Saskatchewan Flood and Natural Hazard Risk Assessment

Prepared for Saskatchewan Ministry of Government Relations

By V. Wittrock[1], R.A. Halliday[2], D.R. Corkal[3], M. Johnston[1], E. Wheaton[4],
J. Lettvenuk[1], I. Stewart[3], B. Bonsal[5] and M. Geremia[3]

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EWheaton Consulting

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Flooded road – *Government of Saskatchewan*
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Snow banks along roadway – *J.Wheaton March 2013*
Oil well surrounded by water – *I. Radchenko May 2015*
Participants at Stakeholder Meetings – *D.Corkal June 2017*
Kneeling farmer on cracked soil – *istock photo*
Tornado by Last Mountain Lake – *D.Sherratt Summer 2016*

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“The people of this province [Saskatchewan] have the right attitude and demeanour to endure these hardships [natural hazards] and improve upon them. They need good vision and science to help them make the best decisions”
(Anonymous Stakeholder in Corkal 2018).

EXECUTIVE SUMMARY

Natural hazards and associated extreme events are key determinants of the character of many natural and human-influenced systems. Historically, Saskatchewan has been affected by various natural hazards including droughts, wildfires and floods. The effects of these events have influenced various facets of Saskatchewan's society (e.g., urban, rural, First Nations communities). At times, the natural hazards pose severe economic impacts to Saskatchewan and Canada. For example, the 2001–2002 drought caused an estimated $5.8 billion drop in Canada's gross domestic product, with the most significant impacts being to the Prairie provinces. In Saskatchewan, the drought of 2001–2002 resulted in an estimated reduced agricultural production of more than $1.6 billion. The Saskatchewan forest fires of 2015 cost more than $100 million with 1.7 million hectares burned and over 10,000 people evacuated from northern communities. Floods are a common occurrence in Canada, including Saskatchewan, and constitute the largest accumulated payout of federal disaster assistance. The Provincial Disaster Assistance Program expended more than $300 million in calendar years 2010 to 2014, with 2011 expenditures greater than $150 million. Most of these expenditures were flood-related.

Multi-year wet or multi-year dry periods are part of Saskatchewan's natural climate and hydrological characteristics. Recent research for Saskatchewan has determined that natural hydrologic variability is greater than indicated by the instrumental record. When climate change impacts are considered, it is estimated that even greater future climate variability will occur, with increasing risks from droughts, storms and floods and potentially fires. The wider range of variability of natural hazards and associated risks to Saskatchewan must be considered for the province to strengthen its resilience and reduce risks to the economy, social well-being and the environment. As the Province of Saskatchewan moves to a more proactive risk management strategy for dealing with natural hazards, an important step is to determine the province's vulnerability to various natural hazards. By learning from the past and considering future vulnerability to climate change, the province can determine feasible mitigative responses and initiatives to reduce future risk.

The team that undertook this project, Saskatchewan's Flood and Natural Hazard Risk Assessment developed a standardized risk assessment that was utilized with all the selected natural hazards. This approach was undertaken to help inform and prioritize longer and shorter-term risk reduction strategies. Selected natural hazards that pose a threat to Saskatchewan industry, the general public and governments at all levels were included in the analysis. The natural hazards selected for analysis were flooding (mountain runoff, plains runoff, lake, overland and groundwater), drought (agricultural, hydrologic, meteorological and socio-economic), forest fires (human caused close to communities), grass fires (greater than 1,000 hectares), summer convective storms (tornadoes, high winds, heavy rain, hail), winter storms (freezing rain, high winds, snow, blizzard conditions) and earthquakes. These natural hazards have already been experienced and have the potential of occurring under future climate conditions.

The risks of each of the selected natural hazards were assessed individually using two types of approaches. The first utilized a plausible worst-case scenario that incorporated historic events, that

typically resulted in having occurred at some point in the last 100 years, but was adapted to present-day situations. The second scenario added a layer of climate change to the plausible worst-case scenario focused on the modeled climate of the 2050s.

Each of the natural hazards tends to impact different regions of the province. Natural hazards such as drought, overland flooding, forest fires and winter storms can affect both localized and extensive geographic regions. Others like plains runoff flooding, lake flooding, convective summer storms, mountain runoff flooding and grass fires are generally relatively localized in geographic exposure. Groundwater flooding and earthquakes are highly localized. In addition, each of these natural hazards can occur over varying time frames. For example, drought can last many years while severe convective summer storms take place in a matter of hours or less. Antecedent conditions are critical in determining the severity of the natural hazard. Linkages also occur among many of the natural hazards and if one is occurring or has occurred, another natural hazard may happen as the result of the first one. For example, all forms of flooding can be heavily influenced by both winter and summer storms, and flooding could be considered a secondary impact to these storm events. Similarly, drought conditions can lead to an increase in the occurrence and severity of grass fires and possibly northern forest fires.

The first scenario examined the plausible worst-case natural hazards. Most of these have occurred at some point in the last 100 years. The likelihood of present-day occurrence can range from almost certain to rare A good estimate of present-day consequences of the plausible worst-case scenario for each hazard is applied based on these historic events. The level of impacts resulting from these various hazards ranges from insignificant to catastrophic depending on the impact category of the natural hazard. An aggregate risk level for each natural hazard is estimated for each of the natural hazards based on these impacts and the likelihood of occurrence (Table A and Figure A).

Table A Comparison of Plausible Worst-Case Natural Hazard Scenarios

Natural Hazard	**Case Study Location**	**Likelihood of Occurrence**	**Impact Categories**					**Aggregate Risk**
			Human Health & Safety	*Social*	*Public Administration*	*Economic*	*Environment*	
Mountain Runoff Flooding	Prince Albert	Rare	Moderate	Minor	Moderate to Major	Minor	Minor	Low to Moderate
Plains Runoff Flooding	Regina	Unlikely	Moderate	Minor to Moderate	Major	Major	Moderate	Moderate
Lake Flooding	Fishing Lakes Last Mountain Lake	Unlikely	Moderate	Minor	Minor	Minor	Moderate to Major	Moderate
Overland Flooding	Agricultural region of Saskatchewan	Unlikely	Minor	Minor to Moderate	Minor	Major	Moderate	Moderate
Groundwater Flooding	Highly localized	Unlikely	Insignificant to Minor	Insignificant to Minor	Insignificant to Minor	Insignificant to Minor	Insignificant to Minor	Low
Drought – All Types	Agricultural region of Saskatchewan	Unlikely	Major to Catastrophic	Major to Catastrophic	Catastrophic	Catastrophic	Moderate to Major	High
Forest Fire	Human-caused forest fires close to communities; forested zone of province	Unlikely	Major	Moderate to Major	Major	Moderate	Minor to Moderate	Moderate to High
Grass Fire	Grass fire > 1,000 ha; agricultural region of Saskatchewan	Unlikely	Major	Moderate to Major	Minor	Minor to Moderate	Minor	Moderate
Convective Summer Storms	Regina and area	Unlikely	Catastrophic	Major to Catastrophic	Major	Major to Catastrophic	Major to Catastrophic	High
Winter Storms	Southern Saskatchewan	Unlikely	Major	Minor to Moderate	Moderate to Major	Major	Moderate	Moderate to High
Earthquake	Highly localized along the Saskatchewan and Montana border	Unlikely	Insignificant	Insignificant	Moderate	Moderate	Insignificant	Low

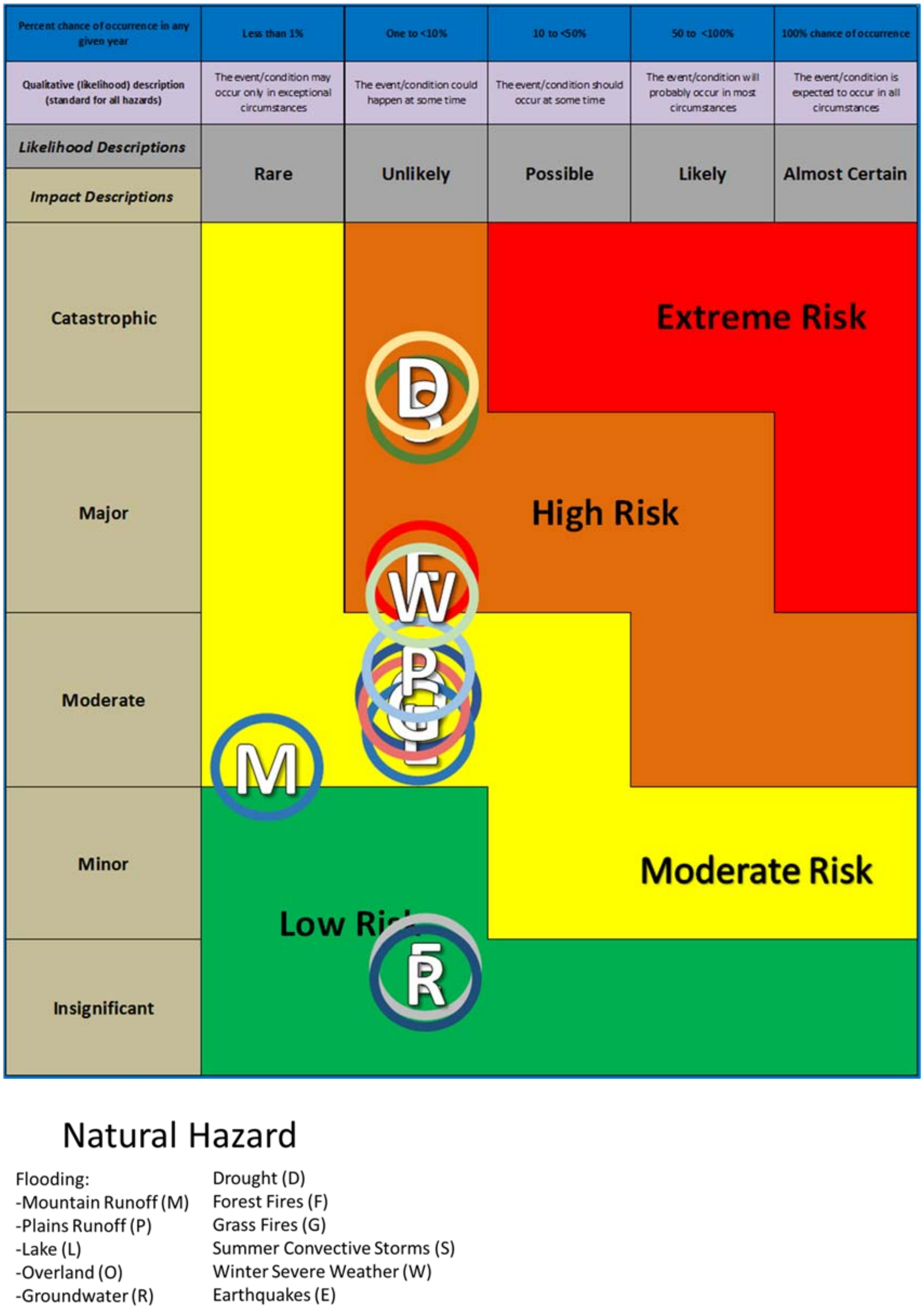

Figure A Aggregate Risk Matrix of the Plausible Worst-Case Scenario for all the Selected Natural Hazards

Table A and Figure A assist with the comparison of the case study location of the hazard, the likelihood of occurrence, and impact categories, as well as each natural hazard's aggregate risk. The side bar entitled "aggregate risk of plausible worst-case scenarios" provides an itemized list of severity of the aggregate risk level of each of the examined natural hazards.

AGGREGATE RISK OF PLAUSIBLE WORST-CASE SCENARIOS

High Risk
- Drought
- Convective Summer Storms

Moderate to High Risk
- Forest Fires
- Winter Storms

Moderate Risk
- Overland Flooding
- Plains Runoff Flooding
- Lake Flooding
- Grass Fire

Low to Moderate Risk
- Mountain Runoff Flooding

Low Risk
- Groundwater Flooding
- Earthquake

Natural hazards that were deemed to have a **high aggregated risk level** were drought and convective summer storms. There are several reasons for these two natural hazards having high associated risks. *Droughts* (Chapter 7) tend to affect large geographic areas of Saskatchewan, and their occurrence often lasts longer than other hazards. Consider, for example, the severe drought of 2001–2002 or those of the 1930s. Droughts have severe consequences for society, the economy, health, safety, critical resources, and the environment. Human activities require adequate and reliable water supplies. Droughts of the plausible worst-case scenario would have a major to catastrophic negative influence on the province's agricultural sector and economy. They also affect the availability of water for both urban and rural residents, as well as for other water uses (including industry). These factors led to assessing the social and public administration impacts as major to catastrophic.

Convective summer storms (tornadoes, high winds, heavy rain, hail) (Chapter 9) generally last only a few hours or less and can have catastrophic impacts on human safety including the potential for multiple deaths and injuries. Impacts on infrastructure, especially in an urban hub like Regina, can be major to catastrophic. Ultimately, the level of impact depends on secondary influences that an EF5 tornado would have on the region affected. Consider, for example, the Regina cyclone of 1912. Aside from loss of life, a severe tornado could result in major damages to industrial or transportation sectors.

Forest fires (Chapter 8) and *winter storms* (Chapter 10) have an **aggregate risk level of moderate to high**. *Forest fires* can cover large forested regions of the province and can result in multiple fatalities and widespread evacuations. Infrastructure would likely be lost, and provincial and municipal government bodies would encounter a reduction in the ability to deliver core functions, particularly in the region affected by the fire. The 2015 forest fires are a recent example. *Winter storms* tend to affect large geographical regions of the province. Such storms may include freezing rain, high winds and blizzard conditions and can persist for multiple days. These storms would have moderate to major impacts because of the potential for loss of life arising from vehicular fatalities due to road conditions, infrastructure damage due to the freezing rain and blizzard conditions, and disruption in services due to power outages.

Three of the five flooding scenarios have an **aggregate risk level of moderate**. *Overland flooding* (Chapter 6) can affect large portions of the agricultural regions of the province and result in minor to major impacts. Overland flooding can lead to significant income losses for agricultural producers as well as infrastructure damage. Other than overland flooding, most floods affect relatively small regions of the province, thus making the impacts more localized. *Plains runoff flooding* (Chapter 6) tends to be associated with spring runoff and, in recent years, summer storms. As with the convective summer storms themselves, the level of flooding impacts can increase with potential damage to infrastructure like dykes (secondary negative impacts) resulting in more extensive damage. *Lake flooding* (Chapter 6) affects small regions when compared to the entire province, with minor impacts on the provincial economy, public administration and social well-being. The impacts on human health are classified as moderate due to the possibility of spring time "ice shove" that could result in loss of life.

Many Saskatchewan communities have experienced multiple flooding events at greater intensities during recent times, particularly the 2010–2016 period. This led to many insurance claims, where available, and disaster recovery activities to address flooding damages to infrastructure. Three case studies were undertaken that demonstrate the types of challenges flooding poses for Saskatchewan communities and the types of mitigation strategies utilized. The case studies examining an urban area (Moose Jaw in the Moose Jaw River watershed), a rural community (Southey in the Southey basin), and rural municipalities in the Quill Lakes watershed provide examples of economic, social and environmental impacts caused by flooding (Chapter 17).

Grass fires have a **moderate aggregate risk level**. They tend to be relatively localized but can have moderate to major impacts. For example, they can result in multiple fatalities and cause large evacuations. They can also have significant impact on local infrastructure and can result in severe damage to the local agricultural sector. The fires in the autumn of 2017 provide an example. *Grass fires* also occur more often in drought situations and therefore can be a secondary impact of the *drought* scenario.

Mountain runoff flooding has very localized impacts and is considered to have an **aggregate risk level of low to moderate.** There are only a few communities at risk of mountain runoff flooding, with Prince Albert being the most significant. A mountain runoff flooding event in Prince Albert would result in extensive evacuations and large portions of the city damaged or destroyed. Prince Albert plays a significant role in the public administration for the northern half of Saskatchewan, and therefore a hazard such a flood could imperil management and administrative responsibility for the north.

Groundwater flooding (Chapter 6) and *earthquake* (Chapter 11) **aggregate risks are low.** This is because both are highly localized in nature with insignificant impacts. The only reason earthquakes rate higher than may be expected is because the highest relative risk in the province lies on the Montana boundary. The economic impact of the failure of the Morrison Dam leading to the loss of some of Saskatchewan's power supply would be significant. In addition, the dam is located on an international waterway. Therefore, if that dam is compromised, it would result in a provincial, federal and international response to the situation.

When the modeled climate change scenario is added to the plausible worst-case scenario, the likelihood categories of each of the natural hazards may change. In general, there will be greater risk and increased vulnerability. Good estimates of the consequences of the plausible worst-case scenario for each hazard were provided because they are based on historic events. The future scenario impacts are estimates, based on the current state of knowledge in relation to the projected climate change scenarios and associated potential impacts.

As noted in Chapter 5, the projected increases in temperature and precipitation set up a scenario for increasing the number, intensity and duration of both drought and flood events. With the warmer temperatures, the atmosphere will be able to hold more moisture. This implies there will be increases in intensity and frequency of extreme precipitation events, with the result of dry times becoming drier and wet times wetter.

The climate change layer results in *drought* increasing its likelihood of occurrence from unlikely to possible (Table B and Figure B). This results in *drought's* **aggregate risk factor** increasing from **high risk to high to extreme risk**.

Convective summer storm likelihood of occurrence may increase from unlikely to possible under future climate change due to the increased water holding capacity of the atmosphere. However, as stated in Chapter 9, the initiation mechanisms for convective storms need to be considered, and the effect of climate change on those mechanisms is unknown at this time. This results in a range of likelihood levels and the **aggregate risk level** of *convective summer storms* ranging from **high to extreme**. Due to convective storms' shorter time period of influence and impact area, they are rated lower than drought in the aggregate risk matrix.

The unusual weather of the recent past (2010–2016) may or may not be an indicator of future challenges. Future climate will likely have greater variability in intensity and frequency for severe storms and weather events. For example, it has been many, many decades since a serious flood affected communities along the North and South Saskatchewan rivers. As well, climate change promises to bring new challenges. Extreme weather may make what are now rare events more common. The province may experience floods that occur in the fall or mid-winter because of variable ice conditions.

