did not get the financial support intended. Therefore, the design of government program should also be improved so as to make sure that the producers are the ones that are being supported.

Some of the producers wished that both federal and provincial government programs in general were simpler with less paperwork. In the past few years, there have been many changes to the programs and many producers admitted that they have a hard time keeping up with the programs and they often mixed up the names and details of the programs. Because of the complicated paperwork, this makes the accountants the winners that get all the money out of these programs and the money often do not come back to the producers at all. One producer said “I’ve always enjoyed, my strengths I think are in agronomy, to grow something or produce something. I just try hard to put my efforts and stuff to do it on my own and do it that way rather than with government.” (CN25). Instead of spending a lot of time in understanding the details of those programs, some producers will rather spend time on developing better farming practices. Also, a lot of money sent out by the government to help the producers to cope with extreme events does not go directly to the producers. A large proportion of the funding ended up going to the administration of the payout. Furthermore, producers also complained that they do not receive the payment until a year after they need it. Producers have already done what they had to do to get through the disaster before they receive the payout two years later. Therefore, they have to have their own program set in place to deal with the delay in payment. A producers said “We take part in those programs because we find it’s probably a benefit to us but to say that if I had a crop failure this year and rely on those programs to make it through for us I think that’s impossible to be honest with you, because by the time the program comes through, our bankers are gonna be awfully mad” (GB37). Therefore, timely payment is crucial in helping the producers in need. Programs should target people that need the support instead of a blanket approach that ended up benefiting those who are not intended for.

6.1.2.2.3 Local Government

Regional resource-based sharing is practiced among the Town of Coronach, Assiniboia and Gravelbourg. Regional meetings are held twice a month among the economic development officers to discuss the possibilities of sharing resources to contribute to the overall economic prosperity of the region. This initiative facilitates communication among the three major service centres in the region and helps to improve community adaptive capacity.

The Town of Coronach is designed for a population greater than the current population. Therefore, the water treatment plant has a higher capacity in treating more water than currently demanded. Water is one of the items on the future strategic plan. The town has been looking into ways to improve rural access to water by developing water infrastructure and designing better usage policies to build their adaptive capacity towards future climatic events (CN1). Some of their initiatives include installation of meters for leakage detection and odd/even day lawn watering restriction so as to prevent people from using more water than the treatment plant can handle. As soon as there is a sign of water shortage, the town will put up notices to inform people of the situation. In order to ensure the security of water, the town is also working on a water assessment to look for wells near the reservoir of the power plant, so that the town does not have to rely on the dewatering line from the mine. The assessment also checks whether the water quantity and quality of their wells are under the influence of surface water.

Figure 47 Irrigation during the heat of the day

The RM of Hart Butte (Coronach) has made use of government assistance to build three community wells for the farmers to load their water tanks with non-portable water for spraying and their livestock. It is an adaptation strategy provided by the RM "for the security of the people down the road in a drought" (CN3). If the producers want treated water, they can haul water from town and this gives them two different options. Also, when the mine first moved to Coronach, they had to pump groundwater out to mine the coal. While most of the farm wells in the area were in the coal seams, it has created a lot of the issues. Therefore, they had to re-drill a lot of farm wells, pipe water to some farms, and set up some load out facilities for local agriculture producers. This has improved the community's ability to cope with future water shortages.

In the late 1990s, the Town of Gravelbourg realized that there was an opportunity in starting a valued-added industry; therefore, they used a few years to conduct feasibility study and encouraged the producers to participate in this initiative. Through the town, MCI was established and it helped to maximize the value of local farmer's grain by taking their grain and manufacturing it to another product that worth more money. As a result, it provides the farmers with more stable income in the long run.

The RM of Gravelbourg has also built a number of wells and load-out stations for producers. Almost one-third of the RM has access to those systems and producers do not need to drive for a long distance to fill up their tanks. The RM also took over the rural pipelines from a water board, so that they can expand the pipeline to different farms and have the water pipe directly to their house. After the rural pipeline is being built in Gravelbourg, around 70 percent of the farmyard in this RM will have access to water directly and producers can rely on water from the pipeline.

6.1.2.2.4 Other Support

Hail insurance is usually offered by private insurance company where the farmer pays 100% of the premium. As it is not subsidized by the government, it is not as beneficial as crop insurance. Many producers carry hail insurance because it is not possible to guess which year it is going to hail. They think if they try to guess it, they will miss it. So most of them carry hail insurance all the time for security reason.

There are a number of community-based institutions that help to enhance adaptive capacity. Agricultural Producers Association of Saskatchewan (APAS) is a grassroots farm organization that focuses on improving the economic well-being of producers in Saskatchewan. It represents different views of producers to lobby for agricultural policies that can benefit all the sectors of the society (Agricultural Producers Association of Saskatchewan, 2011). The Prairie Conservation Action Plan (PCAP) aims at providing a forum for collaborative effort on grasslands where people with similar projects can work together and avoid work duplication. It promotes the ecological health of species at risk and improves public understanding of the Prairies.

Not just community-based institution, there are also a number of grassroots lobbying efforts. One of the examples is the law that demands producers to treat the water before piping it out of the source. If water is transported more than a certain distance through pipeline, it has to be chlorinated again because chlorine settles out in the pipe during transportation. As it is unnecessary to use potable water for most of the agricultural activities, this law has unreasonably increased the workload as well as the resources demanded from the producers. Therefore, there has been a big lobby to the government to change that law so that if producers are getting non-potable water from a pipeline for household use, they will treat the water for portable uses; but if the water is only going to be used in the garden or for the livestock, producers will not have to treat that water and make them portable.

Local groups are essential in dealing with issues that concern the producers. In Coronach, the Surface Rights Organization was formed when SaskPower has taken the producers' land. SaskPower were drying up the wells around the area because they wanted to mine the coal. As a result, the producers got together to formed the Surface Rights Organization to bargain for another water source. That is one of the key reasons why the producers have free access to community wells. While in Gravelbourg, the Wood River Riparian Authority helps to promote beneficial management practices that protect the health of the riparian area along with the Wood River. By maintaining a healthy riparian area, it improves the water quality greatly by preventing chemicals from entering the water and encouraging the absorption and storage of water. With the growing awareness of water quality, producers have started to fence off their dugouts and pump water into troughs for their cattle. The water source is protected by not having cattle drink water directly from the dugouts. To prevent straws and cattle manure from entering the system, ranchers do not to feed their cattle in places where water is going to be running in springtime. Some producers also try to protect their water quality by having grass runways that water can filters through before flowing into their dugouts. The Wood River Riparian Authority not just holds educational programs that teach the producers how to protect the water quality in the Wood River; they also help the producers to fill out application forms for financial support programs.

6.1.2.3 Information and Education

Education is identified as one of the most important things to improve community's adaptive capacity. Information through education helps to enhance public awareness and build adaptive capacity. For example, SWA and SaskWater have resources to educate people on water conservation techniques that they can adopt at home. Some respondents said that through education they know they should not water their lawn during the heat of the day, so they started to water their lawn in the morning or at night. Some of the households have even adopted underground watering systems that prevent the waste of water. Local watershed group, such as the Wood River Riparian Authority, is helpful in providing information based on local conditions and make funding information available to local producers. Information is also available from other sources and helps producers to be more aware of their own vulnerability in face of drought. For example, stories from their parents can change the producers' attitudes towards drought because experiences from their parents have shown them weather in the Prairies fluctuates dramatically. It can be wet today and completely dry tomorrow. Some informants also pointed out the importance of education through their children. Some of them learned different water conservation measures from their children that go to school in town.

Producers find that they are always learning new farming and ranching techniques from research. For example, ranchers no longer turn their cattle into full pasture. They turn them into paddocks and change them more often, so that the grass will grow better and different species of grass can be utilized. Also, they learned that if cattle drinks clean water, they will have healthier calves. Therefore, they realized the importance of water quality protection. Without access to information, producers may not adopt these beneficial changes owing to the initial costs of implementation. Not just getting information from the internet, some producers also do experiment on their own. They educate themselves from the internet and then conduct experiment to find out the best combination of adaptation strategies that can maximize their yield in a specific farming area. For example, a few conventional farmers try to reduce the costs of chemicals by experimenting with different type of crops. They practice intercropping where they grow a cocktail of crops that are mixed together in the same field. One producer tries to grow canola and peas in the same field, so that the nitrogen produced by the peas will support the canola and he can reduce the amount of nitrogen that he uses.

Figure 48 Canola and peas in the same field

Access to weather information is crucial for the day-to-day planning of the producers' activities. When they are haying, it is crucial to have dry conditions. Therefore, they want to have an accurate weather forecast so as to plan ahead. If there is a weather system moving in, they will not cut as much hay down, because they know that they cannot bale the hay when they are too wet. However, the current forecast is not always right and that affects the producer's schedule. The lack of accurate information hinders the producers in adapting to the changing weather. One producer said, "I got three different networks on there and they can't tell me what's going to happen tomorrow…we can never have enough information" (CN7). As weather plays an important part in producers' lives, an accurate weather forecast will greatly improve their adaptive capacity in different climatic events.

In small communities, experience from neighbours is an important source of information. Information from neighbours can help producers to change their negative attitudes towards certain issues. Sometimes, producers learn better farming practices by observing their neighbours. When their neighbours adopted a new farming technique and succeeded, they will follow their neighbours and make changes. If more producers in the area are switching their way of farming, the more reluctant producers are more likely to change their farming practices as well.

With technological advancement, agricultural representatives are getting further away from the producers. In the past, producers used to bring samples and go to their local agricultural representatives whenever they have a question. As more local offices are being closed down, this discouraged producers to ask questions. Some producers claimed that they used to visit their local agricultural representatives quite often; yet, the distance hindered them to do that anymore (CN 22). Information flow is also prevented by the fact that a lot of the seminars for grain production happen in March and April when ranchers are calving. The timing of seminars makes it difficult for mixed farmers to attend workshops that interest them. Having to work off-farms also hinders producers from attending seminars and workshops. Most of the producers agreed that information has become more accessible compared to the past and they are satisfied with the amount of information that is available to them. However, producers also pointed out that the time lag between experimental information and applied information is too long (CN 7). It takes too long for the experimental information to be applicable to actual farming practices.

Merely considering the availability of information itself is not enough. Education should also include components that improve people's willingness to learn and to change. A few respondents admitted that they have changed their feelings towards green lawn. They said as drought is a recurring event in this area, "having a green lawn isn't a status symbol. So actually it might be a sign of not being frugal with your money because everybody knows it costs you more money" (CN19). With this change of perception, they have increased their adaptive capacity towards drought by saving water for essential uses. According to data collected from the interviews, respondents are concerned that in spite of the increasing awareness of the benefits in changing personal behaviour, there is still a lack of willingness to change. They noticed some people prefer financial help from the government rather than changing their own practices, which is more effective in the long term. Therefore, a more holistic approach in education is needed to improve community's adaptive capacity.

6.1.2.4 Technology

Many producers admitted that technological advancement has contributed significantly to their livelihood in the dry years. In the past, discers are commonly used for seeding. With the invention of air-drill and air-seeder, the seed is placed more accurately, and no-tillage is made possible; therefore, it helps to conserve soil moisture and the crop has a better chance of growing than previous drought years. The technology of auto-steer also helps the producers to pay attention to the bad weeds that they do not want. With auto-steer, farmers are able to spot weeds better than before. Technologies have also improved the quality of the seed. With drought tolerant seed and many other new varieties, farmers are growing crops that used to be grown in different parts of the world and they are also getting a high yield than before.

Figure 49 Air-Seeder

The Palliser Triangle is prone to drought and has low agricultural potential because of its geographical location. Old farming practices diminished soil organic matter and nutrient at a rate faster than it could regenerate naturally. As a result, producers have changed their farming practices over time and they are now more dependent on fertilizers, pesticides and other chemicals to maintain their productivity. In the past, producers used to work on the field for seven times. In order to deal with the increasing cost of fuel, more producers are using seeder with dual shoot system and combine that can do two things at the same time. Many people think that shelterbelts are for wind. However, not just preventing wind from speeding up evaporation, they can also trap a huge amount of snow. As the amount of water uptake by trees is very small in comparison to the amount of snow that they can trap, it can improve the producers' overall adaptive capacity to drought effectively. However, one of the major reasons producers stay away from new technologies is because of the lack of knowledge in fully utilizing them and fixing the electronic parts in the machines. Some people attend workshops or search on the internet whenever a new technology comes out; yet, the cost and the maintenance of electronics remains as major concerns that hinder producers' decision.

In terms of household, there have been great changes in appliances that reduce the amount of water usage significantly. Some people conserve water by replacing old appliances with water-efficient ones or using rain barrel to store rainwater for irrigation and other cleaning purposes. As technological development improves water efficiency without the need for consumers to change their behaviour, it is an effective way to build adaptive capacity. These appliances are made affordable with rebates programs and most of the interviewees claimed that they are open to the option of changing their appliances into water-efficient ones when the old one needs to be replaced.

Figure 50 Rainwater harvesting practiced by a producer for his garden

6.1.2.5 Social Network

The analysis of social network is used to determine the importance of relationship in assisting producers to build adaptive capacity towards climate and water related issues. The forms of social ties that are evaluated are kinship, friendship, social club, and workplace relationships.

All the informants stressed the importance of relatives and neighbours. Many of them gave examples of help being offered because of sickness or other emergencies. Ranchers have stressed the value of social network during the time of calving, branding, vaccinating, moving cattle, and other yearly routines. When ranchers have a large amount of cows, it is difficult for them to do everything by themselves; therefore, ranchers tend to have stronger social ties than farmers. As for farmers, the most common form of help is, if some of their neighbours cannot finish seeding, they will lend their machines to them and help them seed.

There is a lot of learning that happens among producers. They are willing to share information with each other, such as how they are managing their farm or ranch to get a better yield or heavier calf. One of the respondents mentioned "If there's more than a bunch of guys sitting around and they're all in it, well, then you might have a look at it", so everyone is trying to improve their adaptive capacity by learning from each other (CN 3).

With the prohibitive costs of farming, clubs are formed to share machines' costs. In the early '90s, around 50 producers in Coronach joined together to rent machines with new technologies and try to take advantage of it on a small scale in their own farms. The club allowed them to try new and expensive equipment, such as no tillage drills from different machine companies. Within a few years, they saw a significant increase in their income and improvement in their adaptive capacity towards dry years that they all bought their own drills (CN 3). Also, during a drought, producers with extra hay/pastures may offer their hay/pastures to producers that they know. "Word of mouth is usually how news travels. It is not by advertising in the newspaper. You just know if someone is trying to get rid of some (hay) and you need some you will get a call…that is super important in rural areas"(GB19). Many producers said that the hay that they bought from other family members and friends helped them to get through a drought. Access to information by the word of mouth, improves the producer's adaptive capacity by saving the producer's money in buying hay from a closer location.