AGGREGATE RISK UNDER FUTURE CLIMATIC CONDITIONS (~2050s)

High to Extreme Risk
- Drought
- Convective Summer Storms

Moderate to High Risk
- Forest Fires
- Winter Storms
- Overland Flooding
- Grass Fires

Moderate Risk
- Plains Runoff Flooding
- Lake Flooding

Low to Moderate Risk
- Mountain Runoff Flooding

Low Risk
- Groundwater Flood
- Earthquake

Overland flooding **aggregate risk** is projected to increase to **moderate to high** under projected climate change scenarios for the 2050s. The increased water holding capacity of the atmosphere could increase the amount of precipitation, leading to more rain events and resultant overland flooding. In addition, the economic consequences can change by an order of magnitude, thus leading to an aggregate risk level of moderate to high under future climate conditions.

Mainly due to the increasing *drought* frequency projected with future climate change, the likelihood of *grass fires* increases from unlikely to possible. This results in an increase of **aggregate risk** to **moderate to high risk**.

The *rest of the natural hazards* are expected to **maintain the same aggregate risk levels** under a changed climate as was determined with the plausible worst-case scenario.

Earthquakes in Saskatchewan are not influenced by climate or climate change. This results in their likelihood of occurrence dropping to rare by the 2050s, based on the percent chance of occurrence, with their overall aggregated risk level remaining **low**. The potential impacts would remain at the same level.

Table B Natural Hazard Comparison of Plausible Worst-Case Scenario with Projected Climate of the 2050s

Natural Hazard	**Case Study Location**	**Likelihood of Occurrence**	**Impact Categories**					**Aggregate Risk**
			Human Health & Safety	*Social*	*Public Administration*	*Economic*	*Environment*	
Mountain Runoff Flooding	Prince Albert	Rare to unlikely	Moderate	Minor	Moderate to Major	Minor	Minor	Low to Moderate
Plains Runoff Flooding	Regina	Unlikely to possible	Moderate	Minor to Moderate	Major	Major	Moderate	Moderate
Lake Flooding	Fishing Lakes Last Mountain Lake	Unlikely	Moderate	Minor	Minor	Minor	Moderate to Major	Moderate – less shoreline ice damage
Overland Flooding	Agricultural region of Saskatchewan	Unlikely to possible	Minor	Minor to Moderate	Minor	Major	Moderate	Moderate to High
Groundwater Flooding	Highly localized	Unlikely	Insignificant to Minor	Insignificant to Minor	Insignificant to Minor	Insignificant to Minor	Insignificant to Minor	Low
Drought – All Types	Agricultural region of Saskatchewan	Unlikely to possible	Major to Catastrophic	Major to Catastrophic	Catastrophic	Catastrophic	Moderate to Major	High to Extreme
Forest Fire	Human-caused forest fires close to communities; forested zone of province	Unlikely to possible	Major	Moderate to Major	Major	Moderate	Minor to Moderate	Moderate to High
Grass Fire	Grass fires > 1,000 ha; agricultural region of Saskatchewan	Unlikely to possible	Major	Moderate to Major	Minor	Minor to Moderate	Minor	Moderate to High (depending on biomass availability)
Convective Summer Storms	Regina and area	Unlikely to possible	Catastrophic	Major to Catastrophic	Major	Major to Catastrophic	Major to Catastrophic	High to Extreme
Winter Storms	Southern Saskatchewan	Unlikely	Major	Minor to Moderate	Moderate to Major	Major	Moderate	Moderate to High (with greater risk of freezing rain)
Earthquake	Highly localized along the Saskatchewan and Montana boundary	Rare	Insignificant	Insignificant	Moderate	Moderate	Insignificant	Low

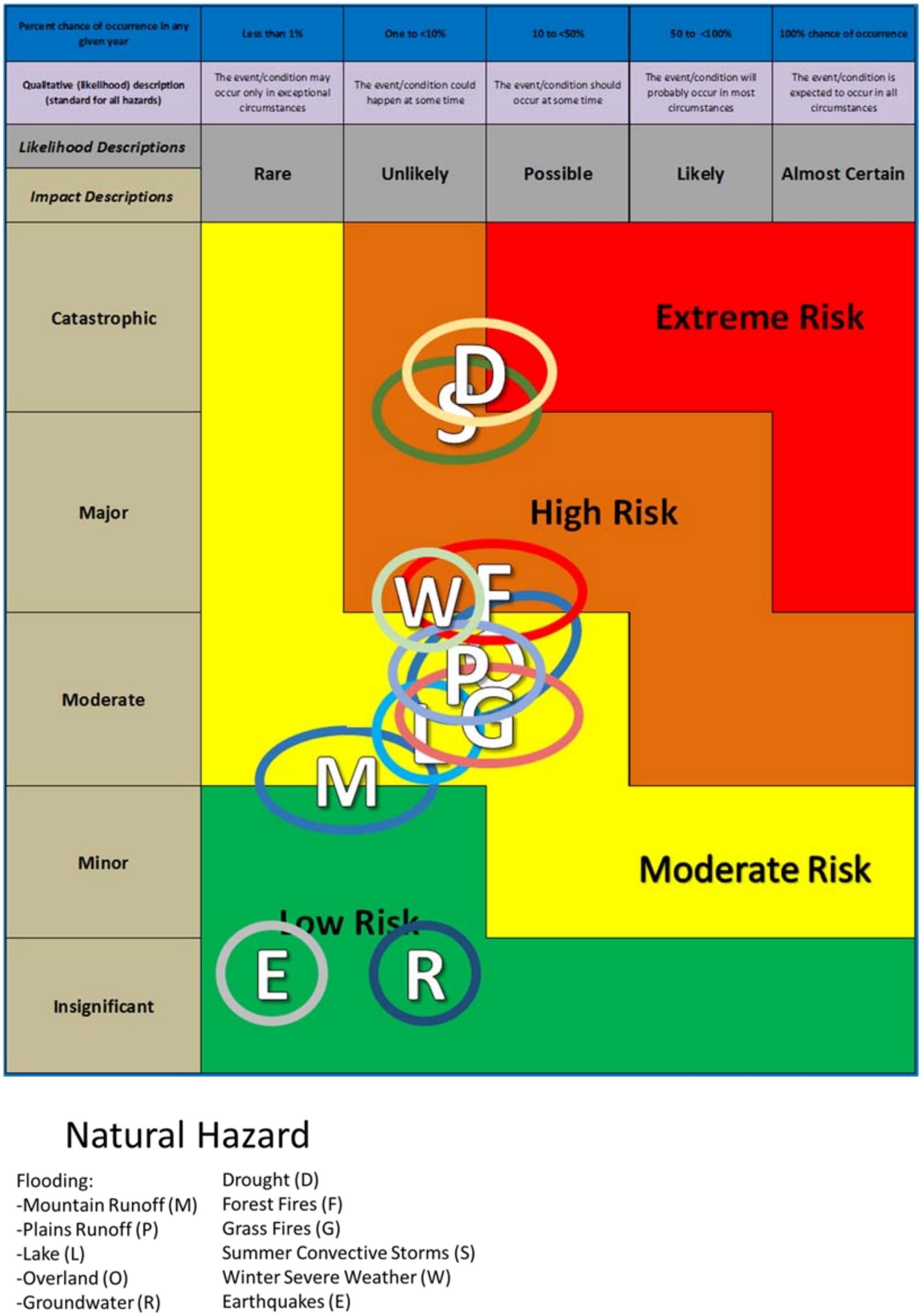

Figure B Aggregate Risk Matrix of the Plausible Worst-Case Scenario with Projected Climate of the 2050s for all the Selected Natural Hazards

Existing Mitigation Strategies

In addition to the risk assessments, a brief examination was carried out of proactive and reactive mitigation strategies that include risk reduction measures. These include emergency response capacity (Chapter 15) (reactive mitigation) and existing controls (Chapter 14) (proactive mitigation). These strategies assist in reducing the exposure to a natural hazard and reducing the vulnerability. There are many measures that can be taken to reduce the risk associated with natural hazards in Saskatchewan. In a general sense, risk reduction measures can include reducing the potential impacts from the hazard, reducing the exposure, and thus reducing the overall vulnerability. Once measures are implemented, the remaining risk to people and assets is termed the residual risk. Residual risk will exist, but risk can be significantly reduced.

Saskatchewan has multiple levels of emergency response agencies and organizations ranging from government (federal, provincial and municipal), to various types of non-government organizations to community volunteers. The general approach to emergency response is that first responders are local people and groups. As the severity of the emergency becomes more apparent, more senior levels of government become more engaged in the response. The Government of Saskatchewan has the authority to declare a state of emergency through an Order-in-Council and to direct municipal resources or to direct one municipality to assist another during an emergency. When an emergency escalates beyond the capacity of a local jurisdiction or multiple jurisdictions, the Provincial Emergency Operations Centre may be activated. The Centre has access to emergency services offices and rapid response teams as well as equipment and supplies that the individual jurisdictions may not have access to.

The federal government has the Emergency Management Act, which assists with coordinating emergency management activities at the federal level and in cooperation with the provinces and other entities. As well, the federal Government Operations Centre provides watch, warning, analysis, planning, logistics, support and coordination across the federal government and its partners. In addition, the Canadian Armed Forces will assist with various types of emergency situations if requested by the province.

The community engagement portion of this project highlighted some of the local stakeholder concerns regarding emergency response capacity (Appendix A). These concerns and recommendations include:

- The capacity of emergency response planning to deal with evacuations is not always adequate. Stakeholders recommended that this situation needs to be considered in greater detail and improved upon due to limited capacities of remote communities, particularly in the northern portions of the province.

- Communication among agencies involved in both emergency planning and response is a challenge and often seen as inadequate. The consultation process identified that local understanding and awareness and engagement is essential, and may require various communications strategies. Frequent continual initiatives and attempts by officials are needed to ensure that common, clear information is disseminated to those affected in order to maintain credibility and public safety.

The existing controls (longer term) or mitigation strategies can reduce the level of emergency response required during an emergency. Longer-term strategies usually require costly investment but have proven to reduce the vulnerability to various natural hazards. In the long run, the benefits of these measures outweigh the costs. Examples include many measures undertaken during Saskatchewan's recent Emergency Flood Damage Reduction program.

Mitigation measures can be proactive or reactive, depending on the event. Examples of proactive controls would be government safety nets like crop insurance and FireSmart. Other examples would be spring flood forecasting (provincial) and severe weather forecasting (federal). A good example of both a proactive and reactive mitigation would be from Saskatchewan Ministry of Highways and Transportation. They provide a reactive service after an extreme weather event (i.e., snow clearing) while also providing proactive information to users concerning the state of the road systems.

This risk assessment demonstrates that Saskatchewan is vulnerable to several natural hazards, notably drought, severe weather, floods and wildfires. In many cases the information required to conduct a quantitative assessment is lacking. Furthermore, it can be expected that climate change will lead to increased vulnerability over time. In the absence of significant proactive mitigation measures, the costs associated with disaster assistance will continue to increase. These future costs can be reduced, however, through implementation of various risk reduction policies and strategies.

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ACRONYMS/ABBREVIATIONS

AAFC – Agriculture and Agri-food Canada
ADA – Agricultural Drought Adaptation project
AU – Australia
B – billion
CCDS – Canadian Climate Data and Scenarios
CCME – Canadian Council of Ministers of Environment
CDA – Canadian Dam Association
Cdn – Canadian
CFS – Canadian Forest Service
CMIP5 – Coupled Model Intercomparison Project Phase 5
CP – Canadian Pacific
CRS – Canadian Red Cross
CSRT – Civil Service Response Team
DFAA – federal Disaster Financial Assistance Arrangement
e.g. – example
EC – Economic Impacts
EC – Environment Canada (became ECCC)
ECCC – Environment and Climate Change Canada
EFDRP – Emergency Flood Damage Reduction Program (Saskatchewan)
EF-Scale – Enhanced Fujita Scale
EMO – Emergency Management Ontario
EMO – Emergency Management Organization
EMT – Emergency Medical Technicians
EN – Environmental Impacts
FDR – national Flood Damage Reduction Program
F-Scale – Fujita Scale
GDP – Gross Domestic Product
GOC – Government Operations Center
ha – hectare
HH – Human Health Impacts
HIRA – Hazard Identification Risk Assessment
IJC – International Joint Commission
IPCC – Intergovernmental Panel on Climate Change
ISGP – Institute on Science for Global Policy
MGR – Saskatchewan Ministry of Government Relations
MofE – Saskatchewan Ministry of Environment
NA – Not Available
ND – No Date
NERS – National Emergency Response System
No – Number
NRCan – Natural Resources Canada
ON – Ontario
p.comm. – personal communication
PA – Public Administration Impacts
PDAP – Saskatchewan Provincial Disaster Assistance Program

PFRA – Prairie Farm Rehabilitation Administration
PSC – Public Safety Canada
RCMP – Royal Canadian Mounted Police
RCP8.5 – Representative Concentration Pathway with highest greenhouse gas emissions
RM – Rural Municipality
SCIC – Saskatchewan Crop Insurance Corporation
SDMS WG – Saskatchewan Disaster Mitigation Strategy Working Group
SGI – Saskatchewan Government Insurance
SHIRA – Saskatchewan Hazard Identification Risk Assessment
SO – Social Impacts
SPEI – Standardized Precipitation Evapotranspiration Index
TDS – Total Dissolved Solids
UNISDR – United Nations Secretariat of the International Strategy for Disaster Reduction
USA – United States of America
USACE – US Army Corps of Engineers
WMB – Saskatchewan Ministry of Environment Wildfire Management Branch
WMO – World Meteorological Organization
WSA – Water Security Agency
WUI – Wildland Urban Interface

GLOSSARY OF TERMS

This glossary is primarily related to "natural systems" although many of the terms also incorporate human systems. Assessment of the human systems is beyond the scope of this project.

Adaptation

Adjustment in natural or human systems in response to actual or expected climate stimuli and their effects, which moderates harm or exploits beneficial opportunities. There are various types of adaption including anticipatory, autonomous, and planned adaptation (Lemmen et al. 2008). In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate (IPCC 2012a, 2012b, IPCC 2014).

Changing risk

A variable in the Hazard Identification Risk Assessment (HIRA) methodology that allows for the inclusion of information on changes in the likelihood and vulnerability of a hazard (Emergency Management Ontario 2012).

Climate

Climate is the average weather or is the statistical description in terms of the mean and variability of relevant variables over a period of time ranging from months to thousands or millions of years. Variables taken into account most often include surface temperature, precipitation and wind (Lemmen et al. 2008, IPCC 2012b).

Climate change

A change in the state of climate that can be identified, using methods like statistical tests, by changes in the mean and/or the variability of its properties and that state of climate persists for an extended period, typically decades or longer. Climate change may be due to the natural internal processes and/or external forcings, and/or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC 2012a).

Climate normal

Arithmetic calculations based on observed climate values for a given location over a specified time period and used to describe the climatic characteristics of that location. The World Meteorological Organization (WMO) considers 30 years the standard period for normal calculations (Lemmen et al. 2008, IPCC 2012b).

Climate variability

Variations in the mean and other statistics such as standard deviations or the occurrence of extremes, of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system or a combination of natural and anthropogenic external forcing (Lemmen et al. 2008).

Consequence

The outcome of an event or situation expressed qualitatively or quantitatively, being a loss, injury or disadvantage (Emergency Management Ontario 2012).

Coping

The use of available skills, resources and opportunities to address, manage, and overcome adverse conditions, with the aim of achieving basic functioning in the short to medium time frame (IPCC 2012b).

Coping capacity (Coping range)

The variation in climatic stimuli that a system can absorb without producing significant impacts (Lemmen et al. 2008). The ability of people, organizations, and systems, using available skills, resources and opportunities to address, manage and overcome adverse conditions (IPCC 2012b).

Current risk

The present level of risk associated with a hazard (Emergency Management Ontario 2012).

Disaster

An event that results when a hazard impacts a vulnerable community in a way that exceeds or overwhelms the community's ability to cope and may cause serious harm to the safety, health and welfare of people or damage to property or the environment. A disaster may be triggered by a naturally occurring phenomenon that has its origins within the geophysical or biological environment or by human action or error (Public Safety Canada 2012).

Disaster risk

The likelihood over a specified period of time of alterations in a normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse environmental, human, material, or economic effects that require immediate response to assist with critical human needs (IPCC 2012a).

Disaster risk management

Processes for designing, implementing and evaluating strategies, policies and measures to improve the understanding of disaster risk, foster disaster risk reduction, and transfer and promote continuous improvement in disaster preparedness, response and recovery practices (IPCC 2012a).

Drought

Drought is a prolonged period of abnormally dry weather that depletes water resources for both human and environmental requirements (Atmospheric Environment Service Drought Study Group 1986, Wheaton et al. 2008). Drought has been categorized by type (meteorological, hydrological, agricultural and socio-economic (Wilhite and Glantz 1985). Drought is a relative term; therefore, any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion (IPCC 2012b) (Figure 0.1).

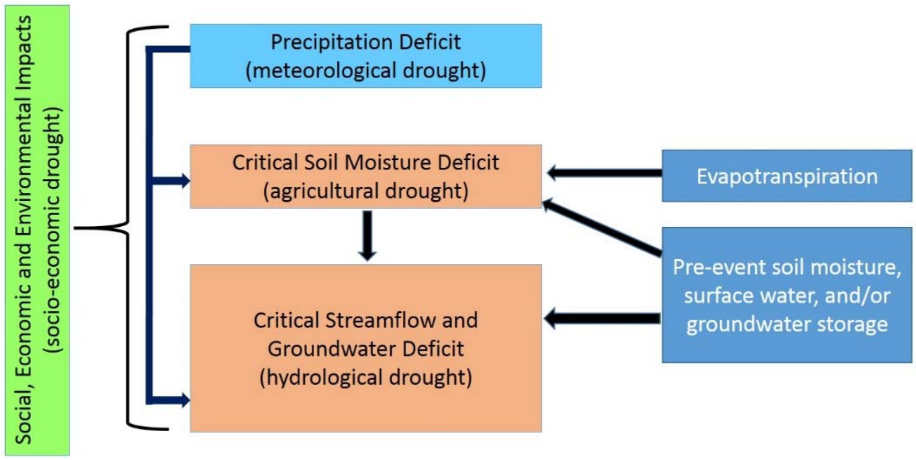


Figure 0.1 Simplified sketch of processes and drivers relevant to the various types of drought (modified from IPCC 2012b and Wilhite 2000).