A major concern in terms of social network is, everyone has their own opinion and it is hard for them reach consensus. Many producers wish that there is a farmer union that can represent them, so that they will have more lobbying powers with the government. However, past experience showed that it was difficult to reach consensus in what should be done. There were many splinter groups within a union and each had its own idea. A producer tried to explain the situation by saying "there's a reason everybody's a farmer. It's because you're the own boss, it's your own business; you're doing it your way. Your way is not the same way as that way or that way or that way, so how can you ever get a consensus? You never will. I find it kind of humorous" (CN32). Therefore, a representative farmers' union is lacking because of the lack of consensus among the producers.

As the town residents are less exposed to changing environmental conditions, the significance of social network is less apparent. Some of the interviewees in Coronach mentioned a fifty-two hours power outage in early 2010 where people with generators invited neighbours over and prepared food for each other. In Gravelbourg, a group of people got together in the late '90s to protect the town from flooding by piling sandbags. Residents in Gravelbourg have also designated a group to fight for the survival of the railway. They hired consultants and done research for the cost and benefit of buying the short line in order to protect local agricultural industry. However, social network may not be particularly important in the town compared to producers in the rural area.

6.1.2.6 Past Experience

Past experience is a valuable learning opportunity that helps to build adaptive capacity. Apart from local climatic events, major events such as the Walkerton or the North Battleford water crisis also have major impacts on local water treatment facilities. Through these events, more resources are dedicated to the protection of water quality and adaptive capacity can be improved. Actual adaptation measures may vary from producer to producer, learning from past experience can help them to fine-tune strategies in the long-run and prevent the same mistakes from happening again. In terms of drought, producers may be more aware of the capacity of their existing water supplies and try to find new sources of water by drilling new wells or digging dugouts. Many producers tried to cope with drought by not seeding any crops if they could foresee a dry year, so that they could reduce their input cost significantly. They also mentioned careful planning and budgeting is another effective strategy that helped them to get through a drought. They tried to do nothing and only paid their bills. If they could not pay their bill with farm income, they would get an off-farm job so as to make their payment. Some producers shared that from their observation, precipitation is often spread out and it can be raining in their neighbour's farm, while they get no rain in their land. Therefore, some of them tried to buy land that are spread out and hope that they may get the rain in one area to make a decent yield of crops. With the decreasing amount of labour in agriculture, some ranchers switched from Charolais to Angus cattle. They learned from their own experience that Angus calves are easier to calve as they do not demand as much attention as Charolais calves.

Through past experience, people are more educated and prepared for the changing condition. For example, after the drought in the late '80s, farming practices have improved considerably and producers have a higher adaptive capacity, which can be shown by the impact of the 2001–2 drought. Nowadays, most ranchers try to carry over at least half a year's supply of hay so that if they have a dry year, they can minimize their expense of buying hay (CN15, 23, 25, 28, 29, 33, GB18, 36). Some ranchers shared their difficulties in buying expensive feed from other places during the dry years (CN 3, 12, 15, 29, 31, GB19, 35, 36). They could barely maintain their livelihood and there was no profit at all. If they have another drought in the future, instead of buying expensive feed, they will sell their cattle and buy them back when the drought is over, so that they can minimize their expenses during those years (CN 3, 6, GB19, 35). Ranchers also try to utilizing their land better with rotational grazing by different fencing arrangements as they learned from the past that overgrazing may lead to soil erosion (CN 3, 14, 29, GB18). Some ranchers try to extend their pasture and graze into winter by seeding annual crops and swathing it for cattle to eat in the field in winter (GB18, 19). So, even if the ranchers have missed out on earlier rains, they can still pick up rains throughout the year. In some cases, ranchers simply ship their cattle out to the North where they have more grass (CN26, 36, GB19, 36). Although some ranchers rent crown land for grazing, they operate it like it belongs to them and protect the land by using it sustainably (CN29, GB26). Some of the ranchers even rent out their land to some farmers and have them break up the grass and grow crops for a couple years in every 6 to 8 years (CN 3). This practice helps to preserve the nutrients that are required to grow good grass and the rancher's income can be maintained without taking the land out of production. Other ranchers let their cattle graze small dugouts first, then move their cattle to pasture with spring-fed dugouts, so when the dugouts start go do dry, they will have back-up pasture for the cattle (CN 3).

Many producers are aware that the best way to live through a drought is to try and conserve moisture (CN 3, 8, 17, 25, 36, GB 2, 18, 26). Crop rotation plays an important role in changing soil moisture conditions and preventing the depletion of certain nutrients in the soil. Farmers practice crop rotation with pulse crop and cereal crop so as to fully utilize the nutrients in the soil and to control pests as well as diseases (CN 3, 5, 14, 16, 17, 20, 30, GB15, 19, 22, 30, 36, 37). When moisture is insufficient in spring, a few producers will decide not to seed anything; while other producers will try to manage and adapt to this condition by seeding more acres in crops that do not use as much water (i.e. drought resistant crops) so as to maximize their yield (CN 3, 8, GB25). An example will be growing field peas that have tap root, so it is not drying out the surface moisture while leaving a certain amount of moisture for the following year (CN14). Mustard is another popular crop in this region because it is very tolerant. It is diseases-proof and can produce a decent yield from low to higher moisture conditions. Some of the producers learned that they should seed earlier to make sure there is enough moisture from the snow melts to germinate their crops (CN 8). Another practice that they learned from their experience is no-tillage farming where crops are grown with no soil disturbance. Air seeders and air drills are used to seed crops directly to the soil so as to minimize soil disturbance. This technology improves soil fertility and reduces evaporation as well as other inputs such as fuel and labour. Moreover, when the producers combine their crops, they will try to leave as much standing in the field as possible (CN 7, 17, 19, 29, GB 15, 16, 26). With the stubbles that are left in the field, the soil will not be washed or blown away. The stubble and grass in the field help to preserve moisture and trap snow in the winter, so that soil moisture can be replenished when the snow melts in spring.

During the period the interviews took place, Saskatchewan suffered from excessive moisture and producers were not able to get to the field to seed their crops. With improved farming practices and more shelterbelts compared to a few decades ago, soil has more organic matter to absorb water and the land does not have standing water or wash away like before. Some of the producers adapted to this situation by practicing summer or chem. fallow in order to save money in chemicals, while others tried to dam up the water or drain the land (CN 7, 32, 37, GB 26, 37). One of the producers commented “you just have to really work around Mother Nature yeah. There’s not much you can do” (GB19). However, depending on the moisture level, some producers made use of the situation and changed their seeding plans drastically. As early frost is not a problem for this part of the county, they changed to crops that have a shorter growth season, such as oats, so as to compensate the delayed seeding time (CN 3, 32, 33). They also took advantage of the moisture by choosing crops that are higher water users, such as canola. For ranchers, they know that excessive moisture increases the cattle's chance of getting foot rot. Therefore, they moved the cattle to higher and drier ground for grazing.

As aforementioned, there was a power outage in Coronach caused by a massive blizzard. Some of them had to haul wood and melt snow for drinking. Therefore after this power outage, more household realized the importance of having back-up generators and keeping emergency food and water supplies on hand (CN 1, 19). For the mine, they have two power lines that come directly from SaskPower. If one of them does not work, they are still able to maintain one drag line for mining. However during the power outage, the mine was forced to stop as they only have back-up plan for small power outages, but not major ones. After this incident, the mine is aware of this problem and is trying to find a solution to ensure that it can deal with similar incidents. The school has also set up places for student to stay if the weather is bad and they cannot get out of town. A town resident also shared that her experience taught her to prioritize the tasks that she needs to accomplish with water if she knows that it is going to be dry. When she receives a water shortage notice from the town, she will not water the lawn nor the garden because she will rather have brown lawn than not having water to wash dishes or for other sanitary purposes (GB15). Therefore, past experience facilitates her adaption process significantly.

6.1.2.7 Other Socio-Economic and Cultural Factors

Adaptive capacity is not just restricted to the above categories. Producers that are forward thinking will also be more adaptable to changing conditions. It is crucial to maintain flexible and be ready to change plans if necessary. One of the producers commented "if you do not hurry up you are going to get stepped on, because it is here and you have got to take advantage of it now" (GB 2). For example, because of the excessive moisture last year, many producers were not able to get their crops in before their original schedule. Therefore, some of them change to crops that have a shorter growing season to avoid frost damage. As a producer concluded "You just can't stay in one mode all the time. It just doesn't work" (GB20)

In the flood in 1997, the Town of Gravelbourg was almost flooded. Proactive leaders asked "what do we do so that we don't have to work as hard next time it happens? It might not happen for 50 years, but it could happen next week. So what do we do? Now what can we do to be proactive?" (GB16). After the flood, dykes are built and the town is protected in future floods. It shows that adaptive capacity can also be enhanced by leaders with proactive thinking. For example, if the leaders are not proactive and enthusiastic about changes, it is hard to change the mindset of the public. Therefore, it is crucial to get the right leader that is not afraid of changes.

6.1.3 Future Exposure-Sensitivity

6.1.3.1 Biophysical Factors

One of the most widely discussed topics that add to future exposure-sensitivity is the increase in climate variability. Despite the fact that almost half of the producers do not believe in climate change, the increasing frequency and magnitude of climatic events are having considerable impacts on the rural communities, especially in the Canadian Prairie where water shortage has been a serious problem throughout the years (Sauchyn et al., 2009; Sauchyn and Kulshreshtha, S. ,2008). All GCMs project an increase in temperature in the Prairies in the next century. The IPCC forth assessment report (2007a) also summarized that western North America will be warmer throughout the year and wetter from September to May.

	Temperature Response (°C)						Precipitation Response (%)					Extreme Seasons (%)			
Season	Min	25	50	75	Max	T yrs	Min	25	50	75	Max	T yrs	Warm	Wet	Dry
NORTH AMERICA (continued)															
DJF	1.6	3.1	3.6	4.4	5.8	25	-4	2	7	11	36	>100	**80**	**18**	3
MAM	1.5	2.4	3.1	3.4	6.0	20	-7	2	5	8	14	>100	**87**	**14**	
JJA	2.3	3.2	3.8	4.7	5.7	10	-18	-10	-1	2	10		**100**	3	
SON	2.0	2.8	3.1	4.5	5.3	20	-3	3	6	12	18	>100	**95**	**17**	2
Annual	2.1	2.9	3.4	4.1	5.7	15	-3	0	5	9	14	70	**100**	**21**	2

Figure 51 Average temperature, precipitation and extreme seasons in western North America in the 2080 to 2099 period (IPCC, 2007a)

Figure 51 demonstrates the regional averages of temperature and precipitation in western North America in the 2080 to 2099 period, compared with the 1980 and 1999 period integration. Based on a set of 21 global models in the multi-model dataset for the A1B scenario, the mean temperature is projected to increase for approximately 3.4^{o}C with an average of 5% increase in precipitation (except for June, July and August where precipitation decreases for approximately 1%). This table shows that the frequency of extreme warmth in Western North America is 100% in 2080 to 2099 in the A1B scenario comparing with the warmest season in 1980 to 1999; while it is also projected that 18% of winter, 14% of spring and 17% of fall are extremely wet in 2080 to 2099 in the A1B scenario comparing with the wettest season in 1980 to 1999.

As models project that both temperature and precipitation is going to depart from climate norms, more extreme events such as droughts and floods are expected in the coming century. Although precipitation is going to increase, most of the precipitation will occurs in the form of rain in winter. Therefore, it may increase the probability of severe floods in spring instead of replenishing soil moisture for the growing season. Although there is going to be a longer growing season, warmer and wetter weather will also provide favourable conditions for pests and diseases. High humidity levels facilitate the establishment of diseases that will not appear in drier condition. Diseases such as left spotting diseases in cereals, Ascochyta blight in chickpeas and lentils, as well as Sclerotinia in canolas, are going to have significant impacts on crop productivity (Saskatchewan Ministry of Agriculture, 2010). Therefore, climate change is going to increase the level of vulnerability in rural communities in the future.

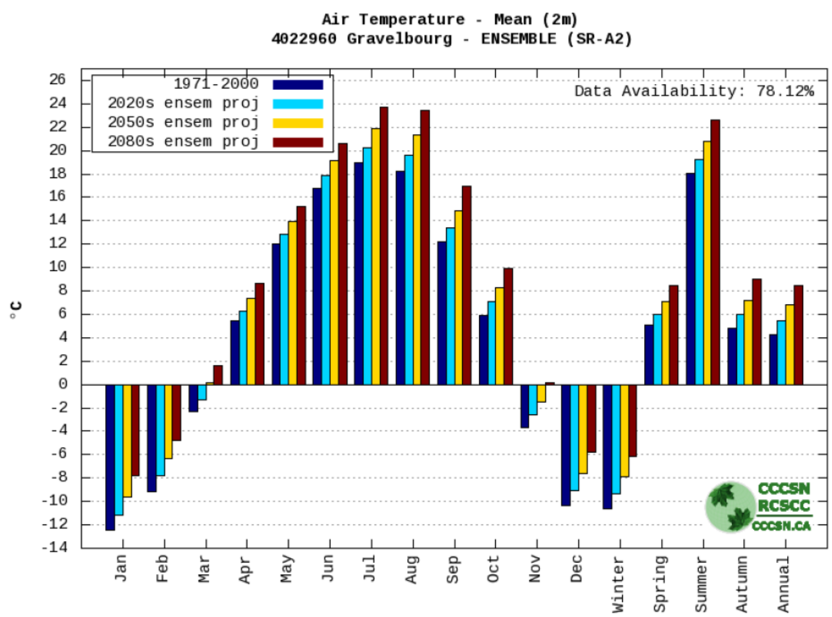


Figure 521 Projected temperature changes in Gravelbourg (IPCC, 2007b)

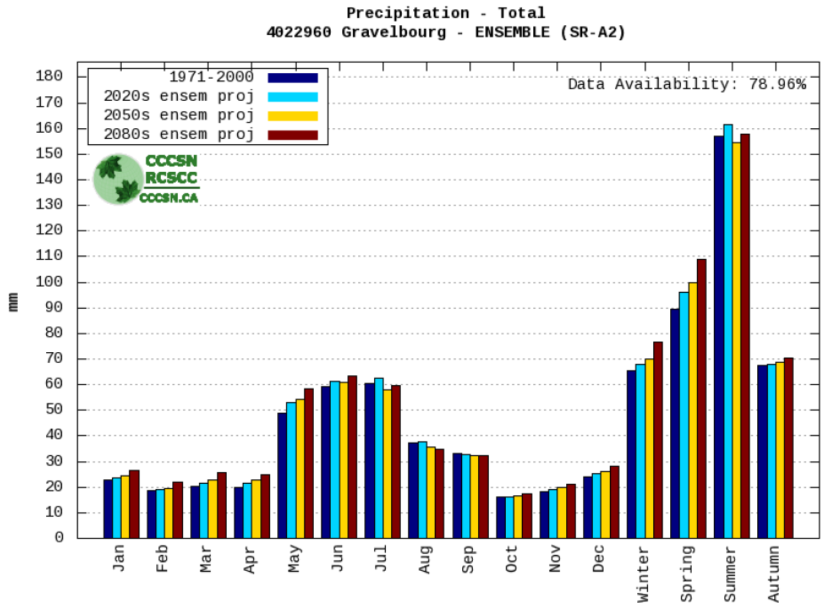


Figure 5253 Projected precipitation changes in Gravelbourg (IPCC, 2007b)

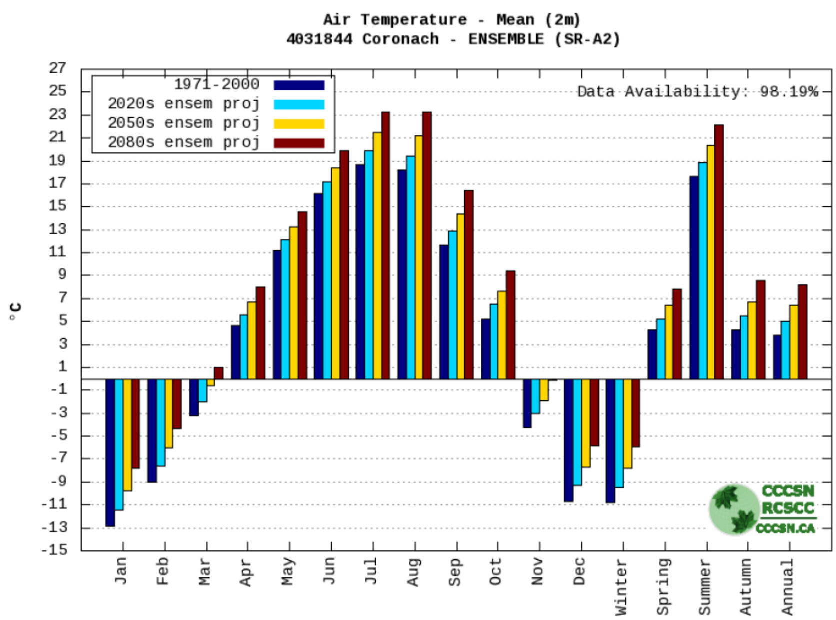


Figure 53 Projected temperature changes in Coronach (IPCC, 2007b)

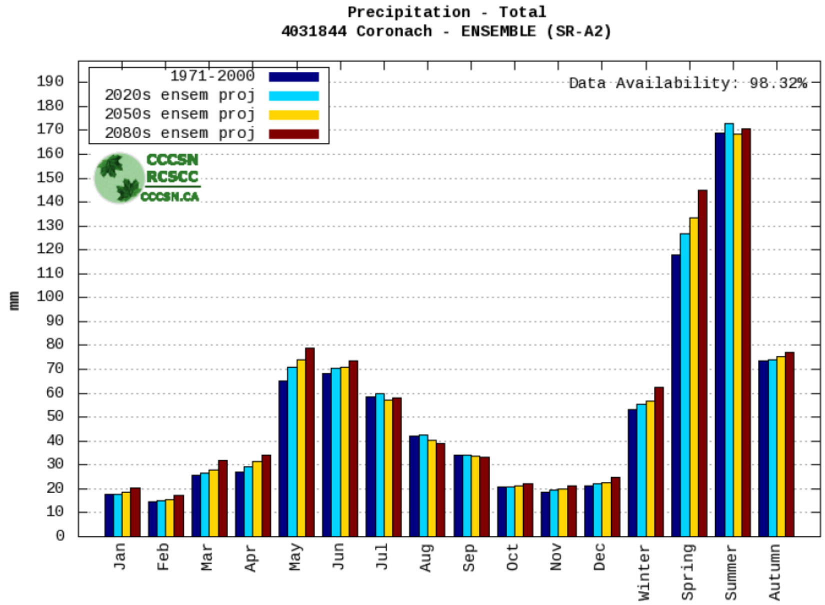


Figure 54 Projected precipitation changes in Coronach (IPCC, 2007b)

Most producers think that as they are used to recurring droughts in this area, they can withstand two to three years of drought. Some producers explained that in the first year, the crops will take up the moisture and nutrients that are available from last year and then grow an average or below average crop. For the next spring, the crops will start off totally dry and if they do not get any moisture throughout the growing season, it will be hard for them to establish any type of crop without any sub-moisture. Therefore, most producers' degree of vulnerability will increase after two years of drought with minimal institutional support.

In order to achieve the economies of scale, producers are expanding their operations to cover the decreasing prices of products. As producers try to ensure a decent yield every year, more chemicals are used in the field. A producer commented "it went from virtually putting no money out to putting pretty near half of your income out for chemicals and fertilizers" (CN22). Continuous cropping has increased the yields of different crops. However, continuous cropping also lead to more diseases, more chemicals are involved in farming and it is becoming more common for producers to use genetically modified crops that are spray-resistant. Therefore, increasing farm size and reliance on chemicals are going to increase future vulnerability of the producers.

6.1.3.2 Socio-Economic and Cultural Factors

In the past, producers can cut back the cost on machine maintenance by fixing their own machines. However, as machines are becoming more specialized with more electronics parts, producers have to send their machine away whenever they are not functioning properly. To make it worse, as farm machine dealerships in small towns are closing down and elevators are getting further away because more companies are amalgamating, producers do not have as many choices as before. They have to send their machines and grains further away. With the increasing price of gas, the freight has increased significantly over the past few years and it increases their financial burden.

One of the major factors that help the producers to go through a drought is not having any debts. Older farmers usually have their land and machines paid and they do not have big payments to make, so they are able to sustain for a longer time. However, young farmers can only make it through a short period of time because they have relatively less experience and have different payments to make. A few producers admitted that they have been living on the edge since the past bad years with the low produce prices; therefore, they could only withstand a year of drought. They are at the break-even point and if their financial situation does not improve, they will quit farming. As payout of government programs are based on the producers' income in the preceding years, if they have too many bad years, the coverage will start to drop and the government may not be able to support them. A number of producers claimed that it will not be worth it if they have to get an off-farm job to cover farm expenses and working day and night but not making any money (GB19); therefore, they may give up farming in the near future.

The majority of the town residents only relies on town water and do not have a back-up plan. Less than 30% of the respondents have a back-up plan in place if anything happens to their water supply. Most of them are taking a reactionary approach in dealing with future droughts. For potable water, most of the respondents rely on store-bought bottled water as their back-up plan. Some of them merely rely on the town and they think that the town may have provisions for them if there is a shortage of water. According to the Town of Coronach (2010), the reservoir holds 475,000 gallons of water and the water tower holds about 75,000 gallons of water (CN5). The town estimated that in winter time, the total amount of water available can sustain the town for about ten days; while summer time is a little bit less. For the Town of Gravelbourg, there is a reservoir that holds 300,000 gallons of water and a water tower that holds 60,000 gallons of water. The town indicated that it will be able to sustain the town for approximately more than three days in the summer (GB 6). As the town needs to retain some water for fire-fighting purposes, they cannot allocate all their supply to local residents. Given the fact that town residents solely rely on town water and bottled water, a few weeks of drought will put a huge pressure on the town.

As for other industries, depending on the time of the year, the mine may have different limits to stress induced by drought. If it is summertime, water is needed to control dust for safety and environmental reasons. It will be very difficult for them to continue operation if their settling ponds are dried up and there is no other sources of water supply except from the dewatering line. As soon as the mine is not safe to operate, the whole mine site has to be shut down. In the case where there is no water for fire suppression, the mine has to be closed as well. However, as they do not have to deal with dust in winter, the mine has a larger adaptive capacity to drought and can maintain its operation for a longer time. For local elevators, as their job is to weight and grade grains, they may be able to sustain a two year drought. If it started to get any longer than that, it is hard to for them to keep their employees and they will need to transfer to some other areas as they will have nothing to do.

6.1.4 Future Adaptive Capacity

"I guess if you're talking about if we could withstand 5 years of drought, then I guess the question was not whether we can but would we want to. Would we quit? I don't know" (GB15)

6.1.4.1 Economic and Financial Resources

As the mine has projected that their mining activities will continue until 2039, which is approximately when the coal resources will be depleted as well as the approximate life expectancy of the power plant will be reached, there are still plenty of working opportunities in the Town of Coronach. Most respondents identified the mine and the power plant as the main industries sustaining the growth of Coronach as they provide producers with abundant off-farm jobs with flexible working hours. However, when the mine and the power plant are closed down after 2039, it is going to have a major impact to the overall well-being of the town and there is going to be a significant decrease in population to sustain economic activities in Coronach. Also, the RM of Hart Butte is one of the wealthiest communities in rural Saskatchewan because of the power plant and the mine. The high disposable income in the community contributes to the negative attitudes towards changes and some people even think that money is the solution to every problem. A few respondents recognized that quite a number of people in the community are willing to pay for fundraising events but are not willing to attend community meeting to voice out their opinion.

Unlike Coronach, the backbone of Gravelbourg's economic growth has always been agriculture and tourism. MCI and Trailtech are able to sustain the growth of Gravelbourg by attracting new people to the town. As Canada dominates the international market of mustard seed by representing 65% to 75% of the world trade, it is a viable industry that will continue to benefit the town and all the producers in the future (GB 28). As MCI is expanding into Vanguard, they are going to hire more people and their projected volume sales will increase from eight to twelve thousand metric tonnes a year (GB 28). As for Trailtech, they are also in the process of expanding their company. Their target is to hire more people and achieve sales of $20 million within the next five years (GB 22). The growth of both agriculture-related industries will continue to provide economic resource to the towns and improve the communities' adaptive capacity.

6.1.4.2 Institution

Learning from past experience, producers know that they can make use of government programs to build dugouts and wells. As long as those government programs still exist, the producers will be able to sustain for a few years of drought with their support. Some of the respondent thought that future drought event was not a concern for them because they were planning to haul water from places such as the town and the community wells. In terms of plans to deal with future exposures, more than half of the respondents believed that the provincial government should provide funding for the construction of pipeline from Lake Diefenbaker. As the Lake is viewed as an ample supply of water, irrigation will be made possible with the pipeline and many producers are looking forward to this project. Producers thought that if the pipeline is being built, the sky could no longer limit on what they could do with water (CN2). Not just for the Town of Coronach, but all the similar communities in the middle. However, the project is not being implemented because of the costs and concern of multiple watershed contamination.

Both of the town have water tower that can supply water for a short period of time. However, as water is also needed for firefighting purposes, water supply in town may not be sufficient to support the town as well as the surrounding area. The Town of Coronach monitors water extracted from the wells regularly. If the amount of water coming out from the well decreases, they will close down that well for a period of time and allow it to be revitalized. The town is planning to put in a second lagoon for sewage, so that water can be better treated before going back to the river. They also plan to work with SaskPower to get permission to pipe from their wells so as to secure a more consistent source of water supply. Whereas the RM of Gravelbourg is planning to extend their existing pipeline to send water directly to each farm, so that it will solve the problems of many households. The school is also trying to obtain a weather station and put up real time weather information instead of the hourly forecast provided by Environment Canada. As the school saw the increasing number of severe weather events in recent years, they recognized the importance of getting real time data for emergency planning. Therefore, they are trying to enhance their resilience to extreme events by establishing a weather station.

6.1.4.3 Information and Education

One of the major barriers identified by the respondents is the reluctance to change. Almost everyone agreed that they are exposed to enough information and do not need more of it, but the problem is they may not believe in the information or they are not concerned about that particular issue. A town resident noticed that there is plenty of information on how climate change is affecting the whole country, but information at the local level is lacking. That is why people fail to put the problem into perspective and relate it to their daily lives (GB1). Misconception also hinders people from changing. Many people think that there is a lot of water in western Canada and water conservation is not an urgent issue in this country. As a result, they are not aware of the need to change. Also, some of them may have a misunderstanding of the consequences of their actions and thought that their practices are helping the environment when that is not the case. Therefore, more communication is needed so as to ensure the effectiveness of education.

6.1.4.4 Technology

Increasing number of farming processes is automated and each step is also getting more precise, such as the depth of the seed and the amount of fertilizers. The technicality of agriculture has decreased the uncertainty of farming, which helps the producers to maximize their output and improve their adaptive capacity.

As some town residents are renting apartment and do not plan to retrofit a place that does not belong to them, they have indicated that if they own a house in the future, they will look into different water saving appliances and have everything set up in a way that conserves water. For other residents, they claimed that they will upgrade their water-using appliances over the next couple years when the old ones are not working. Therefore, the number of household adopting water-efficient appliances is going to increase in the foreseeable future.

6.1.4.5 Social Network

Some people expressed concern that the decreasing number of family farms may affect social ties within the community. If more farms are corporate-owned and are operated by people that are hired, the level of social cohesion in the community may decrease. As farm helpers that are paid are less likely to offer help to their neighbours, there may be an increase in vulnerability. Also, farming has gradually turned into a business instead of an enjoyable way of life. When the producers were asked about their relationship with their neighbours and the social cohesion in their community, some of the producers gave comments such as, "it's dog eat dog world", "your neighbour is your competition…It's basically got to the point, matter of fact, I've even tried going out and helping some people if they need some help with something. Right away, they figure there's a pay cheque involved" (GB35, CN24). Another producer also mentioned that "usually everyone does their own work, and if they have too much work that's that guy's problem basically" (CN37). Moreover, with the increasing farm size, producers are living further away from each other and they are more occupied with their farm and their off-farm work; the availability of modern equipment and the increasing degree of self-sufficiency also contributes to the diminishing social ties.

> "I don't think social capital so much, actually there's less of that. I think as farms have gotten bigger, as farms have gotten more credit dependent, as acres of planting have gone up, people are so busy trying to get their own done that they usually don't have time to help others…if we need something, by and large people just go buy it and borrow the money. It's become very credit dependent" (CN10).

6.1.4.6 Other Socio-Economic and Cultural Factors

People deal with changes in a reactive manner. For example, many people may apply for government financial support for drilling wells and digging dugouts in the dry years. However, once the dry years are over, some producers may cancel their plan and think that the same problem will not happen again. A producer commented "See what happens locally is, there's a drought and everyone bitches about it and they become active and they fight and then it rains and everybody forgets. That's what happens" (CN1). People may talk about how bad the dry year was, but they are not looking at the long term. They think that it is easier to ask government for assistance rather than changing their own practices. For town residents, they are not convinced that small changes can make a difference. For instance, they may focus on the initial cost of implementing water saving appliances instead of the long-term saving on their water bills over the course of the year. Therefore, they do not see the need to adopt changes. In terms of the use of portable versus non-portable water, the lack of grey water system in place has hindered people from adopting such practice. As retrofitting of large scale grey water system is not feasible in a town that is already established, it depends on individual effort to use grey water in a household scale.