Emergency

A calamity caused by various factors including forces of nature that require prompt action to prevent or limit loss of life; harm or damage to safety, health or welfare of people; or damage to property or the environment (Government of Saskatchewan 2015).

Emergency management

Organized programs and activities taken to deal with actual or potential emergencies or disasters. These include mitigation against, preparedness for, response to and recovery from emergencies or disasters (Wellington County et al. 2016).

Environmental damage

The negative consequences of the occurrence of a hazard on the environment, including the soil, water, air, plants and/or animals (Emergency Management Ontario 2012).

Exposure

The nature and degree to which a system (such as ecosystems, species, or humans and their livelihoods) is exposed to a significant environmental hazard with the potential of being adversely affected (Lemmen et al. 2008, IPCC 2014).

Extreme weather event

An event that is rare within its statistical reference distribution at a particular place. Definitions of “rare” vary, but an extreme weather event would normally be as rare as, or rarer than, the 10^{th} or 90^{th} percentile. By definition, the characteristics of what is called “extreme weather” may vary from place to place (Lemmen et al. 2008). For simplicity, both extreme weather events and extreme climate events are referred to collectively as “climate extremes” (IPCC 2012a).

Flood

The overflowing of the normal confines of a stream or other water body or the accumulation of water over areas that are not normally submerged (IPCC 2012b).

Frequency

The number of occurrences of an event in a defined period of time (Public Safety Canada 2012). The events would be at an intensity that may result in an emergency, disaster or service disruption (Emergency Management Ontario 2012).

Flood frequency analysis

Flood frequency analysis is a statistical technique used by hydrologists to predict flow values corresponding to specific return periods or probabilities for a flood of a given size. The flood frequency curve is used to relate flood discharge values to return periods to provide an estimate of the intensity of a flood event, often expressed as a 1:100 flood or one-percent flood. The method requires observed peak flow data from many years of record and may use several frequency distributions.

Hazard

The potential occurrence of a damaging physical event, and/or human-caused incident that may cause environmental degradation, loss of life, injury or other health impacts as well as the potential damage and loss to property, infrastructure, and livelihood (IPCC 2012b, Public Safety Canada 2012, Emergency Management Ontario 2012).

Hazard identification

The structured process of identifying, characterizing and validating hazards within a selected area. Hazard identification looks at the type, causes and other characteristics such as the hazards' properties and the potential effects of hazards and is part of hazard assessment (Public Safety Canada 2012, Emergency Management Ontario 2012).

Historical risk

The level of risk associated with a hazard in the past. The risk levels change due to frequency of event, prevention, preparedness, mitigation, response or recovery practices (Emergency Management Ontario 2012).

Impact(s)

The adverse and beneficial effects of a natural hazard, including those influenced by climatic change, on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts (Lemmen et al. 2008, IPCC 2014, Emergency Management Ontario 2012).

Incident

An occurrence or event that requires an emergency response to protect life, property or the environment (Emergency Management Ontario 2012).

Mitigation (of disaster risk and disaster) (similar to adaptation)

The lessening of the potential adverse impacts of physical hazards, emergency or disaster through actions that reduce hazard, exposure and/or vulnerability (IPCC 2012b, Emergency Management Ontario 2012) in order to protect lives, property and the environment and to reduce economic disruption (Public Safety Canada 2012).

Monitor and review

The part of the HIRA process in which the HIRA is reviewed, and changes in the likelihood and consequences of the hazards are updated (Emergency Management Ontario 2012).

Natural hazard

Natural hazards are those caused by meteorological, environmental, geological or biological events. Examples of natural hazards include tornadoes, floods, glacial melt, extreme weather, forest and urban fires, earthquakes, and insect infestation (Public Safety Canada 2012). Human activity may trigger or worsen the natural hazard (Emergency Management Ontario 2012).

Residual risk

Even with effective natural hazard risk reduction policies and practices in place, it is impossible to reduce all risks to zero and some residual risks will remain (Lal et al. 2012).

Resilience

The ability of a system and its component parts (community or society) to adapt through anticipation, absorption, accommodation or recovery from the effects of a hazardous event in a timely and efficient manner, by persevering, recuperating or changing its essential basic structures and functions to reach or maintain an acceptable level of function (IPCC 2012a, Public Safety Canada 2012).

Return period

An estimate of the average time interval between occurrences of a defined event such as flood or extreme rainfall of a defined size or intensity (IPCC 2012b, Emergency Management Ontario 2012).

Risk

A combination of the likelihood or probability of occurrence of a hazard and the consequences of that hazard (e.g., climate-related hazard) (Lemmen et al. 2008, Emergency Management Ontario 2012, Public Safety Canada 2012).

Risk analysis

A process to comprehend the nature of a risk and to determine its level. Risk analysis provides the basis for risk evaluation and decisions about risk treatment (Public Safety Canada 2012). The process by which hazards are prioritized for emergency management programs at that particular point in time based on their frequency and potential consequences (Emergency Management Ontario 2012).

Risk assessment

The overall process of risk identification, risk analysis and risk evaluation (Public Safety Canada 2012). It is a methodology to determine the nature and extent of a risk by analyzing potential hazards and the evaluation of vulnerabilities and consequences of the risk (Emergency Management Ontario 2012).

Sensitivity

Sensitivity is the degree to which a system is affected, either adversely or beneficially, by variability including climate variability or climate change. The effect may be direct, such as a change in crop yield, or indirect, such as damage caused by an increase in the frequency of flooding due to lake level rise (Lemmen et al. 2008).

Severity

The extent of disruption and/or damages associated with a natural hazard (Emergency Management Ontario 2012).

Threshold

The level of magnitude of a system process at which sudden or rapid change occurs. It is a point or level at which new properties emerge in an ecological, economic or other system, that possibly invalidates previous predictions based on mathematical relationships that were applied at lower levels (Lemmen et al. 2008).

Uncertainty

An expression of the degree to which a value is unknown. Uncertainty of information can result from lack of data or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behavior. Uncertainty can be represented by quantitative measures such as a range of values or by qualitative statements like reflecting the judgment of a team of experts (Lemmen et al. 2008).

Vulnerability

Vulnerability is the susceptibility of a community, system or asset to be harmed by a hazard (Emergency Management Ontario 2012, Lemmen et al. 2008). Vulnerability to change, including climate change, is the degree to which a system is susceptible to and unable to cope with adverse effects including environmental extremes. Vulnerability to is a function of the character, magnitude and rate of variation to which a system is exposed, its sensitivity and its adaptive capacity (Lemmen et al. 2008). Vulnerability is a measure of how well prepared and equipped a community is to minimize the impact of or cope with hazards. The overall process of risk identification, risk analysis and risk evaluation (Public Safety Canada 2012).

Weather

State of the atmosphere at a given time and place with regard to temperature, precipitation, air pressure, humidity, wind, and cloudiness. The term is generally used to describe atmospheric conditions over short time periods (Lemmen et al. 2008).

1. INTRODUCTION

"Without a solid basis for mitigation and collaboration, there will tend to be losers and winners" (Anonymous Stakeholder in Corkal 2018).

Natural hazards and associated extreme events are key determinants of the character of many natural and human-influenced systems (Diaz and Murnane 2008). Saskatchewan has been affected by various natural hazards including droughts, wildfires and floods. The effects of these events have influenced various facets of Saskatchewan's society (urban, rural, First Nations communities). At times, the natural hazards pose severe economic impacts to Saskatchewan and Canada — the 2001–2002 drought caused a $5.8 billion drop in Canada's gross domestic product (GDP), with the most significant impacts occurring to the Prairie provinces (Corkal et al. 2011). In 2010, prairie drought was identified as the number one most costly disaster in Canada, recurring four times in the top five national disasters and 11 times in the top 20 disasters during the period 1900–2010 (Public Safety Canada, 2010). In Saskatchewan, for example, the droughts of 2001–2002 resulted in an estimated value of reduced agricultural production of more than $1.6 billion (Wheaton et al. 2008). The forest fires of 2015 cost more than $100 million (Canadian Press 24 July 2015). Floods are a common occurrence in Canada, including Saskatchewan, and constitute the largest accumulated payout of federal disaster assistance. The Provincial Disaster Assistance Program has had expenditures greater than $300 million in calendar years 2010 to 2014, with 2011 expenditures greater than $150 million (Halliday, p.comm. 2016, PDAP 2016). Most of these expenditures were flood-related.

Multi-year wet or multi-year dry periods are part of Saskatchewan's natural climate and hydrological characteristics, and current research in Saskatchewan has determined that the historic natural hydrologic variability is much wider than indicated by the instrumental record. When climate change impacts are considered, it is estimated that even greater future climate variability will occur, with increasing risks from floods, droughts, and storms (Corkal et al. 2011). The wider range of variability of natural hazards and associated risks to Saskatchewan must be considered to help the province strengthen its resilience and reduce risks to the economy, social well-being and the environment. As the Province of Saskatchewan moves to a more proactive risk management strategy for dealing with natural hazards, an important step is to determine the types of natural hazards the province is most vulnerable to. By learning from the past and considering future risks from climate change, the Province can determine possible mitigative responses or initiatives to reduce future vulnerability (Wittrock et al. 2016).

This report undertakes the Province of Saskatchewan's first province-wide hazard identification risk assessment (HIRA) for selected natural hazards.

2. OVERVIEW OF SASKATCHEWAN

Physical Setting

Saskatchewan is part of the Prairie provinces region of Canada and is bordered by Alberta to the west, Northwest Territories to the north, Manitoba to the east and the United States to the south (Figure 2.1). It covers a total area of 651,036 km^2 of which 591,670 km^2 is land and the remaining area is freshwater (Statistics Canada 2005). This continental centrality influences the physical environment and can impose constraints of distance and isolation on social and economic development (Lewry 2007).

Saskatchewan is classified as having a cold continental climate ranging from humid in the north and east to semi-arid in the southwest (Paul 2007). Its climate is one of extremes, and great variability is a rule rather than exception (Paul 2007). Saskatchewan's climatic variability stems from four major 'controls': latitude, continentality, the presence of a mountain barrier and the province's location relative to the continent's storm tracks or synoptic-scale low pressure systems (Paul 2007). These climatic factors influence soil development and the vegetation characteristics that assist with defining Saskatchewan's four ecozones: Taiga Shield, Boreal Shield, Boreal Plain and Prairie (Figure 2.2) (Lewry 2007, Saskatchewan Conservation Data Centre 2017).

Saskatchewan's water is contained within three continental drainage basins. The first is in the northwest portion of the province and drains toward the Arctic Ocean. The second contains two main sub-basins, the Churchill River sub-basin and the Saskatchewan River sub-basin, both of which drain into Hudson Bay. The third drainage basin, in the southwestern corner of the province, is part of the Missouri–Mississippi basin that drains to the Gulf of Mexico (Pomeroy et al. 2007).

Population

Saskatchewan's population in the 2016 census was 1,098,352, with the majority (655,313) living in cities; Saskatoon and Regina contain over 70 percent of the urban population. The provincial population increased by nearly 12 percent from 2006 census values and nearly 19 percent from 1996 census values (Saskatchewan Bureau of Statistics 2017). This population shift from rural to urban areas results in reduced viability of many rural communities but may also put pressure on the urban communities and create social problems. Under climatic change, this rural-to-urban trend is projected to accelerate (Kulshreshtha and Diaz 2010).

Saskatchewan's age structure has changed over the years. In 2016 the median age of the population was 36.9 while in 1986 it was 30.0. This is because the baby boomers are now between 51 and 70 years of age, and the number of children and young adults has dropped over the same time period (Labour Market Information Directorate, Service Canada 2017). The aging population is more vulnerable to various forms of natural hazards. As people age, their vulnerability to current and future hazards under climatic change will increase (Kulshreshtha and Diaz 2010).

Economy

Agriculture, mining, and oil and gas are the key economic drivers in Saskatchewan (Ward 2009). Saskatchewan's net farm income in 2016 was $4.1 billion, with cash income from crop sales reaching $11.4 billion (Government of Saskatchewan 2017). Mining and oil sales were nearly $13 billion in 2016 (Government of Saskatchewan 2017). The provincial real gross domestic product

(GDP) in 2016 was nearly $59 billion (Government of Saskatchewan 2017). As noted by Kulshreshtha and Diaz (2010), agriculture's economy is and will be heavily impacted by natural hazard events and climate change.

Transportation

Saskatchewan's transportation links have always played a crucial role in connecting the population and transporting goods in and out of the province. With Saskatchewan being a land-locked province, the primary modes of transportation are road, rail and air. There are over 170,000 km of roadways and over 8,500 km of railway track (Government of Saskatchewan 2017, Nolan 2007). Saskatchewan has two larger airports in Saskatoon and Regina owned by local airport authorities on land leased from the federal government, with several other smaller regional airports scattered throughout the province (B. Munro, p. comm. 2018).

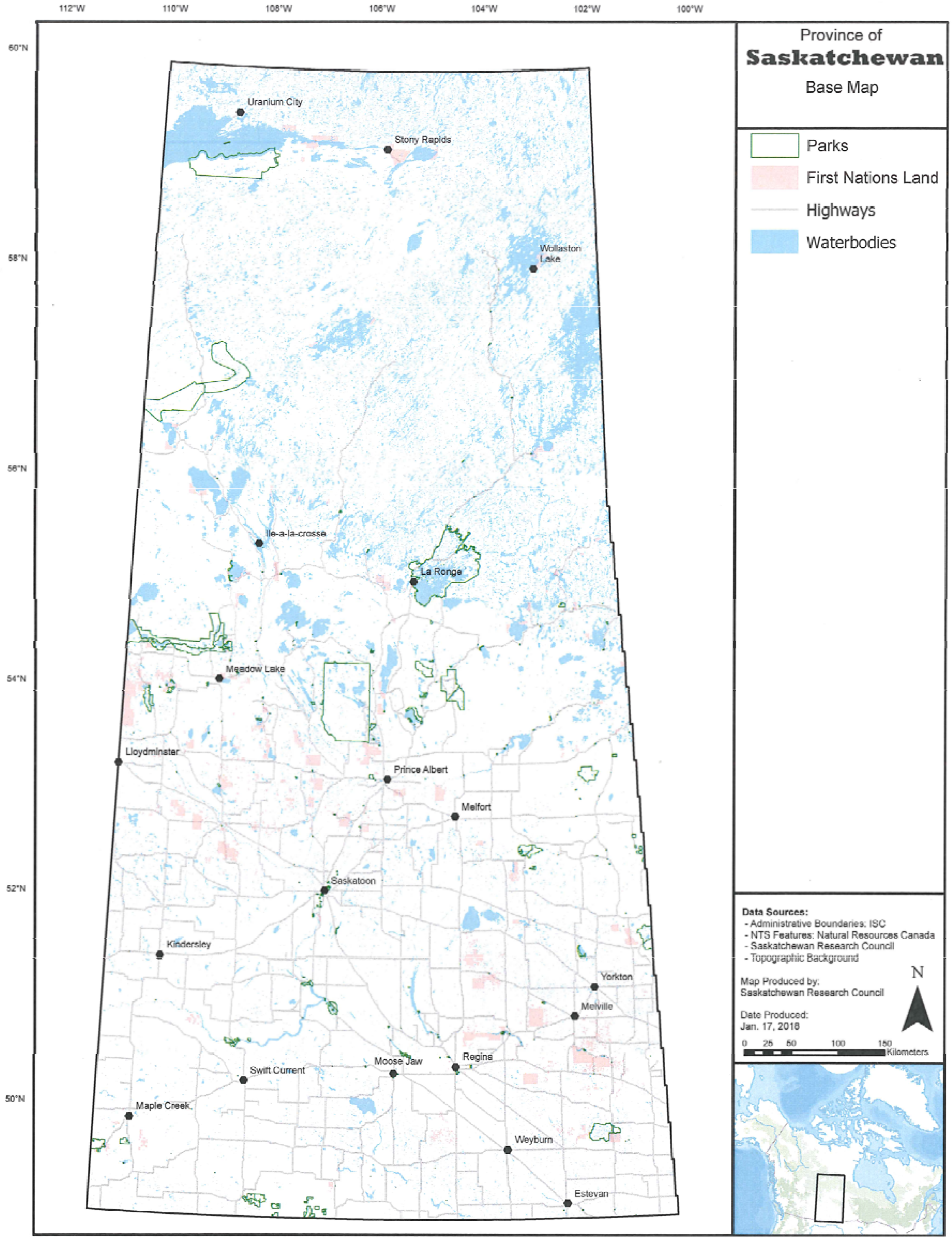


Figure 2.1 Province of Saskatchewan.