6.1.4.7 Conclusion

CBVA conducted in this thesis has identified forces that affected different groups of actors and adaptation measures that have been adopted. As aforementioned, natural and human systems are intertwined closely and the vulnerability of a community is not merely affected by scientific 'facts', such as the extent of drought, but together with other contextual factors such as the socio-economic characteristics of the specific location. Both Gravelbourg and Coronach are affected by multiple stressors that occur at different levels. Major stressors identified by the producers such as increasing input cost and fluctuation in grain prices have increased producers' vulnerability and those factors eventually affected non-producers in the community because of the reduction in economic activities. In face of increasing vulnerability caused by different factors, mustard-processing companies in Gravelbourg was an excellent example showing that when a community took advantage of the opportunity existed, they could reduce their vulnerability and benefit the town as a whole. With the effort of the local economic development office and the town residents, mustard producing companies in Gravelbourg generated more than 10 jobs and encouraged local residents to start their own businesses. Therefore, it demonstrated that by understanding the contextual characteristics of local communities, it can ensure that adaptation strategies suggested are practical and applicable.

As aforementioned, the study of vulnerability should not be an end in itself, but as a means to identify opportunities for adaption strategies. Adaptation can include measures such as increasing water supply by finding alternative water sources, improving water efficiency, reducing water demand, and utilization of greywater. The next chapter discusses the possibility of adopting soft water path as an adaptation strategy for municipal water users. This analysis is based on results collected in the community-based vulnerability assessment and it is hoped that through this case study, soft water path can be incorporated into the long-term water resources management goal of various municipalities in southern Saskatchewan so as to manage the future risks identified in this chapter.

Table 3 Current Exposure-Sensitivity and Adaptive Capacity

Exposure Sensitivity	
Biophysical	Water and soil moisture shortages, Non-contributing area with limited surface runoff, Soil erosion, Fire risk, Pests and diseases, Excessive moisture, Delayed seeding, Spotty rain, Poor water quality, Lowered groundwater level
Socio-Economic	Decrease in farm income, Local economy dependence on the agricultural industry, Remote location, Aging population, Depopulation, Economic Leakage, Lack of employment opportunities, Lack of infrastructure and health care
Adaptive Capacity	
Farming practices	Minimum tillage, Drought tolerant crops, Continuous cropping, Diversification of crops, Grazing management
Information	Research, Weather forecast, Best management practices, International market, New technology
Financial Resources	Crop insurance, Hail insurance, Agri-Stability, Agri-Invest, Farm and Ranch Water Infrastructure program, Off-farm jobs, Producer’s own insurance program
Institutional Support	AESB Office, Saskatchewan Watershed Authority, RM office, Local watershed group
Social Network	Community-based lobbying efforts, Experience sharing, Help from neighbours
Others	Past experience, Forward-thinking mindset, Proactive leaders

Table 4 Future Exposure-Sensitivity and Adaptive Capacity

Exposure Sensitivity	
Biophysical	**Increase in temperature and amount of precipitation (winter and spring)**, Water and soil moisture shortages, Non-contributing area with limited surface runoff, Spotty rain, **Groundwater depletion,** Soil erosion, Fire risk, Pests and diseases, Excessive moisture, Delayed seeding, **Worsen water quality**
Socio-Economic	Decrease in farm income, Local economy dependence on the agricultural industry, Aging population, Depopulation, Lack of employment opportunities, Economic leakage, **Increase geographical isolation**, Lack of infrastructure and health care, **Aging infrastructure, Lack of back-up plan**
Adaptive Capacity	
Farming practices	Minimum tillage, Drought tolerant crops, Continuous cropping, Diversification of crops, Grazing management, **New technology**
Information	Research, Weather forecast (**Real-time weather report in Gravelbourg**), Best management practices, International market, new technology
Financial Resources	Crop insurance, Hail insurance, Agri-Stability, Agri-Invest, Farm and Ranch Water Infrastructure program, Off-farm jobs, Producer's own insurance program, **Expansion of existing businesses**
Institutional Support	AESB Office, Saskatchewan Watershed Authority, RM office, Local watershed group, **New infrastructure, Pipeline from Lake Diefenbaker?**
Social Network	Community-based lobbying efforts, Experience sharing, **Help from neighbours**
Others	Past experiences, Forward-thinking mindset/leaders, **Higher penetration rate of water saving appliances**

Chapter 7
Result – Soft Water Path

Soft water path analysis conducted in this study is divided into three parts. The first part involves the definition of water system. In order to assess the full potential of water soft path, water usage pattern of different sectors has to be identified. The different sectors that were being analyzed in this study were residential, agricultural (farming and ranching), industrial, commercial and institutional sectors. After water usage patterns of the two municipalities were identified, backcasting was performed based on demographic data and information gathered from literature review. A desirable future was defined and different paths that connected the future to the present were identified. A list of possible solutions in reducing water used for different sectors was presented with regard to the results from the CBVA in order to provide context-specific adaptation strategies to the two communities.

7.1 Definition of Water System (Major Water User)

In order to design site-specific measures in conserving water, major water users were identified during field inspection. After a list on the water-using equipment was compiled, the flow rate of each piece of equipment was determined. The data was collected mainly by visual inspection, literature review, and semi-structured interviews. As the flow rates of some of the equipment were written on the equipment, visual inspection provided a general idea of the amount of water running through it. Due to data limitation, the scope of water auditing was limited. As meter was not available in houses outside the towns, assumptions have been made based on the best available resources. Although data used in the analysis was based on the best data available, this analysis should be used as a planning tool for adaptive strategies and not as a complete projection of the future.

In the tables below, major water uses in the municipalities were identified and the amount of water usage based on data for average users is shown so as to demonstrate the potential of improving water efficiency. While most of the buildings were built prior to 2000, it is estimated that they are the earlier version of water using units. Without examining units individually, it is not possible to determine the exact amount of water used. As a result, the best estimation of water used was based on literature review supplement by results from direct observation. It is crucial to keep in mind that the estimated savings from replacing existing toilets may underestimate the potential savings as some houses may be built in earlier periods.

Table 5 Water usage in residential sector - based on an average household in the study area (City of Surrey, 2010)

Water Usage	Amount of water used
Toilet	13L/flush
Laundry	170L/load
Shower	15L/min
Faucet	9L/min
Dishwasher	40L/min
Drinking	2L/day
Lawn	19L/min

Table 6 Water usage in agricultural sector - Farming (Beaulieu et al., 2001)

Water Usage	Amount of water used
Spraying herbicides, insecticides, fungicides	45-180L/acre
Cleaning equipment and facilities	0.1% of spray water

Table 7 Water usage in agricultural sector - Ranching (Beaulieu et al., 2001)

Water Usage	Amount of water used
Livestock watering *Includes equipment washing and sanitizing	Mature cows 45L/day Calf 15L/day

Table 8 - Water usage in industrial sector - Power Plant

Water-using equipment	Amount of water used
Cooling	Not available

Table 9 Water usage in industrial sector - Coal Mine

Water Use	Amount of water used
Dust Suppression	Not available (not metered)
Cleaning equipment	Not available (not metered)

Table 10 Water usage in commercial sector - Car Wash (Capital Regional District, 2007)

Water-using equipment	Amount of water used
In-bay car wash	260L/Vehicle

Table 11 Water usage in institutional sector - Hospital/Health Care Centre (City of Surrey, 2010; Massachusetts Water Resources Authority, 2011)

Water-using	**Amount of water used**
Toilet	13L/flush
Shower	15L/min
HVAC	Not available
Medical processes	Not available
Laundry	170L/load
Landscaping	19L/min

Table 12 Water usage in institutional sector - School (City of Surrey, 2010; Maas et al., 2007)

Water-using equipment	**Amount of water used**
Toilet	13L/flush
Urinal	7.57L/flush
Shower	15L/min
HVAC	Not available
Landscaping	19L/min

7.2 Backcasting

In order to conduct an effective backcasting process, three scenarios were established to illustrate the potential of soft water path approach in conserving water by improving the water efficiency. The three scenarios were Business as Usual (BAU), Enhanced Efficiency (EE) and Soft Path (SP). The amount of water saved in each scenario was calculated by combining water efficiency factors. Water efficiency factors show the amount of water that can be saved by each technology. For details of the water efficiency factors, please refer to Appendix E. This calculation was based on results from the semi-structured interviews and the previous section. The calculation mainly represented the amount of water conserved by average water users. Since a significant amount of water was from private wells, water usage information was not available. Therefore, backcasting in this case study only focused on water situation in the Town of Coronach and the Town of Gravelbourg. However, soft path solutions suggested below could be applicable to the whole Rural Municipality.

7.2.1 Business as Usual (BAU)

The BAU scenario was constructed based on projected population and economic growth without any water-saving measures. The populations of both Coronach and Gravelbourg have remained relatively stable in the recent years owing to the composition of economic activities in this region. Based on the results from the CBVA, the power plant and the mine have been the major employers in the region and its surrounding area in Coronach. As they are planning to remain on the same site until 2040, this helps to sustain the population size as well as economic growth of this community. Therefore, it is predicted that water usage in this community will remain steady in the next few decades.

As for the Town of Gravelbourg, its population has declined for 8.3% from 2001 to 2006 (Statistics Canada, 2007a). Although Trailtech and MCI have indicated their intention in expanding in the next decade, its economic growth may be offset by the population decrease. Therefore it is assumed that the population and economic growth in both communities are going to be constant in the near future. According to the Statistic Canada (2007c), the population of the Town of Gravelbourg is 1089 with its growth rate is assumed to held constant until 2040.

<u>Coronach</u>

Projected Population in 2040 = 770

Current Water Demand = 105,120 m^3/year

Current Population = 770

Current Per Capita Demand = 136.52 m^3/year

BAU Projected Demand = Projected Population * Current per Capita Demand

= 770 * 136.52 m^3/year

= 105,120 m^3/year

<u>Gravelbourg</u>

Projected Population in 2040 = 1,089

Current Water Demand = 125,684 m^3/year

Current Population = 1,089

Current Per Capita Demand = 115.412 m^3/year

BAU Projected Demand = Projected Population * Current per Capita Demand

= 1,089 * 115.412 m^3/year

= 125,684 m^3/year

7.2.2 Enhanced Efficiency (EE)

The EE scenario was constructed based on the projected population with basic water reducing measures and techniques. As municipal Water Efficiency Plans (City of Guelph, 2009; Region of Peel, 2004; Region of Waterloo, 2006) in Canada have set targets of ten to twenty percent reduction in water use over the next decade, this EE scenario followed the same target of achieving twenty percent reduction in water usage based on the current water demand in 2009.

According to the 2010 Municipal Water Use Report (Environment Canada, 2010), the four main water uses for municipal water in communities with population less than 1000 were residential (68.8%), Commercial and Institutional (20.8%), Industrial (10.2%) and System losses (6.4%); while for communities with population from 1000 to 2000, the major water uses are the same with only a slight difference in the proportion of water uses - Residential 70.5%; Commercial and Institutional 13.4%; Industrial 7.4%, and System losses 7.1%. For the current study, both of the towns did not supply water for industrial and agricultural uses; therefore, only water uses for residential, commercial (car wash) and institutional (hospital and school) and system losses were considered.

After adjusting for situation without industrial sector, the three main water uses for municipal water in communities with population less than 1000 are residential (71.7%), Commercial and Institutional (21.7%), and System losses (6.7%); while for communities with population from 1000 to 2000, the major water uses are the same with only a slight difference in the proportion of water uses - Residential 77.5%; Commercial and Institutional 14.7%; and System losses 7.8% (Environment Canada, 2010).

7.2.2.1 Residential Water Uses

Residential water uses mainly come from 4 different aspects: Showers and Baths (35%); Toilet flushing (30%), Laundry (20%), and Kitchen & Cleaning (15%) (Environment Canada, 2011d). Referring to the previous section regarding the flow rate of various equipment, the EE scenario can be calculated as follows:

Coronach

Total water uses in 2040 = 105,120 m^3/year

Residential water uses = Total water uses*71.7% = 75,371.04 m^3/year

Table 13 EE scenario - Residential water uses in Coronach

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Showers	35%	26,379.86	0.47	12,398.53
Toilet Flushing	30%	22,611.31	0.36	8,140.07
Laundry	20%	15,074.21	0.55	8,290.82
Kitchen & Cleaning	15%	11,305.66	0.45/0.47	5,200.6
	100%	75,371.04		34,030.02

Gravelbourg

Total water uses in 2040 = 125,684 m^3/year

Residential water uses = Total water uses*77.5% = 97,405.1 m^3/year

Table 14 EE scenario - Residential water uses in Gravelbourg

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Showers	35%	34,091.79	0.47	16,023.14
Toilet Flushing	30%	29,221.53	0.36	10,519.75
Laundry	20%	19,481.02	0.55	10,714.56
Kitchen & Cleaning	15%	14,610.77	0.45/0.47	6,720.95
	100%	97,405.1		43,978.4

The total amount of water saved in the EE scenario is 54.9%. In this calculation, it is assumed that the toilet is changed from 16.5L/flush to 6L/flush; showerhead of 15L/min is replaced by showerhead of 7L/min; the washing machine is changed from 170L/load to 92.7L/load; traditional dishwasher of

40L/load is replaced with water efficient dishwasher of 18L/load; lastly, the old facet is changed from 12L/min to low-flow faucet of 5.7L/min.

7.2.2.2 Commercial and Institutional Water Uses

In the Environmental Protection Agency report (2009), distribution of water use among commercial and institutional has been studied. After adjusting the proportion of water usage based on the situation in Coronach and Gravelbourg, hospital and health care centre accounts for approximately 54.3% of commercial and institutional water usage, school accounts for 43.6%, while car wash accounts for 2.1%.

7.2.2.2.1 Hospital

Total water usage in hospital can be divided into five major types: sanitary (42%), HVAC (23%), medical processes (14%), food services (9%), laundry (5%), and miscellaneous (9%) (Massachusetts Water Resources Authority, 2011). Referring to the previous sections regarding the flow rate of various equipment, the EE scenario can be calculated as follows:

<u>Coronach</u>

Total water uses in 2040 = 105,120 m^3/year

Hospital water uses = Total water uses*21.7%*54.3% = 12,386.4 m^3/year

Table 15 EE scenario - Hospital water uses in Coronach

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Showers	22%	2,725.01	0.47	1,280.75
Toilet Flushing	20%	2,477.28	0.46	1,139.55
HVAC*	23%	2,848.87	0.68	1,937.23
Medical Processes	14%	1,734.1	---	1,734.1
Food Services	9%	1,114.78	0.45/0.79	691.16
Laundry	5%	619.32	0.55	340.63
Others	7%	867.05	---	867.05
	100%	12,386.4		7,990.47

*HVAC: Southwest Florida Water Management District, 2011

Gravelbourg

Total water uses in 2040 = 125,684 m^3/year

Hospital water uses = Total water uses*14.7%*54.3% = 10,032.22 m^3/year

Table 16 EE scenario - Hospital water uses in Gravelbourg

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Showers & Baths	22%	2,207.09	0.47	1,037.33
Toilet Flushing	20%	2,006.44	0.46	922.96
HVAC	23%	2,307.41	0.68	1,569.04
Medical Processes	14%	1,404.51	---	1,404.51
Food Services	9%	902.9	0.45/0.79	559.8
Laundry	5%	501.61	0.55	275.86
Others	7%	702.26	---	702.26
	100%	10,032.22		6,471.76

The total amount of water saved in the EE scenario is 35.5%. In this calculation, it is assumed that showerhead of 15L/min is replaced by showerhead of 7L/min; the toilet is changed from 13L/flush to 6L/flush; the conductivity level of the cooling tower is adjusted to a higher level; traditional dishwasher of 40L/load is replaced with water efficient dishwasher of 18L/load; the old facet is changed from 12L/min to low-flow faucet of 9.5L/min; finally, the washing machine is changed from 170L/load to 92.7L/load.