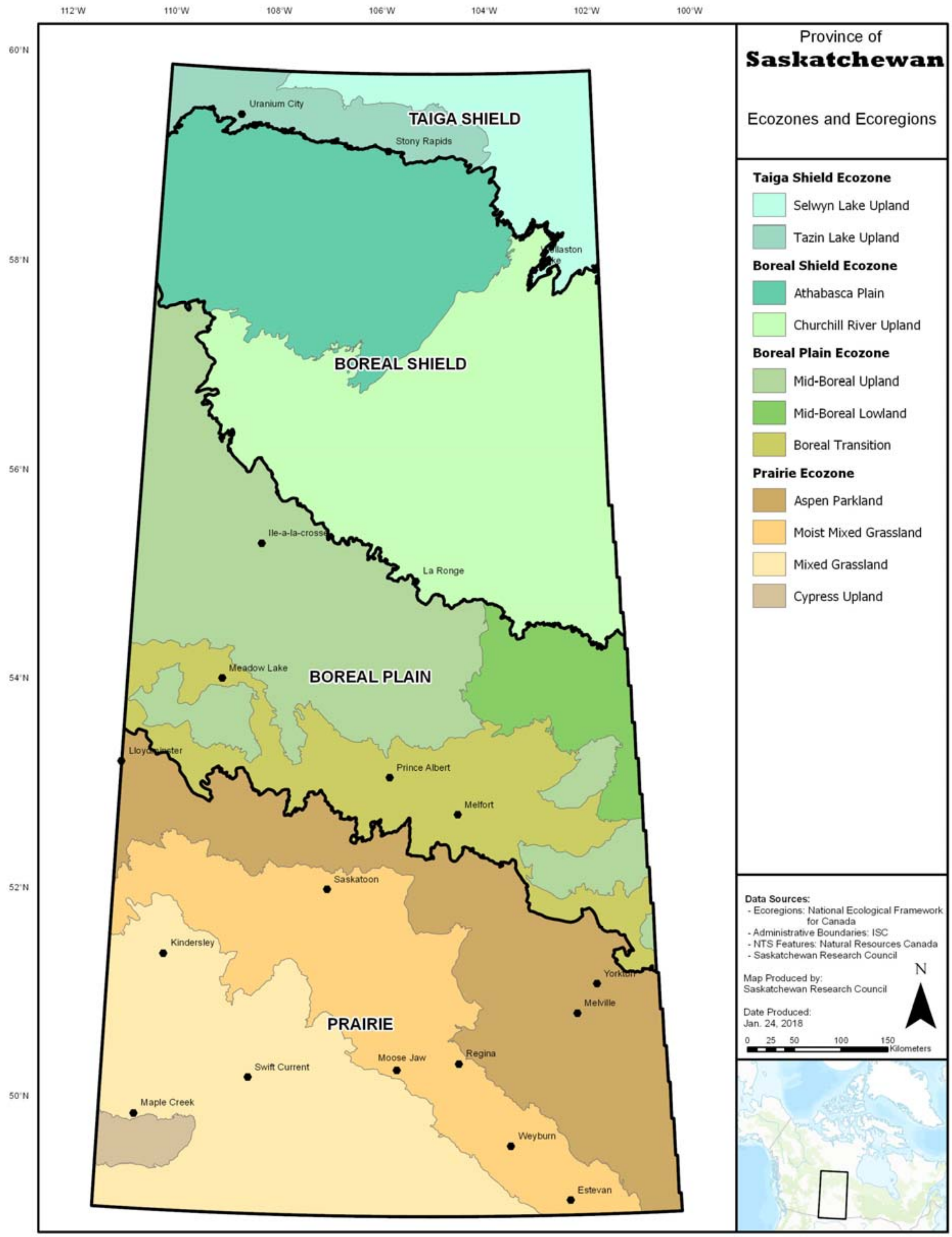


Figure 2.2 Ecoregions and ecozones of Saskatchewan.

Drought (photo source: IStock)

3. PROJECT OVERVIEW

Purpose

This project's purpose is to review, evaluate and compile the best available information on floods and other natural hazards in Saskatchewan, and develop a standardized hazard identification risk assessment methodology based on relevant provincial, federal and international standards to assess the likelihood and impacts and overall risk of such events. The knowledge contained in this report will help inform priority risk-reduction strategies and hazard-mitigation measures. It will also assist the government in determining the provincial risk of various hazard types relative to the other hazards to ensure that mitigative (or adaptive) measures aimed towards a specific hazard do not increase the province's vulnerability to the other assessed natural hazards.

Scope

The Saskatchewan Hazard Identification Risk Assessment (SHIRA) provides a natural hazard identification risk assessment for the Province of Saskatchewan. For the purpose of this assessment, a natural hazard means that the hazard has had a negative or positive impact with implications at a provincial level. The results of this assessment provide an overview of each selected natural hazard, including likelihood of occurrence, regional setting within the province of greatest impact, and overall risk of hazard, as well as incorporating climate change considerations including resiliency.

The identified natural hazards that pose a threat to Saskatchewan industry, the general public and governments at all levels include floods, droughts and wildfires as the primary natural hazards. Other selected natural hazards include summer convective storms that include tornadoes, hail and strong winds, winter storm events (e.g., blizzards, freezing rain and strong winds) and naturally occurring earthquakes. These natural hazards have either already occurred or have the potential of occurring under future climate conditions. An overview of each selected natural hazard is provided. An identification of the current mitigation measures is presented as well as a preliminary analysis of the vulnerability that the province has with respect to each hazard, including identification of Saskatchewan's areas of greatest risk including assessing mitigation measures (Ministry of Government Relations 2016). It is important to note that this HIRA is a first for Saskatchewan. Certain portions of the HIRA process are subjective and, as more information becomes known and more data becomes available, certain aspects will change. This was found to be the case in a similar assessment conducted in Australia (White 2016).

This document has been written by numerous scientific experts in their respective fields such as engineering hydrologist, climate research specialist, climate scientist, and professional forester. Each expert applied the HIRA methodology developed for the province of Saskatchewan to the selected natural hazards based on the best available information.

Structure

The Hazard Identification Risk Assessment (HIRA) methods used by other provincial and territorial governments as well national and international governments are utilized but modified to suit Saskatchewan's natural hazards (e.g., White 2016, Australian Government Attorney-General's Department 2015, Vanguard EMC Inc. 2014, Emergency Management Ontario 2012, Public Safety Canada 2012).

This document contains:

- Brief overview of Saskatchewan including the physical setting, population, economy and transportation systems
- Project overview outlining the purpose and scope of this document
- Methodology on the Saskatchewan-focused HIRA for selected natural hazards
- Brief overview of climate change
- HIRAs of selected natural hazards. Each natural hazard risk assessment contains information on:
  - Description of the natural hazard
  - Provincial risk statement
  - Previous significant events
  - Climate change implications
  - Worst-case scenario
  - Existing controls
  - Provincial risk analysis
- Summary and comparison of all selected natural hazards
- Case study examining the historic flooding of selected Saskatchewan communities
- Summary of existing controls for the selected natural hazards
- Summary of existing emergency response capacity
- Conclusions and recommendations.
- References and bibliography
- Appendices include:
  - Synthesis of the stakeholder consultations

4. METHODOLOGY

Context

A Saskatchewan Hazard Identification Risk Assessment (SHIRA) process contains several components (Figure 4.1). The first step was to establish the context. This step involves items such as objectives, scope, stakeholders, criteria and key elements, and determining and obtaining data and information. The Saskatchewan Ministry of Government Relations (MGR) and the Saskatchewan Disaster Mitigation Strategy Working Group (SDMS WG) undertook this step. This group of provincial agencies established the risk assessment's purpose and scope, and assisted the research team with identifying key stakeholders, determining key natural hazards and obtaining data and information.

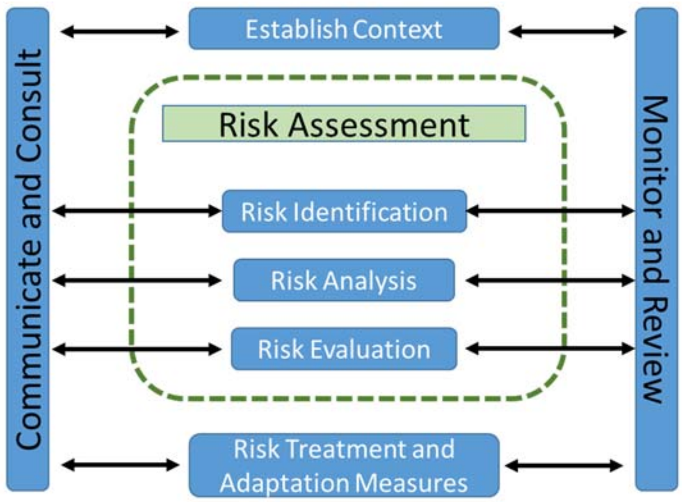


Figure 4.1 Risk management process. (modified from Ontario Centre for Climate Impacts and Adaptation Resources ND; AIRMIC, Alarm, IRM 2010; National Emergency Management Committee 2010 and Australian Government Attorney-General's Department 2015)

The Saskatchewan-focused risk matrix (Tables 4.1 to 4.7 and Appendix 4.1) includes impact and likelihood descriptions applicable to a province-wide assessment. It was formulated through a review of the critical literature from both national and international HIRAs (e.g., Emergency Management Ontario 2012, Public Safety Canada 2012, White 2016, Australian Government Attorney-General's Department 2015), and through consultations with various provincial ministries.

A '*Natural Hazard Risk*' is a combination of natural hazard frequency, the consequence (or impact) of the natural hazard and changing risks associated with that hazard (Emergency Management Ontario 2012). It can be expressed as 'Frequency of natural hazard × Consequence of natural hazard × Changing risk of natural hazard.'

The first step in the process is to identify and describe the natural hazard including time of occurrence, location of occurrence including regionality within the province of Saskatchewan, and the severity of the event (intensity, duration, frequency, etc.), and give a brief overview of mitigation measures.

The Saskatchewan Ministry of Government Relations (MGR) and the Saskatchewan Disaster Mitigation Strategy Working Group (SDMS WG) required that the natural hazards of floods, droughts and wildfires be analyzed in the Saskatchewan HIRA. These three specific natural hazards were presented to six regional stakeholder consultations in various locations across the province of Saskatchewan (Corkal Appendix 1 of this document and Corkal 2018) in scenarios depicting two time frames — one capturing historic risks associated with the natural hazards, and one considering future risks under a climate change scenario. The regional consultations provided input to determine what other hazards were the most important to Saskatchewan residents. As the result, severe convective summer storms, severe winter storms and earthquakes were also analyzed. The workshops also elicited data from stakeholders in identifying current mitigation measures, as well as potential implications for future risks and possible mitigation strategies.

Two time periods were analyzed including the plausible worst-case and future climate scenarios. The plausible worst-case scenario is generally based on a historic event such as the tornadic activity that occurred in Regina and the surrounding region in 1912 but applied to the current-day situation. The second incorporates climate change scenarios where possible to better understand how the changing climate conditions may affect future natural hazards, risks and vulnerabilities in Saskatchewan. The time frame for incorporating climate change models is centered on the 2050s. The information obtained from the regional consultations, experts in their fields, and the literature contributed to articulating the level of impacts of each of the hazards for both scenarios and mitigation measures utilized and what may be needed for future events.

The <u>second step</u> was to examine the consequence or impact of the natural hazard. The Saskatchewan HIRA is based on a provincial scale, not a regional scale, and is thus geared towards a provincial level of impact. A natural hazard event is considered to attain a certain consequence when a specified risk threshold is met or exceeded. The consequences or impacts (Tables 4.1 to 4.5 and Appendix 4.1) are separated into five categories: *Human Health and Safety, Social, Public Administration, Economic, and Environment*. These categories are then subdivided into severity impact or consequence levels: *Catastrophic, Major, Moderate, Minor, and Insignificant*. Each natural hazard has different levels of impacts in each category (Tables 4.1 to 4.5). Utilizing the same risk matrix for each natural hazard allows for cross comparison of the natural hazards. The regional consultations and information obtained from subject experts as well as literature were utilized to determine the various levels of impacts (both positive and negative) based on both the worst-case scenarios and potential future events.

The Human Health and Safety impact/consequence category deals with the level of injury or number of fatalities and air quality problems and whether community evacuations, regardless of length, are required. These types of evacuations could be due to smoke from forest fires, for example, that last only a few days. The Social impact/consequence deals with quality of life which includes longer term evacuation of communities that lasts for longer periods, such as a forest fire burning large portions of a community, psychosocial impacts, civil disobedience, and negative impact on or loss of culturally significant objects such as the Saskatchewan Legislative Building.

The Public Administration impact category deals with the level of impact and response required from municipal through federal governing bodies and whether stakeholder or public trust in those bodies is negatively affected and to what level. The Economic impact, as with the other impacts, is based on the provincial scale. An economic insignificant impact is categorized at less than 0.0005% of the provincial GDP while a catastrophic economic impact is categorized as a decline greater than 5% of the provincial GDP. The GDP in 2016 was nearly $59 billion (Government of Saskatchewan 2017).

The fifth impact category, Environment, is where a catastrophic impact is categorized as significant regional or watershed damage that is incapable of remediation and/or the ecosystem function is permanently disrupted or species become extirpated.

The third step is to determine the likelihood (or percent chance) of the natural hazard occurring and the frequency of such occurrence, whether these are defined, measured or determined objectively or subjectively (PSC 2012). Each natural hazard is described either in general terms and/or by mathematical variables like probability or frequency (PSC 2012). The likelihood includes information on time period during which the risk of the event might be realized (PSC 2012). The natural hazard frequency information was based on existing data provided by the various government agencies, consultations with experts, and scientific literature. The likelihood is divided into five descriptions (*Rare, Unlikely, Possible, Likely, and Almost Certain*) (Table 4.6 and Appendix 4.1) and levels of probabilities.

All the natural hazards in this report have different lengths of historical record, and each of the probabilities determined is based on the best information sources available. In addition, in general, the most recent data, such as in the last 30 to 50 years, is of better quality than that for the earlier period of record. For example, the documentation of the number and intensity of tornados is of better quality in the last 30 years than the previous 100 years, largely due to technological improvements.

The fourth step is to incorporate the consequence/impact information from each of the five categories (*human health and safety, social, public administration, economic, and environment*) for each natural hazard. This is completed by assigning a risk rating to each of the consequence/impact categories based on the impact severity levels (*insignificant to catastrophic*) relative to their likelihood or percent chance of occurrence (*rare to almost certain*) for a given natural hazard. This risk rating is placed on the risk matrix (Table 4.7 and Appendix 4.1). The risk matrix has four levels: *low, moderate, high and extreme*. The aggregate of these four risk levels is subjectively estimated from the five impact categories and likelihoods in order to provide an overall risk level of each natural hazard. The natural hazards include floods, drought, wildfires, summer convective storms, winter storms and earthquakes. Each natural hazard has different levels of impacts on society and the environment, and the likelihood of each event occurring is different. The calculation of event likelihood of occurrence is based on available information and data.

While each natural hazard risk assessment provides its own profile of plausible worst-case risk to the province, it was determined that a final cross-hazard comparison step was needed to compare each of the selected natural hazards on one risk matrix. The aggregate risk of the likelihood category for the hazard and its five impact categories were positioned on the comparative risk matrix as well as in table format. The table format allows for more detailed comparison of each natural hazard's spatial scale and the individual impact categories. Each of the hazards' aggregate position on the risk matrix is the estimated average of the impact descriptions and the likelihood of occurrence. A second aggregated risk matrix is compiled with the added layer of climate change that incorporates the estimated level of likelihood that each natural hazard will occur in the 2050s period as well as the estimated level of impacts. Due to the projected uncertainty of some of the climate variables, such as precipitation amounts, in the climate change models, the estimated likelihood of occurrence can span two likelihood categories and thus allows a hazard risk level to range through multiple risk levels. It is important to recognize that the average positions of each hazard may not reflect the most operationally important component of that risk and therefore require reference to each individual natural hazard risk assessment (White et al. 2016).

Table 4.1 Impact/consequence categories for Human Health and Safety. (Emergency Management Ontario 2012, Public Safety Canada 2012, White 2016, Australian Government Attorney-General's Department 2015, consultations with various provincial government ministries)

	Human Health and Safety (deaths, injuries, illness, psychosocial, stress)
Catastrophic	• Multiple public fatalities (>50) and/or critical injuries with long-term or permanent incapacitation (>50) • Extreme and ongoing exceedance of recognized health-related standards (e.g., Canadian Council of Ministers of the Environment (CCME) Selenium Guidelines or Canadian Ambient Air Quality Standards) • Community evacuations of >50,000 people
Major	• Multiple public fatalities (>5) and/or critical injuries with long-term or permanent incapacitation (>5) and/or serious injuries (>50) • Ongoing exceedance of recognized health-related standards (e.g., CCME Selenium Guidelines or Canadian Ambient Air Quality Standards) • Community evacuations of >5000 people
Moderate	• Single fatality and/or critical injuries with long-term or permanent incapacitation (>1) and/or serious injuries (>5) • Infrequent, periodic exceedances of recognized health-related standards (e.g., CCME Selenium Guidelines or Canadian Ambient Air Quality Standards) • Community evacuations of 500 people
Minor	• One serious injury requiring medical care and medical technology • Approaching limits of recognized health-related standards (e.g., CCME Selenium Guidelines or Canadian Ambient Air Quality Standards)
Insignificant	• First aid injury with no professional care required • No impact on public health and safety

Table 4.2 Impact/consequence categories for Social (Emergency Management Ontario 2012, Public Safety Canada 2012, White 2016, Australian Government Attorney-General's Department 2015, consultations with various provincial government ministries)

	Social (communities, culture, relationships)
Catastrophic	• Permanent reduction in quality of life of impacted and nearby communities • Permanent degradation of surrounding values and natural resources • Permanent relocation/abandonment of communities • Widespread severe psychosocial impacts, e.g., widespread panic and hoarding, mass riots, and long-term psychosocial impacts • Disputes related to development or decisions erupt into large and violent campaigns of civil disobedience • Widespread permanent loss of culturally significant objects
Major	• Quality of life for communities and surrounding area impacted for more than 10 years — major community social problems • Values are degraded but partially recoverable over the long term • Extended evacuation of communities • Irreparable damage to high-value structures or items of cultural and historical significance • Disputes related to development or decisions result in blockades and campaigns of civil disobedience and are extremely disruptive to the general public • Significant regional widespread psychosocial impacts
Moderate	• Quality of life of affected region and surrounding area moderately impacted for up to 10 years • Short-term evacuation of community • Values are degraded but fully recoverable within 10 years • Disputes related to development or decisions result in isolated blockades or other acts of civil disobedience • Significant localized psychosocial impacts including panic, self-evacuation, hoarding • Some damage or localized widespread damage of culturally significant objects
Minor	• Minor effects on quality of life • Short-term adverse impacts on values of the affected region lasting less than five years; recoverable with minor effort • Disputes related to development or decisions result in isolated acts of civil disobedience with minor disruptions to the public • Some localized psychosocial impacts including disruption to routine and some anxiety • Some damage to localized culturally significant objects
Insignificant	• No obvious impact on quality of life • Minor delay in major cultural event

Table 4.3 Impact/consequence categories for Public Administration (Emergency Management Ontario 2012, Public Safety Canada 2012, White 2016, Australian Government Attorney-General's Department 2015, consultations with various provincial government ministries)