7.2.2.2.2 School

According to the studies conducted by Massachusetts Institute of Technology (2008) and University of California, Berkeley (2010), out of the total water used on a university campus, 70% of the water used comes from Academic buildings and 30 % comes from residences. As school residence was not available in both communities, this study only focused on water use in academic building. In academic buildings, the amount of water used by different equipment could be narrowed down to Laboratory 54.33%, Washroom 37.66% (Toilet 23.33%, Urinal 7.33%, and Basin 10%) and cleaning 5% (MIT, 2008; University of California, Berkeley, 2010). Referring to the previous sections regarding the flow rate of various equipment, the EE scenario can be calculated as follows:

Coronach

Total water uses in 2040 = 105,120 m^3/year

School water uses = Total water uses*21.7%*43.6% = 9,945.6 m^3/year

Table 17 EE scenario - School water uses in Coronach

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Toilet	23.33%	2,320.31	0.46	1,067.34
Basin facet	10%	994.56	0.79	785.7
Urinal	7.33%	729.01	0.5	364.51
Laboratory	54.33%	5,403.44	0.79	4,268.72
Cleaning	5%	497.29	0.79	392.86
	100%	9,945.6		6,879.13

Gravelbourg

Total water uses in 2040 = 125,684 m^3/year

School water uses = Total water uses*14.7%*43.6% = 8,055.34 m^3/year

Table 18 EE scenario - School water uses in Gravelbourg

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Toilet	23.33%	1,879.31	0.46	864.48
Basin facet	10%	805.53	0.79	636.37
Urinal	7.33%	590.46	0.5	295.23
Laboratory	54.33%	4,376.47	0.79	3,457.41
Cleaning	5%	402.77	0.79	318.19
	100%	8,055.34		5,571.68

The total amount of water saved in the EE scenario is 30.8%. In this calculation, it is assumed that the toilet is changed from 13L/flush to 6L/flush; urinals are changed from 7.57L/flush to 3.785L/flush; the facet is changed from 12L/min to low-flow faucet of 9.5L/min.

7.2.2.2.3 Carwash

In professional in-bay automatic car wash, nozzles are used to process different carwash cycles. Water use is affected by the number, size and alignment of nozzles, flow rate, and pressure applied. Referring to the previous sections regarding the flow rate of various equipment, the EE scenario can be calculated as follows:

<u>Coronach</u>

Total water uses in 2040 = 105,120 m^3/year

Car wash water uses = Total water uses*21.7%*2.1% = 479 m^3/year

Table 19 EE scenario -Car wash water uses in Coronach

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
In-bay car wash	100%	479	0.9/0.6	258.66
	100%	479		258.66

<u>Gravelbourg</u>

Total water uses in 2040 = 125,684 m^3/year

Car wash water uses = Total water uses*14.7%*2.1% = 387.99 m^3/year

Table 20 EE scenario - Car wash water uses in Gravelbourg

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
In-bay car wash	100%	387.99	0.9/0.6	209.51
	100%	387.99		209.51

The total amount of water saved in the EE scenario is 46%. In this calculation, the water conservation measure taken is to fix leakages, reduce nozzle size and apply the appropriate amount of pressure.

7.2.2.3 System Losses

By fixing leaks in the water supply system, 25% of the water can be saved (Brandes and Maas, 2007).

Coronach

Total water uses in 2040 = 105,120 m^3/year

System losses = Total water uses*6.7% = 7,043 m^3/year

Table 21 EE scenario - System losses water uses in Coronach

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Water leakage	100%	7,043	0.75	5,275.5
	100%	7,043		5,275.5

Gravelbourg

Total water uses in 2040 = 125,684 m^3/year

System losses = Total water uses*7.8% = 9,803.35 m^3/year

Table 22 EE scenario - System losses water uses in Gravelbourg

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Water leakage	100%	9,803.35	0.75	7,352.51
	100%	9,803.35		7,352,51

7.2.3 Soft Path (SP)

The SP scenario was constructed based on changes in “hardware” supplemented by changes in “software”. SP recognizes the physical limits of water resources and promotes changes in personal behaviour to ensure sustainability in water usage. It incorporates all the measures in the EE scenario and adopts more advance technologies that require changes in individual behaviour and perception (Brandes and Brooks, 2007). SP measures are often supported by economic and institutional measures, such as rebates, bylaws, and tax credits so as to achieve the best possible outcome. Changes in “software” include measures such as dual flush toilets which requires the users to alter their behaviour and select a short flush for liquid waste or long flush for solid waste; composting toilets which requires the complete change of perception as composting toilets rely on aerobic biological activity to break down human waste and toilet paper and many people are concerned about the hygiene issue; rainwater harvesting changes the entire concept of water where water usage should not merely focus on water quantity, but water quality as well. In terms of farming communities, “software” changes may include the cultivation of drought pest-resistant crops, zero-tillage, and better weather information. Cultivation of drought-resistant crops eliminates the need for irrigation while the cultivation of pest-resistant crops minimize the amount of water needed for spraying; the practice of zero-tillage prevents moisture loss through evaporation and helps to conserve soil moisture; finally, the availability of accurate weather information may also help farmers to plan their work schedule more effectively and avoid unnecessary water usage for irrigation or spraying. As dryland farming aims at conserving the amount of moisture provided by nature and does not require extra water input; in this case, it can be used as an example for other irrigated farming communities.

Since it is difficult to measure the level of behavioural changes, predictions were made based on the best available resources. In order to help the communities to adapt to potential water shortages caused by climate change, the SP scenario targets a 60 percent reduction in water demand over the next 30 years (based on 2009 level).

7.2.3.1 Residential Water Uses

Coronach

Total water uses in 2040 = 105,120 m^3/year

Residential water uses = Total water uses*71.7% = 75,371.04 m^3/year

Table 23 SP scenario - Residential water uses in Coronach

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Showers	35%	26,379.86	0.47/0.53	13,189.93
Toilet Flushing	30%	22,611.31	0	0
Laundry	20%	15,074.21	0	0
Kitchen & Cleaning	15%	11,305.66	0.47/0.45	5,200.6
	100%	75,371.04		18,390.35

Gravelbourg

Total water uses in 2040 = 125,684 m^3/year

Residential water uses = Total water uses*77.5% = 97,405.1 m^3/year

Table 24 SP scenario - Residential water uses in Gravelbourg

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Showers	35%	34.091.79	0.47/0.53	17,045.9
Toilet Flushing	30%	29,221.53	0	0
Laundry	20%	19,481.02	0	0
Kitchen & Cleaning	15%	14,610.77	0.47/0.45	6,720.95
	100%	97,405.1		23,766.85

The total amount of water saved in the SP scenario is 75.6%. In this calculation, it is assumed that the toilet is changed from 16.5L/flush to composting toilet or grey water toilet; showerhead of 15L/min is replaced by showerhead of 7L/min together with reduction of shower time from 15 minutes to 8 minutes; the washing machine is changed from 170L/load to the use of alternative water sources, such as rainwater; traditional dishwasher of 40L/load is replaced with water efficient dishwasher of 18L/load; lastly, the facet is changed from 12L/min to ultra-low flow faucet of 5.7 L/min.

7.2.3.2 Commercial and Institutional Water Uses

7.2.3.2.1 Hospital

Coronach

Total water uses in 2040 = 105,120 m^3/year

Hospital water uses = Total water uses*21.7%*54.3% = 12,386.4 m^3/year

Table 25 SP scenario - Hospital water uses in Coronach

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Showers	22%	2,725.01	0.47	1,280.75
Toilet Flushing	20%	2,477.28	0	0
HVAC	23%	2,848.87	0	0
Medical Processes	14%	1,734.1	---	1,734.1
Food Services	9%	1,114.78	0.47/0.45	512.8
Laundry	5%	619.32	0.55	340.63
Others	7%	867.05	---	867.05
	100%	12,386.4		4,744.33

<u>Gravelbourg</u>

Total water uses in 2040 = 125,684 m^3/year

Hospital water uses = Total water uses*14.7%*54.3% = 10,032.33 m^3/year

Table 26 SP scenario - Hospital water uses in Gravelbourg

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Showers	22%	2,207.09	0.47	1,038.27
Toilet Flushing	20%	2,006.44	0	0
HVAC	23%	2,307.41	0	0
Medical Processes	14%	1,404.51	---	1,404.51
Food Services	9%	902.9	0.47/0.45	415.33
Laundry	5%	501.61	0.55	275.89
Others	7%	702.26	---	702.26
	100%	10,032.22		3,836.26

The total amount of water saved in the SP scenario is 61.7%. In this calculation, it is assumed that the toilet is changed from 16.5L/flush to grey water toilet; showerhead of 15L/min is replaced by showerhead of 7L/min; reducing the cooling load (raising the set temperature), use of looping and reuse/recycling water source for cooling tower make-up water or even replacing the cooling tower with air chillers; traditional dishwasher of 40L/load is replaced with water efficient dishwasher of 18L/load; the facet is changed from 12L/min to ultra-low flow faucet of 5.7L/min; finally, the washing machine is changed from 170L/load to 92.7L/load.

7.2.3.2.2 School

Coronach

Total water uses in 2040 = 105,120 m^3/year

School water uses = Total water uses*21.7%*43.6% = 9,945.6 m^3/year

Table 27 SP scenario - School water uses in Coronach

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Toilet	23.33%	2,320.31	0	0
Basin facet	10%	994.56	0.47	467.44
Urinal	7.33%	729.01	0	0
Laboratory	54.33%	5,403.44	0.47	2,539.62
Cleaning	5%	497.28	0	0
	100%	9,945.6		3007.06

Gravelbourg

Total water uses in 2040 = 125,684 m^3/year

School water uses = Total water uses*14.7%*43.6% = 8055.34 m^3/year

Table 28 SP scenario - School water uses in Gravelbourg

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Toilet	23.33%	1,879.31	0	0
Basin facet	10%	805.53	0.47	378.6
Urinal	7.33%	590.46	0	0
Laboratory	54.33%	4,376.47	0.47	2,056.94
Cleaning	5%	402.77	0	0
	100%	8,055.34		2,435.54

The total amount of water saved in the SP scenario is 69.8%. In this calculation, it is assumed that the toilets on campus are changed from 16.5 L/flush to composting toilets or grey water toilets; the basin facet is changed from 12L/min to ultra-low flow faucet of 5.7L/min; urinals are changed from 3.785L/min to waterless urinals or grey water urinals; the facet in the laboratory is also changed to ultra-low flow faucet of 5.7L/min; lastly, grey water with minimal treatment can be used for cleaning purposes. Referring to the previous sections regarding the flow rate of various equipments, the SP scenario can be calculated as follows:

7.2.3.2.3 Carwash

Coronach

Total water uses in 2040 = 105,120 m^3/year

Car wash water uses = Total water uses*21.7%*2.1% = 479 m^3/year

Table 29 SP scenario - Car wash water uses in Coronach

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
In-bay car wash	100%	479	0.9/0.6/0.5	129.33
	100%	479		129.33

Gravelbourg

Total water uses in 2040 = 125,684 m^3/year

Car wash water uses = Total water uses*14.7%*2.1% = 387.99 m^3/year

Table 30 SP scenario - Car wash water uses in Gravelbourg

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor(1-water saving%)	Total Usage (m^3/year)
In-bay car wash	100%	387.99	0.9/0.6/0.5	104.76
	100%	387.99		104.76

The total amount of water saved in the SP scenario is 73%. In this calculation, the water conservation measure taken is to fix leakages, reduce nozzle size, apply the appropriate amount of pressure, as well as use of recirculation water system.

7.2.3.3 System Losses

<u>Coronach</u>

Total water uses in 2040 = 105,120 m^3/year

System losses = Total water uses*6.7% = 7,043 m^3/year

Table 31 SP scenario - System losses water uses in Coronach

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Water leakage	100%	7,043	0.5	3,521.5
	100%	7,043		3,521.5

<u>Gravelbourg</u>

Total water uses in 2040 = 125,684 m^3/year

System losses = Total water uses*7.8% = 9,803.35 m^3/year

Table 32 SP scenario - System losses water uses in Gravelbourg

Items	Percentage	Water Demand in 2040 (m^3/year) = BAU projected demand * percentage	Water Efficiency Factor (1-water saving%)	Total Usage (m^3/year)
Water leakage	100%	9,803.35	0.5	4,901.68
	100%	9,803.35		4,901.68

By reducing leaks in the water supply system more aggressively, 50% of the water can be saved (Brandes and Maas, 2007). The total amount of water saved in the SP scenario is 50%.

In the above calculation, all the sectors have successfully achieved the SP goal of 60% reduction in water usage over the next 30 years and the goal is technically feasible in reducing water demand. Although data used in the calculation was based on the best data available, the calculation should be used as a strategic planning tool and not as a perfect prediction of the future. The suggested measures above were only used to illustrate the possibilities of integrating different appliances and adaption measures should not be restricted to the suggestions above. The section below provides a more detailed analysis in possible solutions in different sectors.

7.2.4 Possible Solutions

As aforementioned, with the aim of identifying possible solutions in improving water-use efficiency, a number of questions are considered (Wolff and Gleick, 2002):

- Why do we need the water?
    - What are the goals and purposes that we want to achieve?
- What kind of water is required to meet the goals and purposes mentioned above?
    - What is the different water qualities needed?

7.2.4.1 Why do we need the water?

Table 33 Purposes for water usage in different sectors

Water Usage	**Purpose**
Residential	
Toilet	Disposal of human waste
Laundry	Clean clothes and other fabric to remove dirt, stains and smells
Shower	Rinse bathers for personal hygiene
Faucet	Personal hygiene
Dishwasher	Clean dishes to remove soiling and kitchen utensils
Drinking	Basic human need for nourishment and quench thirst
Landscaping	Aesthetic
Agricultural – Farming*	
Spraying chemicals	Prevent and control pests, fungus, insects
Cleaning equipment and	Remove dirt and prevent spread of pollutants
Agricultural – Ranching	
Livestock watering	Basic need for nourishment and quench thirst
Cleaning equipment and facilities	Remove dirt and waste from animals as well as prevent the spread of pollutants

Industrial – Power Plant	
Cooling	Remove heat from machinery and cool working fluid
Industrial – Mining	
Dust Control	Suppress dust on the haul road
Cleaning equipment	Remove dirt and prevent spread of dust in surrounding area
Commercial – Car Wash	
In-bay car wash	Clean exterior of motor vehicles
Institutional – Hospital/ Health Care Centre	
Toilet	Disposal of human waste
Shower	Rinse bathers for personal hygiene
HVAC	Regulate temperature and humidity
Medical processes	Cool equipment such as X-ray machines, CAT scanners, and
Laundry	Clean clothes and other fabric to remove dirt, stains and smells
Landscaping	Aesthetic
Institutional – School	
Toilet	Disposal of human waste
Shower	Rinse bathers for personal hygiene
HVAC	Regulate temperature and humidity
Landscaping	Aesthetic

*Irrigation is not considered in this study as dryland farming is being practiced in both communities

7.2.4.2 What kind of water is required to meet the goals and purposes mentioned above?

Water unsuitable for a specific end-use may be suitable for another. One of the principles that defined soft water path is to save water by matching water quality with its end-uses. Soft water path supports the use of greywater. Water should be used for a number of times before entering the sewage system so as to lessen the load on the water treatment plant; for instance, rainwater can be used for laundry and then the laundry water can be piped to the garden for irrigation. As the water quality required for irrigation is lower than cleaning clothes, this circular system makes wastewater from one service useful for another service.

From the table below, it shows that most of the water usages only require minimal treatment before it can be reused. Some of the services can even be performed with water that is not being treated. As the availability of high quality water has been decreasing, soft water path should be used to sustain our daily activities without creating extra pressure on our increasingly fragile hydrological system.

Water quality can be categorized into three different levels (Potable, Secondary, and Tertiary). Potable water (e.g. groundwater) means water of drinking quality that can be used to serve any functions; secondary water (e.g. wastewater from any end-uses except from the toilet) means water that are slightly degraded and can be used to perform certain but not all services; tertiary water (e.g. water from toilet) means water that are polluted and cannot be used for any purposes unless being treated.

Table 34 Water quality required for different water usages in different sectors

Water Usage	Quality needed
Residential	
Toilet	Secondary
Laundry	Secondary
Shower	Potable
Faucet	Potable
Dishwasher	Potable
Drinking	Potable
Lawn	Secondary
Agricultural - Farming	
Spraying herbicides, insecticides, fungicides	Secondary
Cleaning equipment and facilities	Secondary
Agricultural - Ranching	
Livestock watering	Secondary
Cleaning equipment and facilities	Secondary
Industrial – Power Plant	
Cooling	Secondary
Industrial – Coal Mine	
Dust Suppression	Secondary
Cleaning equipment	Secondary
Commercial – Car Wash	
In-bay car wash	Secondary
Institutional – Hospital/Health Care Centre	
Toilet	Secondary
Shower	Potable
HVAC	Secondary
Medical processes	Potable
Laundry	Secondary
Landscaping	Secondary
Institutional - School	
Toilet	Secondary
Urinal	Secondary
Shower	Potable
HVAC	Secondary
Landscaping	Secondary

7.2.4.3 Possible solutions based on the above analysis

Possible solutions proposed in this project were based on the table above as well as the following principles (Hoffman, n.d.). The order of the above principles were arranged based on the easiness of implementation (1 is the easiest and 6 is the hardest) and the effectiveness of water-saving measures (1 is the least effective and 6 is the most effective). The first 3 principles were grouped into the category of enhanced efficiency while the last 3 principles are grouped into the soft water path approach.

1. Adjust equipment
2. Modify equipment or install water-saving devices
3. Replace with more efficient equipment
4. Reuse or recycle water or use an alternate water source
5. Change to waterless process
6. Change in personal behaviour

To conserve the maximum amount of water so as to improve the communities' adaptive capacities in future drought events, the measures suggested have to be tailored to address specific needs of different sectors based on results gathered from semi-structured interviews. Examples of possible paths (adaptation strategies) for the two communities are listed below:

Table 35 Possible paths for different sectors

Water Usage	Enhanced Efficiency	Soft Water Path
Residential		
Toilet	▪ 6L toilet ▪ Early closure device	▪ Dual-flush toilet ▪ Composting toilet ▪ Grey water toilet
Laundry	▪ Front-loading washing machine	▪ Avoid partial loads ▪ Alternative water source
Shower	▪ Low flow showerhead	▪ Shorter shower
Faucet	▪ Low-flow faucet ▪ Faucet aerator	▪ Avoid running unused tap
Dishwasher	▪ High efficiency dishwasher	▪ Avoid partial loads
Lawn	▪ Drip irrigation system ▪ Hose timers ▪ Rain shutoffs	▪ Rain barrel ▪ Xeriscaping ▪ Odd/even day irrigation

Agricultural – Farming		
Spraying chemicals	▪ Use finer sprays	▪ Change in farming practices
Cleaning equipment and facilities	▪ Low-flow Spray nozzle	▪ Waterless/grey water cleaning
Agricultural - Ranching		
Livestock watering	-----	-----
Cleaning equipment and facilities	▪ Low-flow spray nozzle	▪ Waterless/grey water cleaning
Industrial – Power Plant		
Cooling	▪ Adjust cooling tower conductivity level	▪ Air cooler tower
Industrial – Coal Mine		
Dust Suppression	▪ Improve water trucks sprinklers	▪ Use of Calcium Chloride or oil mixture ▪ Better haul road design
Cleaning equipment	▪ Low-flow spray nozzle	▪ Waterless/grey water cleaning
Commercial – Car Wash		
In-bay car wash	▪ Fix leakages ▪ Reduce nozzle size ▪ Apply the appropriate amount of pressure	▪ Recirculation water system
Institutional – Hospital		
Toilet	▪ 6L toilet ▪ Early closure device	▪ Dual-flush toilet ▪ Composting toilet ▪ Grey water toilet
Shower	▪ Low flow showerhead	▪ Shorter shower
HVAC	▪ Adjust blowdown rates of the boiler and cooling tower ▪ Check and repair steam traps	▪ Reduce cooling load
Medical processes	▪ Install automatic valves ▪ Eliminate water tempering during non-sterilizing machine cycles	▪ Elimination and recirculation of seal and cooling water
Laundry	▪ 92.7L/load washing machine ▪ Front-loading washing machine	▪ Avoid partial loads ▪ Alternative water source

Institutional – School		
Toilet	▪ 6L toilet ▪ Early closure device	▪ Dual-flush toilet ▪ Composting toilet ▪ Grey water toilet
Basin Faucet	▪ Ultra low-flow faucet ▪ Aerator	▪ Avoid running unused tap
Urinal	▪ Low flush urinals	▪ Waterless urinals
Laboratory	▪ Ultra low-flow faucet	-----
Cleaning	▪ Low-flow spray nozzle	▪ Grey water

7.2.4.3.1 Other measures

Metering itself does not reduce the amount of water used, but it is also important to detect leaks and other problems. As aforementioned, farm households were excluded in the above analysis because water for agricultural purposes was taken from private sources (e.g. wells and dugouts) and were not metered. The absence of data on water usage has hindered the process of soft water path planning. Therefore, it is suggested that water usage from wells should be metered so that agriculture producers will be aware of their water usages not just in agricultural production, but their regular household activities as well. In town, buildings should install sub-meters to help the detection and location of leaks or abnormal water usage. Allowing access to building water use data is a way of allowing the public to be aware of the amount of water used. The data available should include both historical and current data so as to demonstrate the effectiveness of water conservation measures and encourage town residents to work towards a common goal. In addition to the installation of meters and making water usage data public, institutions can support water conservation by providing rebates for water-efficient appliances and changing plumbing codes to make water-efficient plumbing fixtures mandatory and restrict the sale of water-wasting appliances. In the case of Coronach and Gravelbourg, some informants claimed that they were renting their apartment and that is why they do not have the incentive to switch to water-efficiency appliances. In this case, tax-incentives should also be provided to landlords so as to encourage them to change the appliance in their properties.

7.2.4.4 Economic Consideration

After identifying all the possible solutions that are feasible in the two communities, the cost and benefit of each option should be examined in order to assist household's decision making process. To calculate the payback period, the net yearly savings is compared to the sum of the cost of the proposed measure and the cost of all related expenses (Environment Canada, 2009). If the payback period is too long, the public will be less likely to practice the suggested changes. As payback period is influenced by the number of people in the household, the amount of water reduction, the amount of money saved through water reduction, the cost of implementing and installing water conservation measures, and the operation and maintenance costs of the specific water-using appliances, payback period for the above proposed solutions were not available owing to data and time constraints. However, studies show that homeowners and industry typically aim at having a payback period within two years and indoor water-saving appliance that have a payback period of two years and less can achieve water saving ranges from 33% to 50% (Jordaan and Stevens, 2007; Brandes et al., 2006). Therefore, the EE scenario is achievable in the two communities.

The possibility of water financial management was also explored in this study. As increase in the price of water will decrease water demand, water financial management is one of the methods that is commonly used in promoting water conservation. A number of respondents mentioned that "the only thing that will make people conserve water is to start charging them…people are only ready to change if you make them change" (GB 17). If the price of water goes up higher, they may start to conserve water in the future (GB 12, GB 14, GB 17). In the Town of Coronach, the cost of water above base usage (above 3,000 gallons per month) has changed considerably in the last decade from one dollar per thousand gallons to five dollars per thousand gallons so as to penalize overage (CN 1, CN 5). As a result, there were a number of incidents where residents had arguments with the town office with their water bills. In addition to the price of household water usage, the price of coin-operated tank filling station in town has doubled recently and it also led to some upset farmers complaining at the town office (CN 18). Although some households and producers were upset about the increasing price of water, the amount of water usage in town has remained fairly consistent throughout the past few years. In the Town of Gravelbourg, most of the town residents have already accepted the high cost of water as the cost of water is always more expensive than the surrounding area because of the poor water quality that needs to be treated as identified in the CBVA. Some residents mentioned that their water bill usually gone up quite high in the summer time because of lawn watering. Despite the fact that the price of water is increasing and their water bill is getting more expensive, some of them still think that it is necessary to keep their lawn green and have a productive garden. During the semi-structured interview, respondents were asked what they think about the price of water and whether they will be willing to pay more to enhance their water security, almost all of them thought that the price of water was reasonable and claimed that they will be willing to pay more in the future if there is water shortage. Results from the interviews shown that the current price adjustment may not be enough to encourage changes in personal behaviour; therefore, a more progressive change is recommended in order for the water financial management be effective.

7.2.4.5 Social Consideration

Out of all the criteria that are used to assess the feasibility of adopting certain water conservation measures, social consideration is one of the most difficult issues (Harremoës, 1997). "The real differences between soft and hard paths lie not with the technologies but with the socio-political choices about governance of natural resources" (Brooks, 2005). As soft water path focus on the changes driven by a complete change of mindset, social acceptability is crucial in this approach. The degrees to which people are required to change their behavior have the largest effect on acceptability (Burkhard and Craig, 2000). Therefore, research on social acceptability can determine the potential barrier to the implementation of a water conservation measures. As measures suggested have to match the values and priorities of different groups of actors in the communities, it is crucial to understand the social acceptability of the proposed adaptation measures so as to suggest changes that are tailored to the specific needs that were demonstrated in the CBVA.

Information gathered from the interviews and literature reviews were used to assess the social acceptability of water-saving measures. The social acceptability of 6-litre toilet, low flush urinal, rainwater harvesting system, faucet aerator, low flow showerhead and metering are higher than other adaptation strategies. This can be explained by that fact that there is usually little awareness of such systems and it does not require any changes in personal behaviour. One of the concerns for using a dual-flush toilet is that the user may have to flush twice as they may think the new toilet is not as effective as their old 13-litre toilet. Yet, as long as the dual-flush toilet is installed properly, waste should be able to remove effectively. Similar to the dual-flush toilet, users may have concern about the effectiveness of a 6-litre toilet. However, as long as water-efficient appliances, such as 6-litre toilet, do not cause too many changes to personal behaviour, the flush patterns should not change and water can be conserved effectively.

In a survey done on the topic of public attitudes on water issues, the results shown that 94% of the surveyed population support the promotion of a water efficiency program and they realized the importance of water conservation (City of Toronto, 2000). Yet, the willingness to change varies from group to group and it depends largely on the user's experience, and cultural perception. The myth of water abundance has undermines efforts to conserve water and water conservation actions are often hindered by ignorance of users. In Coronach and Gravelbourg, there seemed to be a dichotomy of the perception of water availability in terms of agricultural and daily uses. As dryland farming is practiced in this region, the lack of precipitation created problems such as crop failure or negative impact to livestock. Producer may be deeply concerned with water availability as that may have serious impact on their livelihood. Many respondents from both communities have mentioned that they hope there could be a pipeline that transfers water from Lake Diefenbaker to their communities, so that they can practice irrigation and increase their productivity. However, when interviewer asked about their daily water usage, most of them did not have a back-up plan and they were not concern about water shortages at home. As most of the farms have deep wells and multiple water sources, they did not associate water shortages with their daily lives as they claimed that they can rely on their wells or haul water from nearby community wells. They said that there was no water problem in the region and they believed that their water sources produce abundant water supply most of the time. Therefore, they did not see the need to conserve water in their daily practices at home.

Public attitude towards greater behaviour changes is also affected by their perception towards adaptation measures. Many people are concerned about the hygiene issue of waterless sanitation units. However, as long as the system is properly operated and basic safety rules are followed, the risks associated with a those systems should be no more significant than a traditional ones (GHD, et al., 2003). Therefore, social marketing program is essential to change the user's view on these different measures and increase awareness. It is crucial to educate the public about the importance of water conservation. As the main characteristics of the soft water path approach is to decentralize water conservation measures and to involve the public in changing their practices, it is essential for them to be aware of the true value of water. A lot of water goes down the drain because of the false perceptions that water is plentiful and cheap. As a result, education is necessary to help the public to become conscious of the amount of water they used and to look for ways to use less water whenever possible. All in all, as the extent to which people are required to alter their everyday behaviour will have the largest effect on acceptability; implementation of water efficient fixtures has to go hand in hand with educational programs so as to increase public awareness and to ensure community participation especially in area where water conservation is not a priority.

Chapter 8
Conclusion

This chapter provides main conclusions drawn from the key findings in CBVA and SP analysis. Future research opportunities are discussed to conclude this chapter.

8.1 Summary of Key Findings

Increase in climate variability is posing considerable challenges on rural communities in the Prairies. With the projected increase in frequency and magnitude of droughts, there is a growing need for rural communities to equip themselves and improve their adaptive capacity. This paper has answered the following research questions,

1) How vulnerable are rural communities to water shortage in Southern Saskatchewan? What are the forms of exposures faced by rural communities and what are their adaptive capacities both in the present and in the future?

2) In terms of water scarcity adaptation for municipal water users, how can different sectors in the Town of Coronach and Gravelbourg increase their adaptive capacity by improving their water efficiency with existing water supplies?