	Public Administration (provincial scale)
Catastrophic	• Multi-municipal, provincial, national and international, specialized response • Provincial government is unable to deliver its core functions; inability to govern • Violation of international and national treaties or agreements • Sustained, permanent loss of stakeholder and public trust in the provincial government
Major	• Provincial governing bodies encounter severe reduction in the delivery of core functions • Multi-municipal, provincial and national specialized response • Achievement of key provincial government objectives is threatened and some not met • Major loss of stakeholder and public trust over years, although recoverable with time • Municipal governments unable to deliver core services
Moderate	• Provincial governing bodies encounter significant reduction in the delivery of core functions • Achievement of key government objectives impacted (significant time delay or cost increase) • Moderate loss of stakeholder or public trust, short-term duration (less than 6 months) • Municipal governing bodies encounter severe reduction in the delivery of core functions • Multi-municipal and provincial specialized response
Minor	• Provincial government encounters limited reduction in delivery of core functions • Achievement of key government objective may be impacted • Multi-municipal specialized response • Municipal government encounters a reduction in the delivery of core functions
Insignificant	• Provincial government's delivery of core functions is unaffected and normal • Municipal or multi-municipal general response (mutual aid agreements) • Municipal government encounters limited reduction in delivery of core functions

Table 4.4 Impact/consequence categories for Economic (Emergency Management Ontario 2012, Public Safety Canada 2012, White 2016, Australian Government Attorney-General's Department 2015, consultations with various provincial government ministries)

	Economic (direct and indirect economic implications including infrastructure)
Catastrophic	• Failure of a significant industry or sector in the jurisdiction as a direct result of the natural hazard event • Economic decline and/or loss of asset value greater than 5 percent of the provincial GDP (~$4B) • Closure of an entire resource sector • Permanent loss of investment in the province • Existing markets for Saskatchewan's natural resources are closed • Inability for efficient and leading companies to break even • Destruction of both critical infrastructure and high-value property
Major	• Significant structural adjustment required by identified industry or business to respond to and recover from the natural hazard event • Major damage to and impact on critical infrastructure • Economic decline and/or loss of asset value greater than 0.5 percent of the provincial GDP (~$400M). • Major portions of a resource sector impacted or suffer serious decline • Substantial loss of investment in the province, reversible over time • Existing market access for Saskatchewan natural resources is threatened/new market access not achieved • Inability for various business sectors to break even
Moderate	• Key industry or business sector is significantly impacted by the natural hazard, resulting in medium term (i.e., more than one year) profit reductions directly attributable to the event • Noticeable drop of investment levels in the province • Economic decline and/or loss of asset value greater than 0.05 percent of the provincial GDP (~$40M) • Disruption of 2–3 critical community infrastructure services
Minor	• Significant impact on localized industry or business sector resulting in short-term (i.e., less than one year) profit reduction directly attributable to the event • Economic decline and/or loss of asset value greater than 0.005 percent of the provincial GDP (~$4M) • Disruption of 1 critical infrastructure service for short time
Insignificant	• Insignificant economic impact • Economic decline and/or loss of asset value less than 0.0005 percent of the provincial GDP (~$400,000)

Table 4.5 Impact/consequence categories for Environment (Emergency Management Ontario 2012, Public Safety Canada 2012, White 2016, Australian Government Attorney-General's Department 2015, consultations with various provincial government ministries)

	Environment (air, land, water, biodiversity)
Catastrophic	• Significant regional or watershed damage incapable of remediation • Ecosystem function permanently disrupted or species extirpation
Major	• Significant regional damage not entirely capable of remediation • Ecosystem disruption or reduced species abundance • Severe effects on environmental values
Moderate	• Regional damage capable of remediation over time • Damages last >two years • Values affected tend to be moderate
Minor	• Localized damage capable of remediation • Damages are short term <one year • Values affected tend to be minor
Insignificant	• Localized, reversible and temporary damage • Minor impact on local environmental values

Table 4.6 Likelihood of occurrence general descriptions (modified from Emergency Management Ontario 2012)

Percent chance of occurrence in any given year	Less than 1%	One to <10%	10 to <50%	50 to <100%	100% chance
Qualitative likelihood description	The event/condition only occurs in exceptional situations	The event/condition could occur	The event/condition should occur	The event/condition will likely occur	The event/condition is expected to occur
Likelihood descriptions	Rare	Unlikely	Possible	Likely	Almost Certain

Table 4.7 Individual hazard risk assessment that incorporates the likelihood of the natural hazard and the five types of impacts and their associated descriptions (modified from Emergency Management Ontario 2012)

Likelihood Categories					
Percent chance of occurrence in any given year	Less than 1%	One to <10%	10 to <50%	50 to <100%	100% chance of occurrence
Qualitative (likelihood) description (standard for all hazards)	The event/condition may occur only in exceptional circumstances	The event/condition could happen at some time	The event/condition should occur at some time	The event/condition will probably occur in most circumstances	The event/condition is expected to occur in all circumstances
Likelihood Descriptions / *Impact Descriptions*	Rare	Unlikely	Possible	Likely	Almost Certain
Catastrophic	Moderate Risk	High Risk	Extreme Risk	Extreme Risk	Extreme Risk
Major	Moderate Risk	High Risk	High Risk	High Risk	Extreme Risk
Moderate	Moderate Risk	Moderate Risk	Moderate Risk	High Risk	High Risk
Minor	Low Risk	Low Risk	Moderate Risk	Moderate Risk	Moderate Risk
Insignificant	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk

Risk Treatment and Mitigation Measures

Each natural hazard assessment includes information on current capacity for mitigating the effects of the natural hazards. Additionally, it includes overviews of this capacity as well as existing emergency response capacity in Saskatchewan. Each of the assessed natural hazards incorporates information from literature as well as utilizing information obtained at the regional consultations to determine the shorter term and longer-term mitigation strategies.


#1 Highway east of Regina (Photo Source: Government of Saskatchewan)

5. BRIEF OVERVIEW OF CLIMATE CHANGE

V. Wittrock and E. Wheaton.

"***Climate change will change the playing field for all natural hazards.***" (Anonymous stakeholder in Corkal 2018).

This section consists of a brief overview of what Saskatchewan and the Canadian Prairies can expect for weather and climate conditions in the next 30 to over 40 years, represented by the period 2046–2065 (the 2050s). Each of the ensuing natural hazard risk assessment chapters contains a specific climate change section that examines how future climates are expected to affect that particular natural hazard.

Extreme weather events are considered to be rare for a particular place and time of year, and the occurrence of an extreme event would normally have a less than 1 in 10 chance (McBean et al. 2012). The frequency and intensity of certain types of extreme weather events are expected to change (e.g., Dell et al. 2014) and become part of the new normal (IPCC 2012) (Figure 5.1). Warmer global and local temperatures may lead to more violent weather patterns such as storms and resulting floods and drought events (McBean et al. 2012).

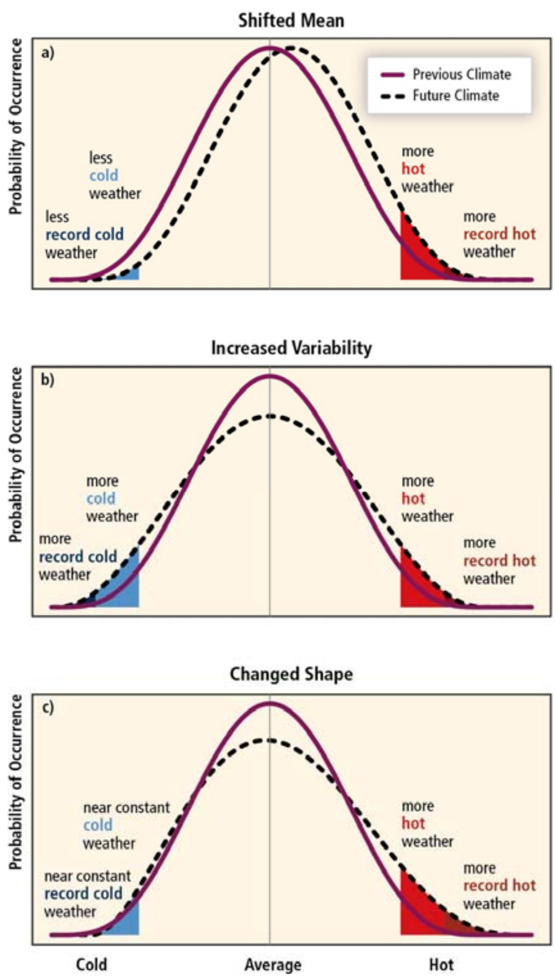


Figure 5.1 Extreme weather events become more frequent (IPCC 2012)

The climate extremes that Saskatchewan has experienced, especially in the recent past, will continue into the future and will likely increase in frequency and severity. Saskatchewan residents can expect that winters will continue to become less cold (Figure 5.2) (IPCC 2012). According to a 'business-as-usual' scenario[1], winters are expected to warm by averages of about 3° to 4°C in the southern and western regions of the province and 4° to 5°C in the northern and northeastern portions of the province. Because of this, a greater percentage of the annual precipitation will fall as rain rather than snow. These warmer winters will likely result in more freezing rain, less time with snow cover on the ground and earlier spring runoff. The potential for more rain-on-snow events is highly possible because of the warmer temperatures. Higher temperatures in all the seasons will lead to more evaporation, resulting in lower soil moisture levels that can lead to drought conditions. The summers are expected to warm about 3° to 4°C, on average, across most of the province (Figure 5.2). The warmer temperatures for all the seasons will lead to longer growing seasons, less cold winters and warmer summers and many other changes.

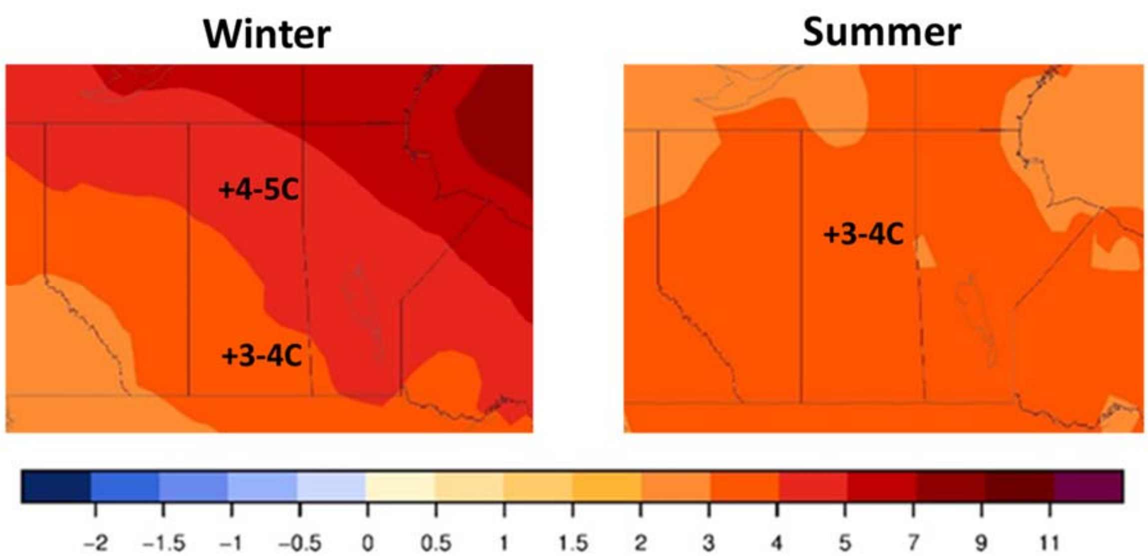


Figure 5.2 Seasonal average temperature change (2050s) (winter left; summer right). Winter is defined as December, January and February, and summer as June, July, and August. Projected temperature change based on the 'business as usual' scenario (RCP 8.5) in 2046–2065 period (50th percentile) as compared with the 1986–2005 period (modified from CCDS 2015).

Within Canada, the Prairies are prone to drought mainly because of their location on the eastern side of the Rocky Mountains, with no large lakes or oceans in the region (Bonsal et al. 2013). Moderate to extreme droughts are expected to increase in number and intensity and cover wider regions (e.g., Bonsal et al. 2017, Wheaton et al. 2013). In addition, Saskatchewan's large geographical coverage results in varied climate and weather events to the point of having drought in one location of the province and floods in another location, such as occurred in 2011 (Figure 5.3). Saskatchewan has had multiple droughts in the last 150 years but the decade-long droughts that occurred in the Dirty Thirties or in the 1800s (St. George et al. 2009) will occur again with greater intensity and cover larger areas.

[1] Business-as-usual pathway is the Representative Concentration Pathway 8.5 (RCP 8.5)

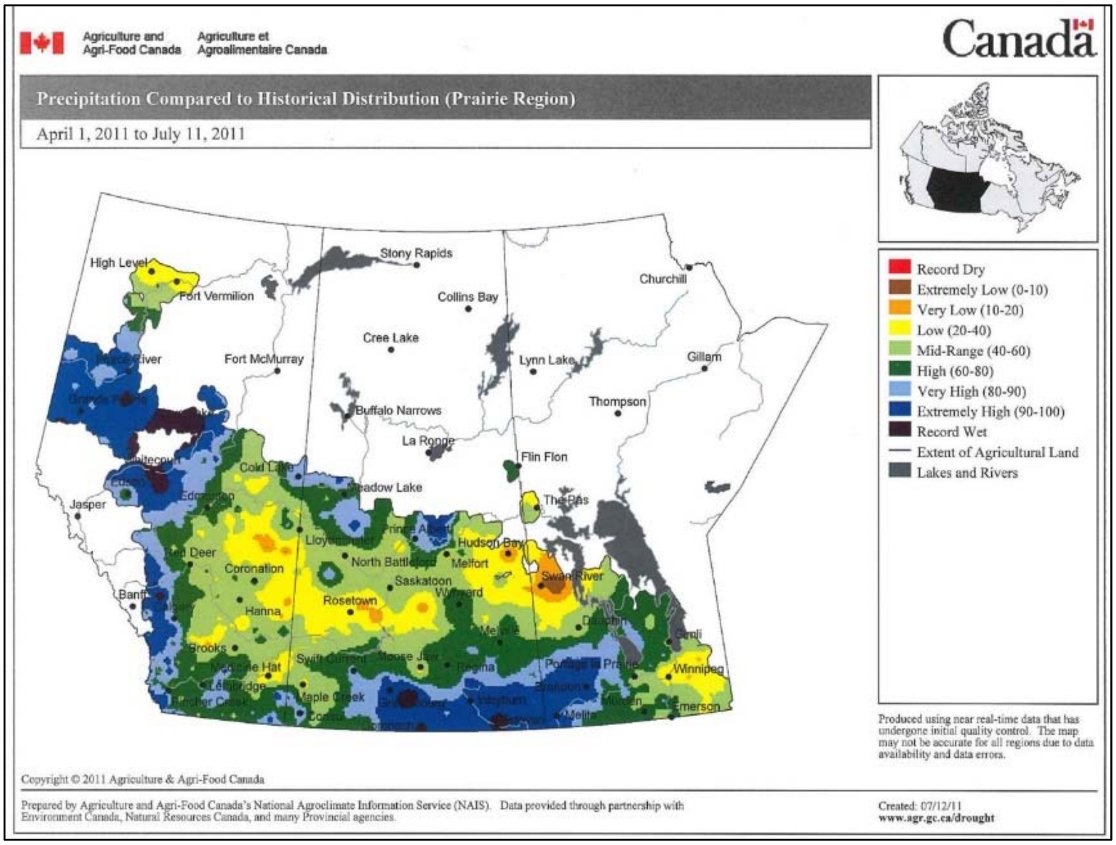


Figure 5.3 Precipitation variability across Saskatchewan in spring/early summer 2011 (AAFC 2011)

The frequency with which Saskatchewan and the rest of Canada experience events such as heavy rainfall is likely to increase (IPCC 2012). For example, a heavy rainfall that occurred once every 50 years may increase to a frequency of 1:30 to 35 years, and a 1-in-100-year event may increase in frequency to 1 in 50 years. The frequency of rainfall events of 1:100 years, for example, can happen within days or weeks of previous events. This occurred in 2011 in southeastern Saskatchewan (Hopkinson 2011).

Figure 5.4 illustrates that precipitation will generally increase, but in general terms, winter is expected to be somewhat wetter, by as much as 20 percent in the 2046–2065 period compared to the 1986–2005 period. The southwest corner of the province is expected to have a zero to 10 percent increase in winter precipitation amounts, but the far north is expected to have higher than current amounts. Summer precipitation should be similar to the 1986–2005 average (CCDS 2015).

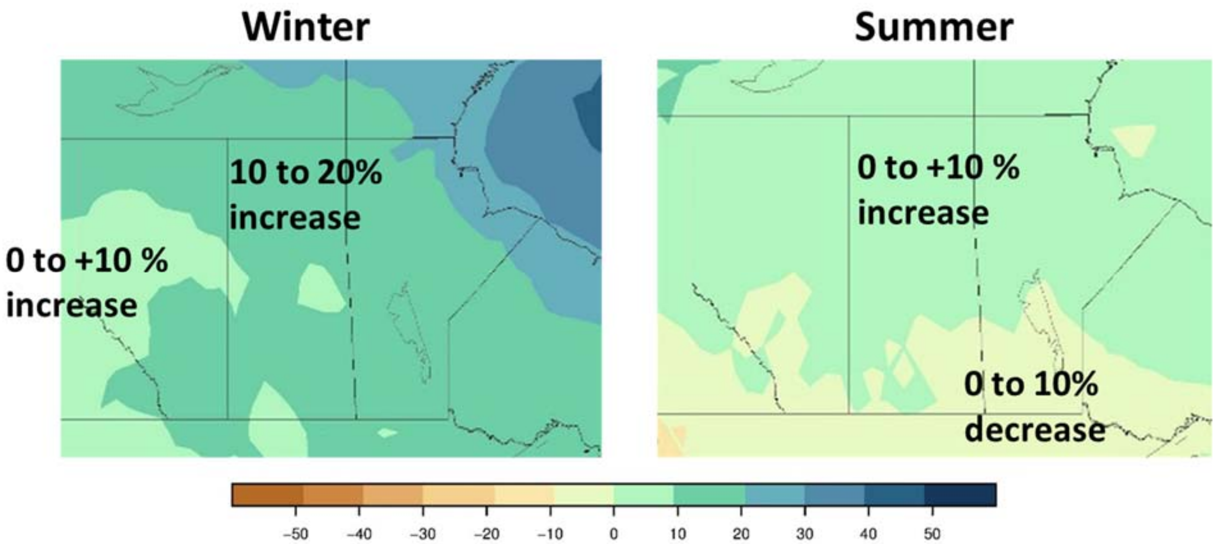


Figure 5.4 Seasonal average precipitation change (2050s). Projected precipitation change based on the 'business as usual' scenario (RCP 8.5) in 2046–2065 period (50th percentile) as compared with 1986–2005 (modified from CCDS 2015).

These projected increases in temperature and precipitation set up a scenario for increasing the number, intensity and duration of both drought and flood events. The droughts in the 20th century are considered relatively mild when compared to pre-settlement droughts in the Prairies. The projected changes to the climate will likely mean returning to those extreme drought conditions (Bonsal et al. 2013). In addition, with the warmer temperatures, the atmosphere will be able to hold more moisture. With each degree of warming, the amount of water the air can hold increases by 7 percent. This implies increases in intensity and frequency of extreme precipitation events in places like Saskatchewan (Trenberth et al. 2007).

Based on these climatic change scenarios, the wet times are expected to become wetter and dry times to become drier (Figure 5.5) (Wheaton et al. 2013). There will be more frequent and more intense droughts similar to the 1800s when they were decade-long but mixed with severe storms and extreme precipitation events.

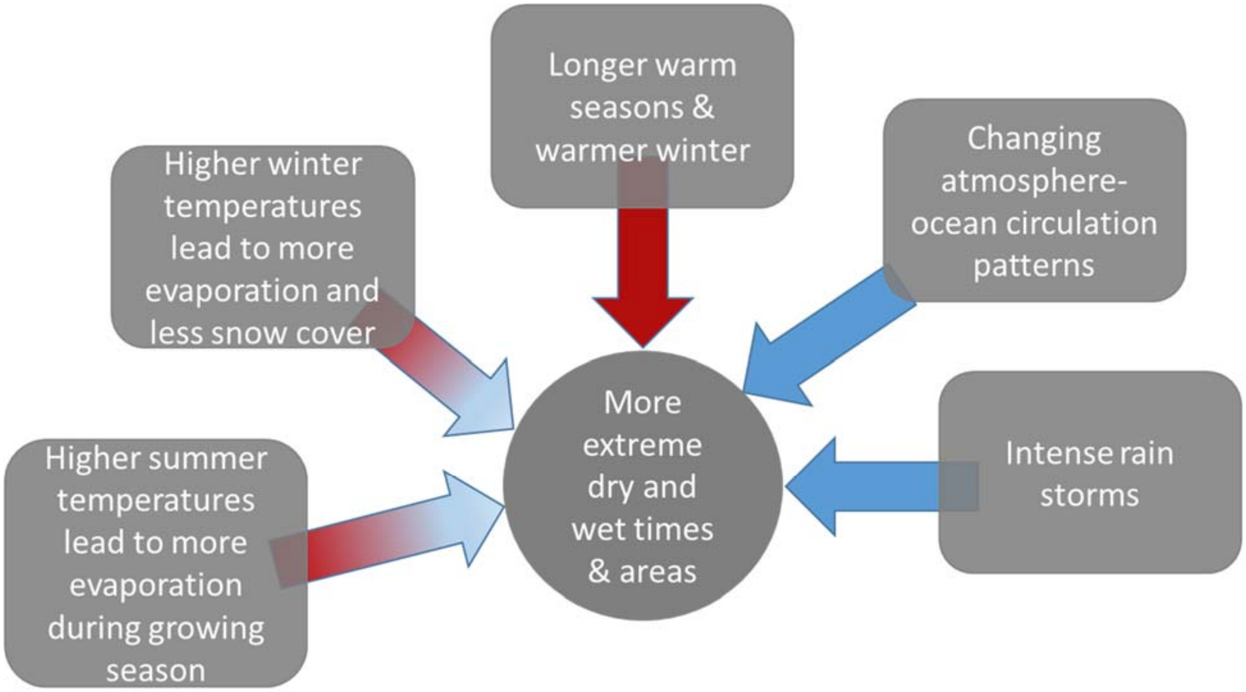


Figure 5.5 Wet times become wetter and dry times drier (modified from Wheaton et al. 2013)

Urban flooding in North Battleford (Photo Source: Government of Saskatchewan)

6. FLOODING

R. A. Halliday

Water does not resist. Water flows. When you plunge your hand into it, all you feel is a caress. Water is not a solid, it will not stop you. But water always goes where it wants to go, and nothing in the end can stand against it.

Margaret Atwood, 2005
(The Penelopiad)

Floods are "acts of God," but flood losses are largely acts of [humans].

Gilbert F. White, 1945
(Human Adjustment to Floods)

Definition

Floods are the result of an increase in runoff beyond the point where the normal stream channel can no longer contain the water. When water overspills its banks, it spreads along the adjoining floodplain. Floodwaters may occupy the floodplain for a matter of hours, weeks or even years (Andrews 1993). Quite simply, a flood is water where it is not wanted. Floods are often defined in terms of flood frequency; a 1:100 or one percent flood has a probability, on average, of recurring once in 100 years.

Runoff in Saskatchewan

The province of Saskatchewan comprises three major continental drainage basins: the Arctic, Hudson Bay and Gulf of Mexico. The Hudson Bay basin can be further divided into three portions. The first of these is the Churchill River basin, which rises in the northern boreal forest of Alberta and Saskatchewan. The second is the Saskatchewan River basin, which rises on the eastern slopes of the Rocky Mountains. The North and South Saskatchewan rivers flow east to unite in central Saskatchewan and flow to Lake Winnipeg. The third portion includes streams that rise on the eastern plains of the province and ultimately flow to Lake Winnipeg and thence to Hudson Bay.

The Saskatchewan River system is the only reliable water supply capable of meeting the needs of about one-half of the province's population. Some 80 to 90 percent of the flow of the North and South Saskatchewan rivers can be considered to be mountain runoff. Indeed, less than two percent of the South Saskatchewan River's flow arises in Saskatchewan.

Runoff in Saskatchewan represents a complex interplay of climate, weather, topography, and landscape. Gray (1970) identifies several distinctive characteristics of Saskatchewan hydrology. First, the high variability of precipitation and resulting runoff lead to both floods and droughts. Second, because of storage of water as ice and snow, runoff in any given year is highly variable. Third, the semi-arid climate and flat topography of the southern half of the province leads to poorly developed and disconnected natural drainage systems. Fourth, on account of relatively small precipitation inputs, land cover and soils are a major factor in controlling runoff. Finally, there is the need for water management to consider both mountain runoff from the North and South Saskatchewan rivers as well as plains runoff (Pomeroy et al. 2007).

About one third of annual precipitation occurs over the winter, yet it is that winter snowfall and precipitation during the spring freshet that usually lead to most of the annual runoff. Redistribution of the snow pack by winds can profoundly affect runoff. The formation of drifts from windblown snow lengthens the spring runoff season and modulates the peak spring flows. Frozen soils result in rapid snowmelt runoff in the springtime. Runoff is also governed by soil moisture. Wet soils reduce the opportunity for water to infiltrate into the soil, thereby leading to increased surface water runoff.

> "*The prairie region is characterized by glacially-formed depressions; these depressions fill with water to form pothole sloughs and wetlands and are very important to prairie hydrology due to their surface storage capacity. A fill-and-spill runoff mechanism is identifiable in prairie basins that are dominated by these surface depressions where flow does not commence until all storage in the depressions is filled. This results in an episodic and rapid increase in contributing area during peak runoff events. However outside of these events much of the prairie landscape is non-contributing to streamflow and even in the most extreme runoff events, some prairie basins are internally drained and never contribute to streamflow. This fill and spill phenomenon is in contrast to forms of hydrological storage found in temperate regions in which the flow rate is proportional to storage. Because of depressional storage and poorly and internally drained basins, most surface runoff in the prairie region does not contribute to the major river systems.*" (Fang et al. 2007)

Figure 6.1 illustrates the non-contributing drainage areas in Saskatchewan. The figure is based on data compiled by the Prairie Farm Rehabilitation Administration (PFRA). It indicates areas of the province that in a state of nature do not contribute to stream runoff in a median year, that is, one year in two. The area shown in red is the part of the province most likely to experience challenges with overland flow during unusually wet conditions.

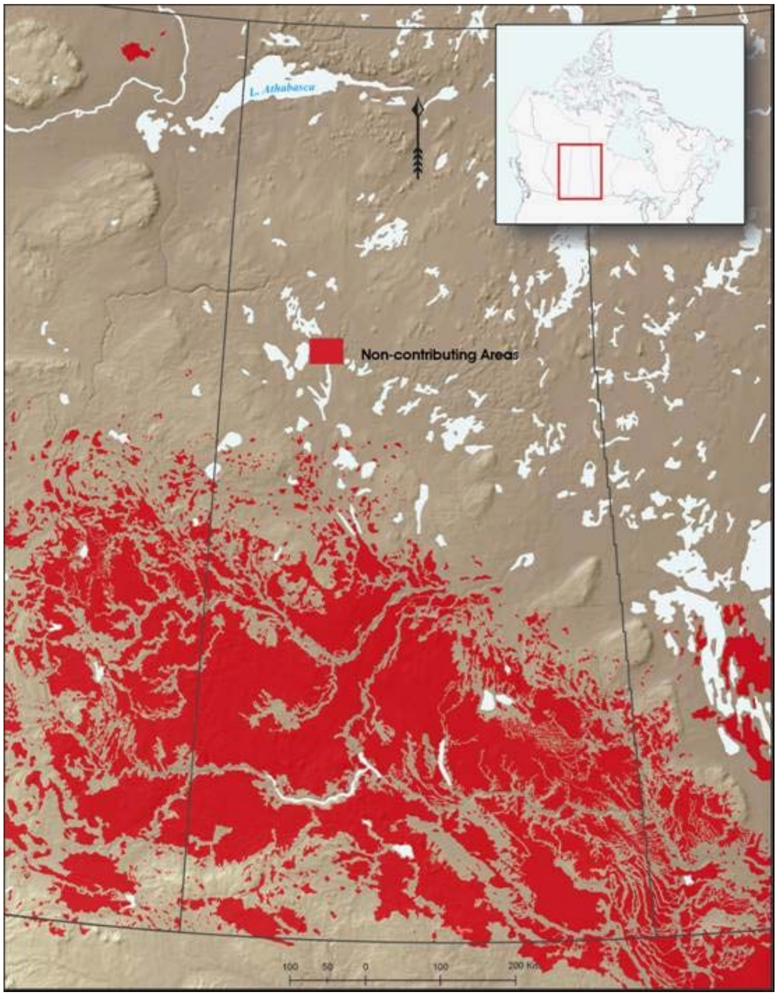


Figure 6.1 Non-contributing area in Saskatchewan based on PFRA data. (Pomeroy et al. 2007)

Flood Hazard Description

Saskatchewan, like Alberta and Manitoba, has a significant flooding problem. One measure of the extent of that problem is the payments made over the years under the federal Disaster Financial Assistance Arrangements (DFAA). From the program's inception in 1970 through to 2014 the three Prairie Provinces have experienced the largest payouts, both in aggregate and per capita. The period from 2005 to 2014 is particularly noteworthy, with Saskatchewan receiving 20 percent of the national payments and the largest per capita payment. Floods, especially in the Prairie provinces, comprise most of the DFAA payments (PBO 2016).

The Saskatchewan Provincial Disaster Assistance Program (PDAP) is aimed at assisting residents, small businesses, agricultural operations, First Nations, non-profit organizations, and communities recover from natural disasters, including flooding. PDAP may help cover the cost of uninsurable losses, clean-up, repairs and temporary relocation. Payments are based on a municipality being designated as eligible for payments. Payments related to flooding have been exceptionally high in recent years. Figure 6.2 shows annual PDAP payments related to heavy rain and flooding in the last several years. Some of the identified damages relate to urban storm sewer systems being overwhelmed by heavy rain. A review of the flood hazard in Saskatchewan follows.

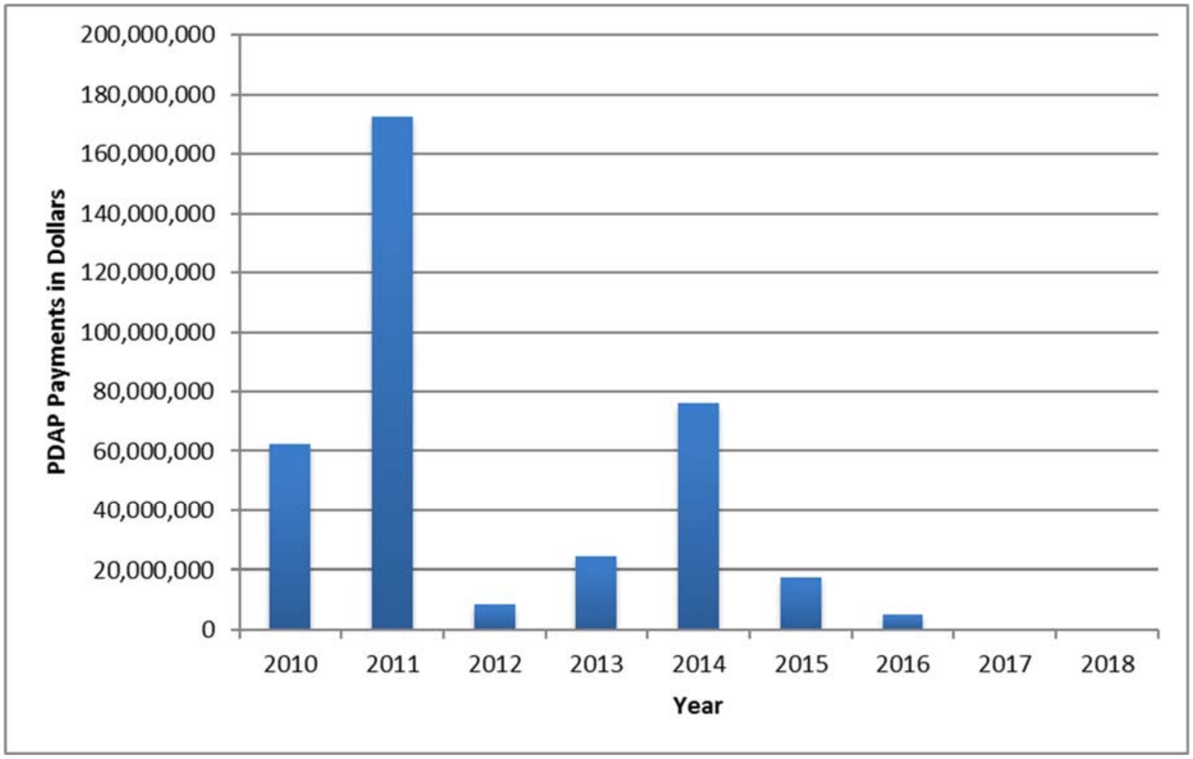


Figure 6.2 Annual PDAP payments related to flooding and heavy rain.

Mountain Runoff

The North and South Saskatchewan rivers and the Saskatchewan River mainstem may experience flooding due to runoff from the eastern slopes of the Rocky Mountains. In Saskatchewan such floods tend to take place with the melt of the mountain snowpack in June and July. Severe flooding is likely to arise when that snowmelt runoff is augmented by rain initiated by flows of moist air from the Gulf of Mexico. Saskatchewan communities become more vulnerable when upstream reservoirs have been filled and floods must be passed downstream.

The only community on the South Saskatchewan River that is vulnerable to flooding from mountain runoff is Saskatoon. Flood impacts in that city are minor and generally are confined to residential areas. Dwellings on the Muskoday Reserve, which straddles the South Saskatchewan River near its confluence with the North Saskatchewan River, are set well away from the river and are generally not at risk.

On the North Saskatchewan River, the cities of the Battlefords and Prince Albert are vulnerable to flooding. Many properties would be flooded in the event of a severe mountain runoff flood. First Nations reserves along the general course of the North Saskatchewan River are well away from the river itself. Although these reserves may be subject to flooding from localized events, mountain runoff floods pose little threat.

On the Saskatchewan River the most significant flooding issue relates to Cumberland House. Access to the community is by means of a single unpaved road. During high flow or wet conditions, the community is often evacuated.

Plains Runoff

The vast majority of flood-prone Saskatchewan communities lie in the agricultural prairie landscape of the southern half of the province. Runoff characteristics tend to be related to the natural regions of the province; many flood-prone communities are located in the Prairie ecozone and the Boreal Transition ecoregion shown in Figure 2.2. Flooding in this area can take place in several different ways. These include urban riverine flooding from established streams, urban lake flooding, and overland flow, both rural and urban.

In Saskatchewan, historically, floods have been associated with the spring snowmelt, most often in April. The severity of the flood relates to autumn precipitation, winter precipitation and snow redistribution, frost penetration, melt rate, and precipitation during the melt. In recent years, however, southern Saskatchewan has experienced very significant summer rains that have led to riverine flooding. While such events did take place in the 1920s, 1950s and 1970s, they did not persist for more than a year or two. Many Saskatchewan communities are subject to riverine flooding.

Lake Flooding

Lake flooding may be due simply to high water levels, but damage can occur as well due to ice shove when strong winds, ice cover and high water combine to cause damage. Communities set in the Boreal Plain ecozone as well as prairie communities may be subject to lake flooding. One unusual aspect of lake flooding is that it often applies to resort villages composed of second homes or to provincial park properties. As such, flood damages sustained are not eligible for DFAA assistance from the federal government. Several Saskatchewan communities, including some northern communities, are subject to lake-related flooding.

Overland Flooding

Finally, Saskatchewan has sustained considerable flood losses because of overland flooding in recent years. These losses relate to both rural and urban settings. Overland flooding may accompany spring runoff or may occur on account of heavy summer rains. In rural areas, overland flooding may lead to loss of vulnerable community infrastructure and to agricultural losses. Accounting for these losses will vary, depending on whether landowners have or have not had the opportunity to plant a crop before the flood ensued. Even in the absence of well-defined watercourses, overland flooding may occur in the flat prairie landscape. In general, this is the area shown in red in Figure 6.1.