As presented in this paper, drought is a complex phenomenon that is both spatially variant and context dependent. Results from the study indicated that both study areas were affected by various stressors that were caused by a combination of biophysical and socio-economic factors. As different characteristics of the system interacts with each other in various scales and produce a unique situation in every community, CBVA plays an important role in identifying challenges and opportunities that exist in different communities. The two case studies presented in this thesis have successfully demonstrated that reduction in community vulnerability requires systemic and forward-thinking decision-makers. Contextual factors can never be neglected and adaptation strategies have to be mainstreamed into current measures and tailored to the need of different groups of actors in the community.

This study has shown that future climate change is not the only stressor in the system. The two communities are also faced with other biophysical and socio-economic challenges that are identified by the informants, such as excessive moisture, poor water quality, high feed prices, depopulation, and the lack of infrastructure. Excessive moisture led to problems such as delayed seeding and created problems in water quality that affects different sectors in the communities. Poor growing season contributed to increase in feed prices which aggravated the financial situation of producers and triggered a decline in the town economic activities. Owing to the lack of job opportunities and infrastructure, people started to migrate to bigger cities. It has demonstrated that comprehensive strategies are required to improve the communities' adaptive capacities.

As drought is a recurring event in this region, institutions have played a crucial role throughout the years in supporting the producers through research, education, and the provision of financial resources. Through research and education, public awareness of water conservation techniques has increased and producers were also able to farm more efficiently with limited resources. Adaptive capacity of the producers was also enhanced by their willingness to learn and experiment with different methods. As many informants claimed that there was a strong social cohesion within the communities and they were constantly sharing knowledge with each other, social network was identified as one of the major factors that contributed to the adaptive capacity of the communities. With the increasing input cost of farming and the lower price of agricultural product, the margin of error for farming has been decreasing throughout the years. Some producers expressed that nowadays they can hardly make ends meet and they can only take one day at a time. With such a tight margin, they tend to deal with changes in a reactionary manner. As a result, drought had a serious financial impact to the producers and the town as a whole. However, there were some government programs that helped producers to reduce their vulnerability in a proactive way, such as the farm and ranch infrastructure program where they may gain accessible to new technologies and are able to dig deeper well and build more dugouts. For the towns, by encouraging local economic initiatives such as mustard processing plants and other small businesses, it enhanced the general socio-economic situation of the surrounding area. Those measures decreased their vulnerability and made them more adaptable to other stressors in the long-run. For producers that were more proactive, they were able to reduce their sensitivity towards environmental and market changes. Some of them have off-farm jobs, while others have their own insurance system in place, such as storing up some grains for future sale, cutting their cost of production, and minimizing their spending whenever possible. Therefore, they had a greater level of adaptive capacity and were able to remain in operation after a number of poor years.

Some of the adaptive measures have created new opportunities and improved the community's resilience, while others have created new vulnerabilities and exposed the community to other issues. With the introduction of minimum tillage practice, soil moisture has been conserved for the growth of crops and soil erosion was prevented. This measure has reduced the amount of precipitation needed. Some producers even commented that after they have practiced minimum tillage, they can produce good crops with less than 10 inches of rain. However, adaptation measures such as the use of chemicals to improve productivity in nutrient depleted fields has in turn contaminated water source, worsened the problem of eutrophication, and contributed to future vulnerability. Therefore, CBVA is helpful in providing background information for the planning of context-specific adaptive strategies.

In the second part of this thesis, soft water paths analysis in the Town of Coronach and Gravelbourg were conducted as case studies to test the feasibility of increase the communities' adaptive capacity though improving water efficiency with existing water supplies. In SP analysis, major water systems were assessed to explore further opportunities for water conservation. In the three scenarios that were created to project future scenarios, the EE scenario shows that with basic water conserving appliances, up to 38% of the daily water usage can be saved; while in the SP scenario where basic water conserving appliances is supplement by changes in personal behaviour, up to 63% of the daily water usage can be saved. As SP requires detailed background information on the specific location so as to meet the water-related needs of users and recommend feasible and effective solutions, case-specific adaptation measures are recommended based on the results gathered in the CBVA.

List of possible solutions that aimed at delivering water that match their end-use purposes were identified for different sectors. For example, in the residential and institutional sectors, dual-flush or greywater toilets were suggested in place of the 13L toilets; front-loading washing machines were suggested in place of the top-loading machines that were used by more than 95% of the household. In terms of the agricultural sector, as the current dryland farming practices have already included measures that make use of the amount of moisture that are available to them, the only suggestion to this sector were to improve farming practices so as to minimize the amount of water lose through evapotranspiration and the amount of water used for spraying. The use of greywater for cleaning farming machines is also another option that can be considered so as to avoid the use of unnecessary high-quality water. For the mine and the power plant, air cooler tower was suggested instead of the traditional water cooling tower and the use of calcium chloride should be used to suppress dust instead of water. Results from the socio-economic analysis have shown that measures with a payback period of less than 2 years and require minimal behavioural change have a higher penetration rate in the communities. As people's perceptions of water usage are deeply rooted in their mind, social marketing is required to change public perceptions. Implementation of water efficient fixtures has to go hand in hand with educational programs so as to create the paradigm shift that is needed for effective soft water path.

According to the results from the CBVA and Soft Water Path analysis, adaptive capacities of both communities can be improved through changes made in the residential, industrial and institutional sectors. In terms of agricultural operation, both communities can be used as case studies for other irrigated agricultural communities so as to encourage improvement in their water efficiency and minimize their reliance on ew water sources. By decreasing the communities' exposure-sensitivity and improving their adaptive capacity to different stressors, their vulnerability towards future environmental changes can be greatly reduced.

8.2 Future Work

The issue of complexity and uncertainty is opening various research opportunities for future work in this area. The impact of climate change is highly uncertain and more research should be conducted on local scale. It is crucial to understand the relationship between social and scientific components. Further interdisciplinary research can be done to assess stress from multiple sources and their interrelationships that contribute to rural community's vulnerability and their adaptive capacity.

As soft water path is a data intensive management method, detailed information on water consumption pattern is required in order to design alternatives that are suitable for the specific needs of the communities. Due to time and data limitation, the scope of water auditing in this thesis was limited and assumptions had been made based on the best available resources. A more detailed water audit should be done in the future. As economic factor is a crucial determinant for public acceptance, payback period should be calculated to determine the feasibility of each alternative so as to encourage different sectors to adopt water-saving appliances and practices.

Social acceptability is another area that needs to be further explored. Since social acceptance defines the legitimacy of the adaptation actions, if the communities think that building adaptive capacity for droughts is not urgent or important, the chances of suggested measures being implemented is low. As people tend to prioritize risk and focus on issues that have immediate impact on them. Adaptation to drought may not be their first priority as it is not as urgent as other quicker onset disaster. Therefore, more research is needed to explore different ways to improve public awareness.

With the increasing frequency and magnitude of extreme climatic events, vulnerability assessment has become increasingly important in building local adaptive capacity. The growing interdependency and complexity of the biophysical and socio-economic systems have also increased the challenges that are faced by rural communities. It is crucial to find flexible adaptation measures that do not create social and environmental externalities at other spatial and temporal scale. As a result, there is an urgent need to turn research findings into useful information for policy planning so as to build communities' adaptation capacity effectively.

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Appendix A

Information Sheet

I am conducting interviews of the residents of your community. I am affiliated with the University of Waterloo in Ontario, and the Project is Co-ordinated by the Canadian Plains Research Center of the University of Regina. I am working under the supervision of Dr. Johanna Wandel at the University of Waterloo.

This interview is part of a study of drought related vulnerabilities and mitigation activities in and around your community. The study is supported by the Social Sciences and Humanities Research Council of Canada (SSHRC) to a team headed by Dr. Harry Diaz at the University of Regina. This interview deals with your impressions about drought related vulnerabilities and management activities, with emphasis on the impacts on water resources in your area. The four main topics in which our questions will be focused are:

The conditions (exposures or stresses) that communities and households have had to deal with in the recent past, especially with regards to drought and/or water issues.

1. The way in which communities and households have dealt with those water and/or drought conditions.
2. The roles that external institutions have played in reducing the exposures or stresses to climate and/or water conditions of communities and households.
3. The capacity of the community to deal with more serious possible changes to water and/or climate conditions in the future.

Participating in the study is voluntary. As well, if there is a question you would rather not answer, just say so and we will move on to the next one. You are free to discontinue your participation in the interview at any time. With your permission, this interview will be audio-recorded.

We have already informed members of the municipal government about this study. The interview will take approximately 60 minutes.

All your answers are completely confidential – no one will know what you have said. Once we have recorded all the information, it will be impossible to identify you or any other participant. Anonymous quotations may be used in reports and publications. Audio-recordings, paper records, and electronic data with no personal identifiers will be kept for ten years in secure locations and then confidentially destroyed. In case of any doubt you can contact the Project Director, Dr. Harry Polo Diaz (306-585-4151 or by e-mail: harry.diaz@uregina.ca) or my supervisor, Dr. Johanna Wandel (519-888-4567 ext 38669).

This project has received ethics clearance through the University of Waterloo's Office of Research Ethics. If you have any questions or concerns about your rights as a participant in this study you may contact Ms. Sykes, Director, Office of Research Ethics at 519-888-4567 ext. 36005 or ssykes@uwaterloo.ca

We think that this is an important project and we would very much appreciate your participation. Please accept my most sincere thanks in advance for your consideration of this matter.

Fanny Luk
MES Candidate, University of Waterloo

Appendix B

Interview Consent Form

By signing this consent form, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

I have read the information presented in the information letter about a study being conducted by Fanny Luk and Johanna Wandel of the Department of Geography at the University of Waterloo in collaboration with Dr. Harry Diaz of the Canadian Plains Research Centre at the University of Regina. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted. I am aware that I may withdraw from the study without penalty at any time by advising the researchers of this decision.

This project has been reviewed by, and received ethics clearance through, the Office of Research Ethics at the University of Waterloo. I was informed that if I have any comments or concerns resulting from my participation in this study, I may contact the Director, Office of Research Ethics at 519-888-4567 ext. 36005 or ssykes@uwaterloo.ca.

With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

☐ I consent to this interview being audio-recorded, and understand that any quotes used from the interview will be used in such a way as that I remain anonymous.

____

Print Name

____

Signature of Participant

____

Dated at Coronach/Gravelbourg (circle), SK

____

Witnessed

Appendix C
Interview Guide

Basic demographic questions:

- Can you tell me a little bit about your background?
    - Do you mind telling me your age?
    - What do you do to make a living?
    - What is the size of your household? Who are living with you? Do the kids help in the farm?
    - What is the main source/balance of sources in your household?
    - What is the last grade you have attended?

- Farmers
    - How big (how many acres) is your farm?
    - What kind of crops do you grow? What are their percentages?
    - Can you describe the sorts of practices you use?
    - Does anybody irrigate here? What kind of irrigation method do you use?
    - What type of equipment does u use?
    - Do you have any livestock? What type of livestock do you have? How many?
    - Would u replace your source of income when _______?
    - Do you owned most of your land? Do you also leased/rented? How about your machinery?
    - Is it a family farm or it is incorporated?

- Others
    - Could you talk briefly about your duties as a _______?
    - Can you talk about the existing water management measures, saying what's good about it? In what way or ways you think it is deficient? In your opinion, what should be done?

How do people live/livelihoods?

- How long have you been working/living in this field/area?
    - Have there been changes? What are they? Why there are such changes?
    - How did you manage through?
    - Was there anything that has helped you?
    - Why did you decide to act in this way? Who helped you decide to act in this way?
    - Would you done something differently?
    - What in your opinion is the worst problem faced by the community?

How do they use water?

- Does the livelihood of your household depend on water? How? How much?
- Do you haul your drinking water? From what sources do you get your drinking water?
- On average, how much water do you use?

- Is your livestock operation comes from the same source?
- What is the quality of the water you get? Do you treat all your sources?
- Have the source always been reliable (quantity and quality)?
- Does the source change seasonally/throughout the year?
- What did you do when you had no water? How much supply do you have if anything happen?
- How are you dealing with current problems?
  - What helped you decide to take these actions?
- How do you ensure the security of the supply?
- Do you anticipate problems in quantity and quality of the sources? Why?
- Would you live differently if there were more secure access to water?
- Would you be willing to pay more for water to enhance the security?
- Have you invested in any water conservation measures/appliances in the past?
  - Are you willing to pay for efficient appliances?

How does weather influence what they do?

- What kind of weather do you need for good production?
- Can you describe a good year/bad year?
  - What do you do when there aren't ideal conditions? What do you do when there are?
- How does the timing of water availability influence what happen?
- Is too much water/precipitation ever a problem? How does this affect you?
  - Is too much water ever managed with consideration given to the next drought?

What has happened in drought situations in the past?

- Recent droughts – when were they? How long did it last? How bad were they?
- What did you do?
- When has this happened before, how long did it last, how severe was it?
  - What was done to get through it?
- What (if anything) was done to prepare for the next drought?

What are some of the things that worked, didn't work, barriers, incentives?

- How well did things work in the past?
- In your opinion, what strategies were particularly effective?
- How long would these have continued to work?
- Would they work for other people in similar situations?
- What was tried and less successful? Why?

- Was there any institutional involvement?
  - Did you participate with any support programs?
  - What was successful about the experience, how could it have been better?
  - Would you participate in those programs again?

- Did you have any friends that help you out on the farm? How did they help you?
- What would have made the drought more manageable last time?
- What would you like to see available in the next drought?
- What would you do in the next drought?
- What sorts of information do you need to help you manage through a drought better? Who should provide it?

Are there future considerations?

- If agricultural background
    - Do you see your children farming? Why, why not?
    - What will they have to do to stay viable?

- Did the last drought (or bad year) change how things were done? Did the last good year change how things were done?
- If there's a drought how long would you be able to make it through?
- What if you had a four-five-six year drought?
- Are you planning for changes in water quantity and quality?
- Do you have a succession plan? Why and why not?

What can be done at the institutional level to build more adapted communities?

- What can be done to ensure that the communities can cope better?
    - What do they need from the province, federal government, local government?
    - What are the price points that enable participation in existing programs?
- If you need assistant with programs where do you get the info?

Last questions

Is there anything I should have asked you about water and drought that I missed?
Is there anybody else you think would like to participate in this study?

Appendix D
NVivo Coding Guide

I ATTRIBUTES

1) Gender
- Male
- Female

2. Occupation

What are the livelihood categories that apply to the respondent?

- Farmer
  A producer whose operation involves crop production, with no livestock other than hobby animals or pets.

- Mixed farmer
  A producer whose operation includes both crops produced for market as well as commercial livestock.

- Rancher
  A cattle, sheep, bison or horse producer who does not typically produce crops for market, but may raise some crop for her/his own use as livestock feed.

- Other Agricultural (This would include certain other agricultural livelihoods such as intensive livestock operations – hog barns, feedlot, dairy, poultry, etc.)

- Self-employed
  A self-employed professional or business operator.

- Employed
  Earns a salary or wage

- Retired
  A person who is primarily retired but may still assist in the family business or farm

- Other (town residents who are not classified in previous categories, store owners, etc.)

- Unemployed, student , disabled, etc.

- Unknown

3. Community

The rural-urban centre that serves as the major farm service centre or hub community in the respondent's neighbourhood.

- Maple Creek
- Shaunavon
- Gravelbourg
- Coronach
- Kindersley
- Maidstone

4. Watershed

Name the watershed where the respondent resides

5. Age

Intervals

- (0-18), (19-30), (31 –50), (51 – 65), (65-75), (75 and over)

6. Marital Status

- Married
- Single
- Divorced
- Widowed
- Common law
- Unknown

7. Number of people in the household (including respondent)

- Number
- Unknown

8. Residence

- Town
- Out of town (farm, ranch or acreage)

9. Water Source (primary –domestic)

- Personal well
- Municipal/town supply
- Cistern/hauled water
- Other (spring, creek, dugout)

II Nodes

1. **Tree Node LIVE** LIVELIHOODS (livelihoods- how people live)

1.1 **LIVED** LIVELIHOOD DESCRIPTION

- How does the respondent earn a living/what are the sources of income?
- What is the balance e.g. farm and off-farm?
- How long has the respondent been involved in her/his current occupation(s)
- How many family members/employees participate in the operation?

1.2 LIVEGR LIVELIHOOD GENDER ROLES (sharing workload and income earning responsibilities)

- How is gender reflected in the sorts of income generating activities different family members are engaged in?
- How are management responsibilities and workload share?

1.3 **LIVEVC** LIVELIHOOD VULNERABILITIES AND CHANGES

- What are the livelihood sensitivities and vulnerabilities faced by the respondent?
- How is livelihood threatened by drought, low income, rising costs etc.
- What, if any, have been the changes in the way the respondent and her/his family have made in the ways they earn a living, and why were those changes made i.e. what issues trigger changes?
- Would they continue to work off-farm if their farm income situation improved?

2. **Tree Node WATERU** WATER USE (How does the respondent use water?)

2.1 **WATERUDU** WATER USE DOMESTIC - URBAN

- How does the urban respondent/community obtain and use domestic/household water? What sorts of water quality and quantity concerns does the respondent have?
- Does the respondent have an idea of what her/his use rates are?
- What sorts of changes are they making or would they make if they could?

2.2 **WATERUDF** WATER USE DOMESTIC – FARM

- How does the non-urban respondent obtain and use domestic/household water?
- What sorts of quality and quantity concerns does the respondent have?
- Does the respondent have an idea of what use rates are?
- What sorts of changes are they making or would they make if they could?

2.3 **WATERUL** WATER USE LIVESTOCK

- How does the respondent obtain and provide water for livestock (e.g. wells, dugouts, pipelines, solar pumps, grid electric, hauling)?
- What sorts of quality and quantity issues, if any, does the respondent have? What sorts of changes would they make if they could?

2.4 **WATERUI** WATER USE IRRIGATION

- Does the respondent irrigate?
- What crops are irrigated?
- How is the water allocated, obtained and used e.g. pivot or flood, once per year or twice)?
- Is the irrigation system performing satisfactorily or are there issues?
- What sorts of changes would they make if they could?

2.5 **WATERUO** WATER USE OTHER

- Do the respondents or their communities have other significant uses for water? (e.g. oil and gas extraction, the town's golf course, farm field sprayer use.)
- Is supply quantity and quality satisfactory for these uses?

2.6 **WATERSPRO** WATER SOURCE PROTECTION

- How does the presence or absence of a watershed group affect source water protection, allocation and use in the respondent's neighbourhood?
- How is watershed planning managed in the respondent's community: what is the process, how are decisions made? who is involved, are plans revisited, changed?
- How are water quality issues addressed locally? (e.g. how is wastewater managed by the respondent/community, are there concerns about pollution from oil and gas operations or intensive livestock operations?)

3. **Tree Node CIMES** CLIMATE EXPOSURES AND SENSITIVITIES

3.1 **CLIMPR** CLIMATE PREFERRED

- What is the optimal or normal range of climate/weather, snow, rain etc. that the respondent either relies on or would prefer?

3.2 **CLIMDR** CLIMATE EXPOSURES AND SENSITIVITIES – DROUGHT

- How does drought impact respondent's lives and livelihoods
- What are the characteristics of drought
- At what times of year does drought sensitivity arise
- How frequently do they experience drought and associated impacts?

- Can the respondent recall specific years of serious drought; especially recent events e.g. 1988, 2001, 2002

3.3 **CLIMEW** CLIMATE EXPOSURES AND SENSITIVITIES - EXCESS WATER (too much water or moisture at the wrong time)

- How, if at all, has the respondent been affected by excess moisture or flooding

3.4 **CLIMO** CLMATE EXPOSURES AND SENSITIVITIES – OTHER

- What other climate exposures besides drought excess moisture and flooding are respondents sensitivities to (e.g low snow fall and run-off, cold spring weather, early or late frosts)?

4. **Tree Node ADAPTS** ADAPTIVE STRATEGIES

What adaptive strategies have respondents employed to improve resilience and mitigate the impacts of vulnerability to drought and other climate hazards, and challenges to water supplies?

4.1 **ADAPTSD** ADAPTIVE STRATEGIES FOR DROUGHT

What sorts of adaptive strategies have respondents and their communities engaged in to improve resilience to drought, and challenges to their water supplies:

4.1.1 ADAPTSDC ADAPTIVE STRATEGIES FOR DROUGHT -COMMUNTIES

- What adaptive strategies have respondents' urban communities employed to obtain and sustain optimal quality and quantities of water (e.g. drill new wells, dams/reservoirs, conservation/rationing,, improved treatment, wastewater management)
- What government programs have respondents taken advantage of to secure water and or mitigate the impacts of drought and water management and delivery challenges
- Have respondents lobbied government for programs or assistance to improve resilience, or finance infrastructure
- How have these strategies changed over time
- What plans are in place or being designed to deal with hazardous exposures in the future

4.1.2 ADAPTSDP ADAPTIVE STRATEGIES FOR DROUGHT – AG. PRODUCERS (AND OTHER RURAL RESIDENTS/BUSINESSES)

- What adaptive strategies have respondents employed to obtain and sustain optimal quality and quantities of water for domestic and agricultural use (e.g. drill new wells, dams/reservoirs, irrigation, improved treatment)
- What have producers done to conserve soil moisture and prevent drifting?
- What do they do to conserve water for livestock and protect sources?
- What government programs have respondents taken advantage of to secure water and or mitigate the impacts of drought (e.g. Crop Insurance, AgriStability, FRWIP, PFRA programs, etc.)? Why or why not?
- Have respondents lobbied government for programs or assistance to improve resilience?
- How have these strategies changed over time?
- What plans are in place or being designed to deal with hazardous exposures in the future?

4.2 **ADAPTSO** ADAPTIVE STRATEGIES FOR OTHER CLIMATE HAZARDS AND WATER STRESS

- What sorts of adaptive strategies have respondents and their communities engaged in to improve resilience to climate/weather challenges other than drought that can impact their livelihoods and water needs (how do they deal with issues like floods, threats to water quality?
- How have these strategies changed over time?
- What plans are in place or being designed to deal with hazardous exposures in the future?

5. Tree Node ADAPTC ADAPTIVE CAPACITY

What are the assets available to respondents and communities that support their capacity to adapt to drought and water problems?

5.1 ADAPTCT ADAPTIVE CAPACITY – TECHNOLOGY

- What is the level of access that respondents have to the technologies that could help them deal with drought and water management issues – is it readily accessible - is it affordable?
- What sorts of technological innovations have respondents invented or adopted to help them adapt?
- Are technological advice and solutions available locally, through governments, or private industry?
- What resources are available (e.g. PFRA offices, local suppliers such as well drillers and track hoe operators)?
- Are these resources available locally, are they affordable or cost-prohibitive?
- What level of technical capacity (knowledge, skill, machinery) do individual producers have?

5.2 ADAPTCI ADAPTIVE CAPACITY – INFORMATION AND EDUCATION

- Do respondents have access to the information and educational opportunities they require to deal with drought and water issues?
- How do they obtain the information they require (is it available locally, through government, via the internet etc.)?
- How does the availability of local/regional climate and water supply data affect adaptive capacity?

5.3 ADAPTCER ADAPTIVE CAPACITY - ECONOMIC AND FINACIAL RESOURCES

- How do personal or community economic/financial issues impact adaptive capacity?
- What sorts of financial resources are available to assist producers in making adaptations (e.g. government programs, savings)?
- What is the relationship between resilience in the face of drought and water issues and general economic conditions in agriculture and business?

5.4 ADAPTCIN ADAPTIVE CAPACITY – INSTITUTIONAL SUPPORTS

- What sorts of institutions play a role in helping the respondent deal with drought and other water and climate related issues? (e.g. local irrigation associations, the RM, the province, federal government, banks and credit unions, watershed groups.)
- What roles do local, regional, provincial and federal institutions play in enhancing adaptive capacity?
- Which funding and program supports offered by government do respondents utilize?
- How do respondents perceive these institutions are they seen as cooperative, well-informed, obstructive etc.?
- How do respondents view the programs and services offered by institutions, are they beneficial, counterproductive, irrelevant etc.?
- Are there producer or community-based institutions that enhance adaptive capacity through planning and lobbying, such as the Stock Growers, Agricultural Producers of Saskatchewan, irrigation associations, cooperatives?

5.5 ADAPTCSN ADAPTIVE CAPACITY – SOCIAL NETWORKS

- What sorts of social networks are operating in the respondent's neighbourhood and how do they affect resilience to drought and other climate and water related issues?
- Are local community-based lobbying efforts ever employed?

6. Free Node BAR BARRIERS TO ADAPTIVE CAPACITY

- What are the barriers to adaptation identified by respondents? (e.g. economic/financial; institutional intransigence; increasing frequency and intensity of exposure events; community decline; etc.?
- Are their sufficient incentives or penalties in place to encourage change?

7. Free Node IMPIN IMPROVING INSTITUTIONAL SUPPORT

- What do respondents say about the ways local and external institutions could improve their performance and help individuals and communities cope better, and enhance their adaptive capacity?
- What could be done to improve institutions and programs that are not performing satisfactorily?
- Are new institutions and/or new institutional approaches required – have some institutions outlived their usefulness?

8. Tree Node FUTR FUTURE RESILIENCE

8.1 FUTRTH FUTURE RESILIENCE – THRESHOLDS

- What are the limits of drought/climate induced stress that the respondent believes he/she could withstand without incurring significant livelihood damage (e.g. the insolvency of a farm or ranch operation, the need to move to a new community and/or occupation)?
- How many years of severe drought (1988 or 2001), for example, could the respondent's farm unit withstand and remain in business?
- What are the limits of drought/climate induced stress that respondents and community officials believe local watershed resources could withstand without incurring ecological and financial losses that exceed current adaptive capacity?
- Can the community sustain or encourage growth given the current state of its water resources?
- How much additional water related expenditure can the community incur without raising taxes to the point that its population can be sustained?

8.2 FUTRP FUTURE RESILIENCE - PLANS

- What sorts of planning activities are respondents engaged in to enhance their resilience?
- Have past exposures (droughts/floods etc.) changed attitudes, plans, strategies?
- What range of conditions are people planning for?
- What are their plans?

9. Free Node GEN GENDER ROLES

- What are the gender related components of adaptation and sensitivity to drought and other climate and water related exposures?

10. Free Node WATERFM WATER FINANCIAL MANAGEMENT

- Does the community charge for water use or delivery?
- Is town water metered?
- Is rationing employed due to infrastructure or supply issues?
- How is new infrastructure financed – taxes; use or delivery fees; grants, or personally (for farmers)?
- How are irrigation projects managed and financed – grants, government/AESB operations, producer fees, cooperative producer arrangements etc.?
- Do respondents have the financial capacity to make the investments to meet their future and current water needs?

11. Free Node OTHER OTHER ISSUES AND RESPONSES OF INTEREST

- Any issues, concerns or items of interest and concern mentioned by respondents but not adequately addresses by the preceding NODES.

Appendix E

Water Efficiency Factors

Technology/Practice	Water Efficiency Factor	Context
Structural and Operational Strategies		
6L toilet	0.36	6L replacing 16.5L
6L toilet (commercial)	0.46	6L replacing 13L
3.78L/flush urinal	0.5	Replacing 7.57L/flush urinals with 3.785L/flush urinals
1.89L/flush urinal	0.5	Replacing 3.785L/flush urinals with 1.89L/flush urinals
Dual-flush toilet	0.22	4.4/3L replacing 16.5L
Composting toilet	0	Replacing 16.5L average water use for toilet
Waterless Urinal	0	Replacing 3.785L/flush urinals with no water urinal
Alternative water source toilet (greywater/rainwater)	0	Replacing 16.5L toilet
Early Closure Device	>0.65	Installing an early closure device on toilet
Showerheads and Faucets		
Low-flow showerheads	0.47	7L/min replacing 15L/min
Shorter showers	0.53	Reduce time for shower from 15 min to 8 min
Low-flow faucets	0.79	9.5L/min replacing 12L/min
Ultra-low flow faucets	0.47	5.7L/min replacing 12L/min
Aerators	0.84	Adding an aerator to a faucet to reduce water usage
Dishwashers and Clothes washers		
Water efficient dishwashers	0.45	18L/load replacing 40L/load
Water efficient clothes washer	0.55	Average 92.7L (average) replacing 170L
Horizontal axis washing machine	0.67	Average 113.5L replacing 170L
Outdoor Water Uses		
Xeriscaping	0.7	Xeric landscape replacing turfgrass
Water saving equipment for irrigation	~0.38	Increase water efficiency of municipal irrigation

Alternative water source (rainbarrel)	>0	Using rainwater for lawn irrigation
Leaks		
Fixing leaks	0.24	Repairing household leaks
	0.85-0.88	Repairing leaks in water supply system
Water saving equipment and leakage detection in schools	0.21-0.49	Improving efficiency of schools
Cooling tower meters (commercial)	0.8	Sub-meter installation for cooling towers
Socio-political Strategies		
By-laws	0.7	Mandatory restriction limiting watering to twice per week
	0.47	Mandatory restriction limiting watering to once per week
Public education and behaviour changes	0.95-0.98	Information and education of water conservation
	0.85	Reduce peak water usage
Indoor Audit (commercial)	0.85	Using an audit to identify water inefficiencies
Indoor Audit (residential)	0.77	Using an audit to identify water inefficiencies
Economic Strategies		
Home retrofit program	0.68	Providing households with rebates to install low-flow fixtures
Increasing residential water rates and Universal metering	0.96-0.98	10% increase in price
	0.66-0.75	Installing meter on residential water accounts; pay according to use
Submetering	0.6-0.8	Install meters in subunits, such as apartments and condominiums

Calculation is based on 3 flushes per person per day
Average household residential water usage is assumed to be 329 litres per day (Environmental Canada, 2011c)

(Maas et al., 2007)