In urban areas intense runoff events may simply overwhelm the capacity of municipal drainage systems, leading to flooding of municipal infrastructure and of private property. Urban areas have been hardened to the extent that a very high percentage of incident precipitation runs off. One study in Calgary indicated that the effect of urbanization was akin to increasing the size of the drainage basin by a factor of 10 (van Duin and Garcia 2008). There are many best practices that will reduce urban storm water runoff but a residual risk of flooding remains.

Groundwater Under Direct Influence of Surface Water

In some locations topography, adjacent watercourses and soil type may lead to shallow aquifers being hydraulically connected to surface water sources. Groundwater levels will therefore respond quickly to surface water flooding. A typical manifestation of this situation is a residential sump pump that runs almost continuously in wet weather. Such situations will also affect the efficacy of dykes and berms. As well, the safety of community water supplies from groundwater sources may be directly affected by surface water contamination. While special situations may exist, in general, groundwater under direct influence of surface water is not a major factor in flooding in Saskatchewan.

Dam Safety

While matters pertaining to dam safety can be considered as human-induced hazards, there are close links to natural hazards. Dam failures can be induced by extreme hydrological or seismic events (see chapter 11 of this report) or by technological failures. The consequence of a significant dam failure is a flood. For that reason, a brief discussion of dam safety is included in this chapter.

There are 44 large dams in Saskatchewan, that is, dams greater than 15 m in height. The Water Security Agency is the principal dam owner and operator in the province and is responsible for 69 dams, including 20 dams transferred from the federal government in 2017. Other dam owners include SaskPower, Agriculture and Agri-food Canada (AAFC) and local governments.

From a dam safety perspective, dams are classified in accordance with the downstream losses or damages that are caused by their failure. These consequences include loss of life and environmental, cultural or economic losses. One can further consider a hydrologic failure, a seismic failure or a “sunny-day” failure, whichever is worst (CDA 2013). A five-point consequence scale ranges from low to extreme. Dam safety professionals have concerns about assessing relative risk based on failure modes.

Several Saskatchewan dams are considered as extreme consequence dams. These include Gardiner Dam on the South Saskatchewan River, Qu’Appelle River Dam, Rafferty Dam on the Souris River, and Alameda Dam on Moose Mountain Creek, all of which are owned by the Water Security Agency. All four of these dams have been subjected to independent dam safety reviews in accordance with Canadian Dam Association Guidelines (Provincial Auditor 2011). AAFC once owned 29 dams in southern Saskatchewan; two, Duncairn Dam and Lafleche Dam, are deemed to be extreme consequence dams. AAFC has recently examined the associated hydrology of these dams as part of the process of transferring ownership to the province. The Saskatchewan Power Corporation owns one extreme consequence dam, Boundary Dam. Tunnel Control Structures 1, 2 and 3 at Gardiner Dam are owned and operated by SaskPower and are also considered extreme consequence, as a failure at that point could lead to a dam failure. For the most part the extreme consequence rating of many Saskatchewan dams relates primarily to the economic losses associated with a failure.

Unlike some other provinces, the province of Saskatchewan does not have dam safety legislation.

Provincial Risk Statement

In response to DFAA payments in the 1970s and increasing demand for structural measures, the federal government introduced a national flood-damage reduction (FDR) program in 1976 (Bruce 1976, Watt 1995). Over a number of years, the federal government implemented 10-year federal–provincial agreements aimed at delineating and designating flood risk areas in urban centres. The program eventually applied to all provinces except Prince Edward Island and to the pre-Nunavut

Northwest Territories. Some First Nations reserves were also mapped. Side agreements allowed consideration of matters such as structural mitigation measures and flood forecasting.

Under the 1977 Canada-Saskatchewan FDR agreement, 29 flood-prone communities were listed and 22 were mapped. The mapping process consisted of hydrological calculations of the 1:100 and 1:500 floods, hydraulic analysis of the spatial extent of such floods in a given community, and preparation of detailed engineering maps as well as simplified public information maps. These latter maps were used as the basis for formal identification of the at-risk areas of a community — a process known as designation. Of the 29 communities, 20 were designated, most in the 1980s. Notable exceptions to the designation process were Regina, Saskatoon and Prince Albert, although all of these communities have since been zoned at-risk lands. The intent of designation was to commit both orders of government to reducing flood damages by controlling flood plain development. In the case where engineering maps were produced but designation did not take place, community planners often used the flooding information to curtail flood plain development. One unusual feature of the Saskatchewan program was the use of the 1:500-year flood as the regulatory flood. The minimum requirement for the national program was the 1:100-year flood. Ontario, British Columbia and recently Manitoba, have also adopted higher standards.

With the withdrawal of the federal government from the program in the 1990s, little has been done to keep the flood risk maps for Saskatchewan communities current. This task requires periodic updating of the regulatory flood based on new information and mapping of urban growth areas. For the most part then, the uncertainty concerning the magnitude of any specified flood in Saskatchewan, with rare exceptions, is considerable. The current status of Saskatchewan communities having a known flood risk is shown in Table 6.1.

Table 6.1 Former FDRP Communities in Saskatchewan

Major Basin	Community	Mapped	Designated	Zoned	Remarks
Souris	Estevan	yes	interim	yes	
	Oxbow	yes	interim	yes	
	Radville	yes	yes		
	Roche Percée	yes	interim		
	Weyburn	yes	no	yes	
Missouri	Eastend	yes	no		update available
Qu'Appelle	Craven	yes	yes		
	Lebret	yes	yes		
	Lumsden	yes	yes	yes	
	Fort Qu'Appelle	yes	yes	yes	
	Moose Jaw	yes	yes	yes	
	Regina	yes	no	yes	
	Tantallon	yes	yes		
South Saskatchewan	Saskatoon	yes	no	yes	
	Swift Current	yes	no	yes, based on 1981 map	update available
North Saskatchewan	Battleford, North Battleford	yes	yes		
	Prince Albert	yes	no	yes	update available
Saskatchewan	Cumberland House				
	Melfort	yes	yes	yes	
	Tisdale	yes	yes		
Churchill	Beauval				
	Big River	yes			
	Buffalo Narrows	yes	yes	yes	
	Green Lake	yes			
	Ile-a-la-Crosse	yes	yes	yes	
	La Ronge/Air Ronge	yes	yes		
Assiniboine	Yorkton	yes	yes		

The Water Security Agency (WSA) recently conducted a preliminary flood risk assessment associated with 75 communities (Water Security Agency 2017). The review was based on flooding experience in the period 2011–2015, a time when extremely wet conditions led to considerable riverine and overland flooding. The review therefore did not incorporate historical flooding from earlier years. Nonetheless there is considerable overlap between the 29 communities identified in the former FDR Program and the recent WSA review. Table 6.2 shows those communities that were not part of the FDR program. Many of these communities are not on an established watercourse and are subject only to overland flooding.

Table 6.2 Other Saskatchewan Communities Vulnerable to Flooding

Major Basin	Community	Major Basin	Community
Souris	Gainsborough	South Saskatchewan	Cudworth
	Glenavon		Duck Lake
	Lampman		Meacham
	Kipling		Neuanlage
Missouri	Val Marie		Rosthern
Cypress Hills North	Maple Creek		Waldeck
Old Wives Lake	Gravelbourg*	North Saskatchewan	Asquith
	Gull Lake		Big Shell Lake
	Hodgeville		Borden
	Limerick		Kindersley
	Ponteix*		Lashburn
	Vanguard		Maidstone
Qu'Appelle	Drake		Medstead
	Foam Lake		Radisson
	Goodeve		Turtleford
	Humbolt	Saskatchewan	Annaheim
	Kelliher		Arborfield
	Kipling		Bruno
	Leroy		Denare Beach
	Lestock		Red Earth Reserve
	Manitou Beach	Churchill	La Loche
	Meacham		Meadow Lake
	Melville	Assiniboine	Buchanan
	Odessa		Calder
	Quill Lake		Invermay
	Raymore		Kamsack
	Southey		Langenburg
	Viscount		Melville
	Wadena		Sheho
	Watson		Theodore
	White City	Lake Winnipegosis	Hudson Bay
	Whitewood		
	Wolseley		
	Wynyard		

* Flood risk data exist

The WSA review incorporated three factors: hydrological, social and economic. Flooding attributable exclusively to inadequate urban storm drainage systems was not included. The hydrological indicator for the assessment was based on three factors: flood frequency analysis, flood severity and the nature of flooding (riverine or lake). Floods with a return period rarer than 1:100 received the highest score. Floods with a 1:25 return period or lower were not considered.

The social indicator was also based on three factors: overall population, growth rate, and community awareness and commitment. Insufficient data exist in the province to determine the number of persons at risk; therefore, total population was used. A five-level score topping out at 4000 persons was used for population and a six-level score for growth. Awareness and commitment was based on matters such as zoning and other participation in mitigation efforts.

Finally, the economic indicator was based on recent participation in the province's emergency flood damage reduction program and on PDAP payments. A five-level score was used.

Almost all of the former FDR communities are on the ranked list developed for the 75 communities. The social and economic indicators affect the ranking of communities on the list. Moose Jaw, for example, ranks high on the list on account, in part, of its significant effort over the years to reduce flood risks. Lumsden ranks low because a dyke constructed many years ago protects it against all but the largest floods.

Flooding in urban settings, both riverine and lake flooding, was the subject of the Canada-Saskatchewan FDR program. The achievements of that program should be reviewed to determine if all flood-prone communities were identified and whether the hydrology, hydraulics and mapping work is up to date. In some cases, dykes[2] have been constructed to protect urban infrastructure. The design flood associated with structural measures needs to be reviewed.

Climate Change Implications

Future climate will unquestionably be warmer but there is considerable uncertainty in the quantity, timing and extremes of future precipitation. Dibike et al. (2016), for example, indicate an overall increase in precipitation in the Saskatchewan River basin, albeit with decreases in summer precipitation. Because of warming, a greater percentage of annual precipitation will fall as rain rather than snow.

With a presumably greater likelihood of precipitation extremes, the occurrence of many types of flooding could increase. This would apply to mountain runoff flooding, plains runoff flooding and overland flooding. The overland flooding of recent years may be a harbinger of floods to come. The nature of the flood hazard may also change, with conventional spring floods being augmented by freeze-up floods due to ice jamming and, in some cases, mid-winter floods due to ice break-up. Climate change will affect lake flooding, as the seasonal development of very heavy ice covers may be reduced overall, leading to decreased risk of shoreline ice damage. The risk of such damage will also depend on the future likelihood of high lake levels as well as that of strong winds.

[2] It is possible to make technical distinctions among terms such as dyke (dyke), berm, or levee (levée). For the purpose of this report, a dyke should be considered as the generic term for an engineered structure designed to keep water away from a building or other asset.

Worst-Case Scenario

Worst-case scenarios should be considered in the context of the nature of flooding. Each flood hazard can be analyzed with respect to both flood history and reasonable foreseeable future events. Floods may affect health and safety, quality of life, public administration, the economy, and the environment. As for most developed countries the primary consequences of floods in Saskatchewan are likely to be property damage and loss of income. Note that the impact levels shown in italics relate to the provincial risk matrix. Refer to the methodology section in Chapter 4 for more information regarding this risk matrix. Because of the paucity of current flood risk information in Saskatchewan, the impact levels are based on best professional judgement and are therefore somewhat subjective.

Mountain Runoff

Floods in the Saskatchewan River system are usually the product of snowmelt runoff in the Rocky Mountains combined with heavy rainfall in the foothills. The rainfall tends to be the result of a low-pressure air mass drawing moist air from the south towards the eastern slopes of the Rockies. The mountainous terrain tends to amplify the rainfall (DeBoer 1990). The 2013 flood in Calgary generally illustrates the phenomenon, although it must be kept in mind that this flood, although damaging, was hydrologically modest (Pomeroy et al. 2015). Very large floods on the mainstems of the North and South Saskatchewan rivers have not occurred for many, many decades. Some tributaries in Alberta, however, have experienced severe flooding (Shook 2015), although the effects in Saskatchewan on the North and South Saskatchewan rivers have been minor. Because of this, perhaps, workshop participants in Saskatoon and Prince Albert tended to speak of flooding matters in a conceptual sense, rather than from first-hand experience.

Prince Albert is the Saskatchewan community having the greatest vulnerability to a mountain runoff flood. The city, while quite resilient in the face of a 1:100 flood, would experience significant damage during a 1:500 event. The realistic worst-case scenario for a mountain runoff flood in Saskatchewan would be a North Saskatchewan River flood of a magnitude much greater than a 1:100 event. In that flood multiple dwellings and businesses would be inundated, likely in early July.

The overall impact of a Prince Albert flood on human health and safety, social including communities, economic and environment categories would be *moderate*. Human health and safety could be compromised, as a considerable portion of the city would be evacuated and destroyed, causing long-term stress and anxiety deemed to be moderate. Many days of warning would precede this flood. Therefore, public and institutional responses could be expected to reduce the social and economic consequences on a provincial scale to minor. Prince Albert plays a significant role in public administration for the northern half of Saskatchewan, with both governmental and private sector organization operating from the city. A significant flood affecting residents with management and administrative responsibilities for the north could imperil northern operations. The flood, for example, could occur at a time when forest fire fighting needs could be considerable. For this reason, the consequences for public administration are considered as *moderate* to *major*. Finally, the environmental impacts of the flood would be both negative and positive and are considered *minor*. (Positive effects include scouring of fine sediments, leading to improved fish habitat and restoration of riparian vegetation, while negative effects include excessive erosion and mobilization of contaminants.) This flood would also have consequences for other communities along the North Saskatchewan River as well as for Cumberland House on the Saskatchewan River.

Plains Runoff

Historic floods from plains runoff in Saskatchewan tend to be associated with spring runoff, although in recent years there have been instances of riverine floods caused largely by significant precipitation events. The 2011 flood in the Souris River basin is one example. That flood was approximately a 1:500 event.

The Saskatchewan community most vulnerable to a damaging flood from prairie runoff is Regina. Zoning regulations in the city require flood proofing of new construction; residential areas along Pilot Butte and Chuka creeks are examples. Nonetheless, many older neighbourhoods along Wascana Creek are flood prone although dykes protect to some extent.

A reasonable worst-case scenario would be a 1:500 flood in the upper Wascana Creek basin. This flood would take place in April. The flood would be a more severe version of the 1974 flood. A wet autumn, heavy winter snows, a late and rapid melt, plus significant rains during the melt would lead to such a flood. A dyke failure in the city of Regina would lead to the inundation of many homes and businesses. It would also severely affect government operations in the capital region.

The overall impact on human health and safety, social including communities, economic and environment categories would be *moderate* to *major*. Human health and safety could be compromised, as a significant portion of the city would be evacuated and destroyed, causing long-term stress and anxiety and other health issues deemed to be *moderate*. It is not out of the question that a dyke failure could lead to loss of life. The flood would affect social cohesion, but because it would come with some warning the consequences are considered *minor* to *moderate*. The flood would have significant consequences for public administration, Regina being the provincial capital and headquarters for many provincial agencies. In addition, the economic consequences would be considerable on account of damage to infrastructure. The effect on public administration and the provincial economy is considered *major*. A Wascana Creek flood would lead to considerable downstream erosion, affecting agriculture and potentially leading to crop losses. It would also mobilize nutrients, thus further degrading the quality of the Qu'Appelle Lakes. The environmental consequences are considered *moderate*.

Lake Flooding

Lake flooding in Saskatchewan is the result of high water levels combined with wind or wave action or, perhaps, ice shove. Resort communities and First Nations lands adjacent to Last Mountain Lake and the Qu'Appelle Valley lakes are most vulnerable to such flooding.

A realistic worst-case scenario would be a significant flood event akin to, but not as great as, the one described previously for plains runoff combined with a major windstorm. Such a flood would likely take place in April. Shoreline properties in the Fishing Lakes (Pasqua, Echo, Mission and Katepwa) and at Last Mountain Lake would be devastated by such an event. Communities such as Lebret and Fort Qu'Appelle would suffer significant damage.

The overall impact on human health and safety, social including communities, economic and environment categories would be *minor* to *moderate*. In a provincial context the consequences of lake flooding related to social, public administration and economic concerns is considered *minor*.

On the other hand, phenomena such as ice shove may occur with little warning; loss of life is not inconceivable. From a human health perspective, the consequence could be *moderate*. Because such an event could lead to mobilization of nutrients and contaminants, the environmental consequence is considered *moderate* to *major*.

Overland Flooding

Overland flooding in agricultural areas is a consequence of excess moisture, usually in the form of rain. Agricultural losses tend to be a function of the timing and duration of flooding as well as the crop grown (Förster et al. 2008). The non-contributing drainage area shown in Figure 6.1 is most vulnerable to such flooding. Because sustained excess rain is more likely to occur in the eastern part of the province, east-central Saskatchewan is more vulnerable to this type of flooding. The overland flooding experienced in the period 2010 to 2015 was unprecedented in the last 100 years. Flooding in the Souris basin in 2011 led to some 20,000 km^2 of cropland in Saskatchewan and Manitoba not being planted in that year (USACE 2012). A reasonable worst-case scenario for overland flooding would be along the lines of the flooding that took place in the 2010 to 2015 period. During that period many agricultural producers and rural communities were affected. Unlike other types of Saskatchewan floods, overland flooding driven by heavy rain could take place over a considerable period of time, likely from April to August. The flooding could also persist for many months.

The overall impact on human health and safety, social including communities, economic and environment categories would be *moderate*. The effects on human health and public administration are considered *minor* and social effects *minor* to *moderate*, in part because such effects can be mitigated relatively easily. On the other hand, environmental effects relating to erosion and deposition can be considerable and are deemed to be *moderate*. Finally, overland flooding can lead to significant income losses for agricultural producers as well as considerable infrastructure damage. Economic consequences could be *major*.

Overland flooding caused by heavy rains does not lend itself to the statistical analysis used in examining spring floods as, with rare exceptions such as described in Hunter et al. (2002), most rain-driven floods have occurred in recent years. The physical mechanisms that create such floods are different from those related to spring flooding. Because of this, there are insufficient events of interest to support statistical analyses. (Hydrologists speak of summer rain floods being drawn from different populations than spring floods.)

Two factors come into play in considering overland flooding: a flat topography with unorganized natural drainage and excess moisture due to rainfall. Predicting areas vulnerable to overland flooding is a particular problem in Saskatchewan, as the province lacks the detailed topographical information that would allow the movement of water on a flat landscape to be calculated. As well, the low density of the climate-observing network presents challenges. Because of this, it is not possible to make quantitative risk assessments pertaining to overland flooding. One can make inferences based on the wet conditions that prevailed in recent years.

One approach is to use the Standardized Precipitation-Evapotranspiration Index (SPEI), described in Chapter 7 of this report, to consider periods of excess moisture. Figure 6.3 shows the index for Estevan and Regina, locations that bracket the Souris River basin. The excess wet years in the

1950s, 1970s and 2010s are evident in the graphs. Developing an analytical tool for dealing with excess moisture could be based on using a moisture index to identify vulnerable areas, imposing a rainstorm of a certain magnitude on the area, then using a hydrodynamic numerical model to route that precipitation over a well-defined topography.

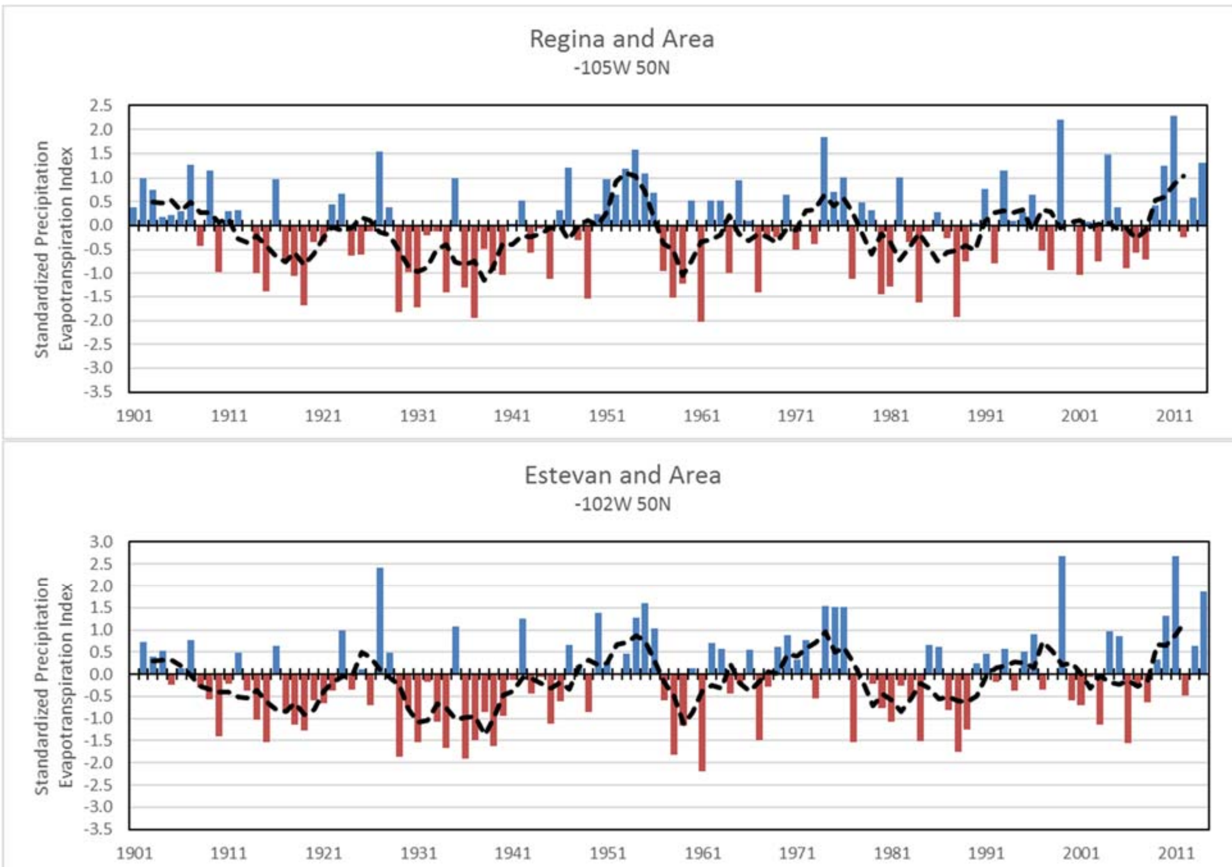


Figure 6.3 SPEI Values for the Souris River Basin. The blue bars indicate wetter conditions and the red bars indicate drier conditions. The black dashed line is the five-year running average over the 1900 to 2014 period. (SPEI data sources: Tam et al. 2016, Vincent et al. 2015, Tam et al. 2018)

In addition to typical overland agricultural flooding, urban areas may be subject to stormwater management damage because of undersized storm sewer facilities. Generally urban developments are designed so that small floods are conveyed by pipes, while both pipes and roads convey larger floods. Other features such as wet or dry ponds, constructed wetlands or grassed swales may also be used to manage urban stormwater (Saskatoon 2017). Urban areas may use a specific historical event — the June 24, 1983 storm in Saskatoon, for example — to guide urban stormwater design. Storm damage may be accompanied by sanitary sewer back-up as well. Such problems tend to be the result of ineffective urban design, both on a community and individual landowner basis. There are examples, however, of hailstorms leading to blocked storm sewer drains in both Yorkton and North Battleford. Urban flooding may be, as well, exacerbated by our changing climate.

Groundwater Flooding

As indicated earlier in this chapter, groundwater flooding is Saskatchewan is highly localised. Although individual property owners may experience damage, the overall significance to the province is small. Even under a worst-case scenario the consequences of groundwater flooding are deemed to be *minor*, perhaps *insignificant*.

Existing Controls

The Water Security Agency (WSA) is responsible for water management in the province. Its responsibilities include managing the province's water supply, protecting water quality, ensuring safe drinking water and treatment of wastewater, owning and managing 69 dams and related water supply channels, reducing flood and drought damage, protecting aquatic habitat and providing information about water. The Water Security Agency also represents Saskatchewan on transboundary water issues. The agency has several key responsibilities relating to reducing flood risks.

Foremost among these is flood forecasting. Experience has shown that timely and accurate flood forecasts are a primary factor in avoiding loss of life on account of floods and in reducing flood damages (Pilon et al. 2000). The provincial flood forecasts are developed using hydrometric data collected by the WSA and by Environment Canada and meteorological data from Environment Canada and other sources plus ancillary data such as snow water equivalent and soil moisture. Historically the primary flood hazard in Saskatchewan has been flooding due to spring snowmelt. The flood forecasting system has developed around this flood risk and needs improvement for forecasting other types of floods.

Even in the case of an excellent flood forecast, the province is dependent on communities and other entities having a detailed emergency response plan and putting the plan into effect as required. Individuals also need to accept a high degree of responsibility for safeguarding their personal safety and interests, especially in the early days of a flood threat.

The WSA is also responsible for approving community development plans from a flood risk perspective. In many cases the province lacks the data to thoroughly evaluate such plans. These data gaps include topographical, hydrological and hydraulic data.

Provincial Risk Analysis

As previously discussed, various flood hazards exist in Saskatchewan. It is possible to devise realistic worst-case scenarios that would lead to extensive damage to Saskatchewan's economy, environment and public well-being. Translating the flood hazard into risk may be carried out on a qualitative or quantitative basis. A quantitative analysis requires consideration of both the likelihood of an event occurring and of the consequences of that event. Several methods of representing that analysis exist. The preferred method for this report is the use of a risk evaluation matrix as shown in Table 4.7 and Appendix 4.5. The risk matrix summarizes the worst-case scenario conditions. The red circle in the center is the aggregate risk level of the worst-case scenario. The aggregate risk is the approximate average of all the impacts and likelihood description as described in the methodology section of this report.

The likelihood of a flood event can be captured by flood frequency analysis. A five-point scale of probabilities could consist of the 1:2, 1:25, 1:50, 1:100, and 1:500 floods. The 1:2 flood, or median flood, is one that would occur, on average, one year in two. Note that this is the event used to define the non-contributing areas in Figure 6.1. It also helps define the area that is at risk from overland flooding. The 1:25 flood is often used as the minimum design flood for municipal drainage systems and roadways. A 1:25 flood event, therefore, should have no effect on urban and rural infrastructure. The 1:50 flood has no import to design or regulation. One could consider such a flood as one that would cause some difficulty for low-lying areas or vulnerable structures. A resilient community should not experience any difficulty in managing a 1:50 flood. Most communities will experience some difficulty with a 1:100 flood, and in some cases damage to infrastructure, homes and businesses will be severe. Although it is the regulatory flood in Saskatchewan, the 1:500 flood is an extreme event. A few resilient communities may be unaffected, but most communities will experience difficulties. While floods greater than the 1:500 flood can occur and such floods are a concern in designing long-lived infrastructure such as dams, they are exceptional.

Communicating flood risk based on annual probabilities is fraught with problems, as many people have difficulty in putting the cumulative risk in context. As an example, the probability of a 1:100 flood occurring over the length of a 25-year mortgage is 22 percent, while that of a 1:500 flood occurring is 5 percent. Another example is that the probability on average of a 1:100 flood occurring in any given 100-year period is 63 percent.

For the purpose of this report a five-point likelihood scale somewhat different from the one previously described has been developed so that all natural hazards can be consistently discussed. A likelihood table of these probabilities is shown in Figure 6.4.

		Likelihood Categories		
		Average number of occurrences over specified time frame	Percent of times of occurrence over given time frame	Qualitative description
Likelihood Descriptions	Almost Certain	1:1	100%	Insignificant
	Likely	1:1 – 1:2	50 ≤ 100%	Minor
	Possible	1:2 – 1:10	10 ≤ 50%	Moderate
	Unlikely	1:10 – 1:100	1 ≤ 10%	Major
	Rare	> 1:100	< 1%	Catastrophic

Figure 6.4 Hydrology likelihood table

There is a danger that any discussion of flood frequency may imply a much great degree of specificity than is intended. There are several reasons why uncertainties exist in flood frequency calculations. In a prairie context there is considerable between-year variability in streamflows or lake levels. Even streamflow records collected over many years may be insufficient to support a good calculation. Furthermore, streamflows can be affected by human activity such as drainage or construction of dams or diversions. While adjustments can be made to naturalize a streamflow record, this adds additional uncertainty. Also, flood frequency analysis is based on the notion of stationarity, that is, the record is unperturbed by spatial or temporal influences. Milly et al. (2008) famously declared that stationarity was dead but, in truth, it was never alive. Razavi et al. (2015) show that even 89 years of record for the North and South Saskatchewan rivers provide a poor representation of the long-term hydrologic record. Adding to historic conditions, climate change promises to increase the statistical uncertainty in hydrologic records. While this section attempts a quantitative approach to flood risk assessment, the uncertainty in specific results should not be underestimated. Workshop participants were concerned that Saskatchewan lacks the hydrological capacity to conduct the myriad analyses that are required, now and in the future.

Floods will have various consequences. Foremost is the risk to human health and safety. People are particularly vulnerable when stream velocities are high or flood waters deep. Generally the elderly or infirm are the most likely flood victims. Given the nature of flooding, particularly the lack of flash flooding more common in mountainous environments, loss of life in a Saskatchewan flood is highly unlikely. Such a loss would probably be through misadventure — driving into a flooded underpass, for example, rather than a direct consequence of the flood itself.

People could be injured, acquire infectious diseases or suffer respiratory ailments through mould growth. They could also be subject to psychosocial stress arising from flood fighting, evacuation, residential flooding, or job losses. Burton et al. (2016) provides a good review of flood-related health issues. Depending on the magnitude of the event, these may be localized or widespread. Social well-being may be affected by the impacts of a flood event on communities, culture and relationships. Flooding may affect cultural and aesthetic values, irreparably damage important community structures, and generally degrade quality of life. Severe weather warnings and flood forecasting tend to dramatically reduce human impacts of flooding. Even when physical losses associated with flooding are compensated, the human impacts will persist.

Floods can affect public administration by limiting the ability of local governments to deliver core services. The provincial government may also be affected by the diversion of resources to meet flood response and recovery needs. The challenges to public administration are compounded when administrators are also personally affected by the flood event.

Economic losses during flooding and the cost of flood fighting can be considerable. The direct damages of flooding, for example, may include damage to buildings and infrastructure, loss of stock of capital and consumer goods, loss of ecological goods, and crop and livestock losses. Indirect damages may include the disruption of physical and economic linkages and the additional costs of flood response (Tapsell et al. 2006). Many workshop participants identified crop losses and damage to rural infrastructure as significant concerns.

Flood damages could also be considered as tangible and intangible. The health and social aspects of flooding would be deemed to be intangible.

Flooding will increase economic activity during the recovery phase. The net effect of the 2013 floods in Alberta on provincial gross domestic product, for example, was positive (Alberta 2013). Similarly, an analysis of post-flood income in New Orleans following Hurricane Katrina shows no loss in personal income (Deryugina et al. 2014). The economic costs and benefits associated with flooding are poorly distributed, however: some people and organizations will suffer losses while others will gain. In a Saskatchewan context, flooding that affects the long-term viability of a small community or excessive moisture leading to uncompensated crop losses would cause the greatest provincial concern.

The environmental consequences of flooding can be evaluated on the basis of the regional scope of the problem, its significance and its duration. Floods may modify many physical, chemical and biological stream processes. They may, for example, disrupt and degrade ecosystems, disperse invasive species, increase erosion and sedimentation, or mobilize nutrients and contaminants. Moderate floods may also prove beneficial to some ecosystems by scouring riverine settings and prompting riparian growth (Peters et al. 2016). As well, they will promote wetland restoration and groundwater recharge. In Saskatchewan the most visible environmental consequence of flooding is erosion and deposition of sediments. The workshops identified slope stability in the Qu'Appelle Valley and inundation of regional landfills as concerns.

The consequences of various types of floods will vary from site to site. For example, a 1:500 flood in Saskatoon would have minor consequences while such a flood in Prince Albert would have major consequences. The consequences of reasonable worst-case scenarios for various types of Saskatchewan floods are displayed in Figures 6.5 to 6.9.

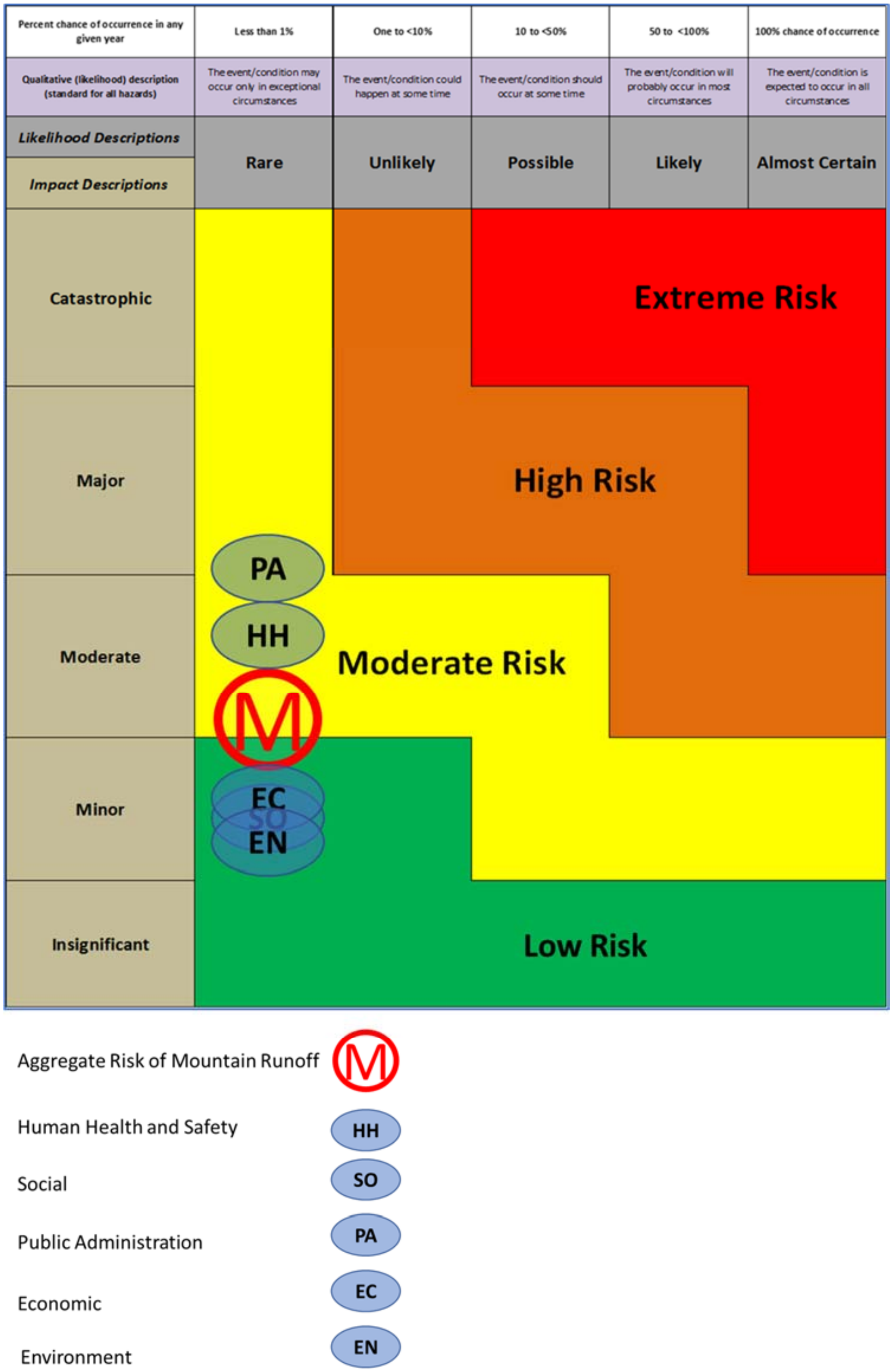


Figure 6.5 The risk of mountain runoff flooding in Saskatchewan based on impact categories and percent chance of occurrence. The red circle with the M in the centre indicates the aggregate risk of mountain runoff flooding across the provincially based impact categories for the plausible worst-case scenario.

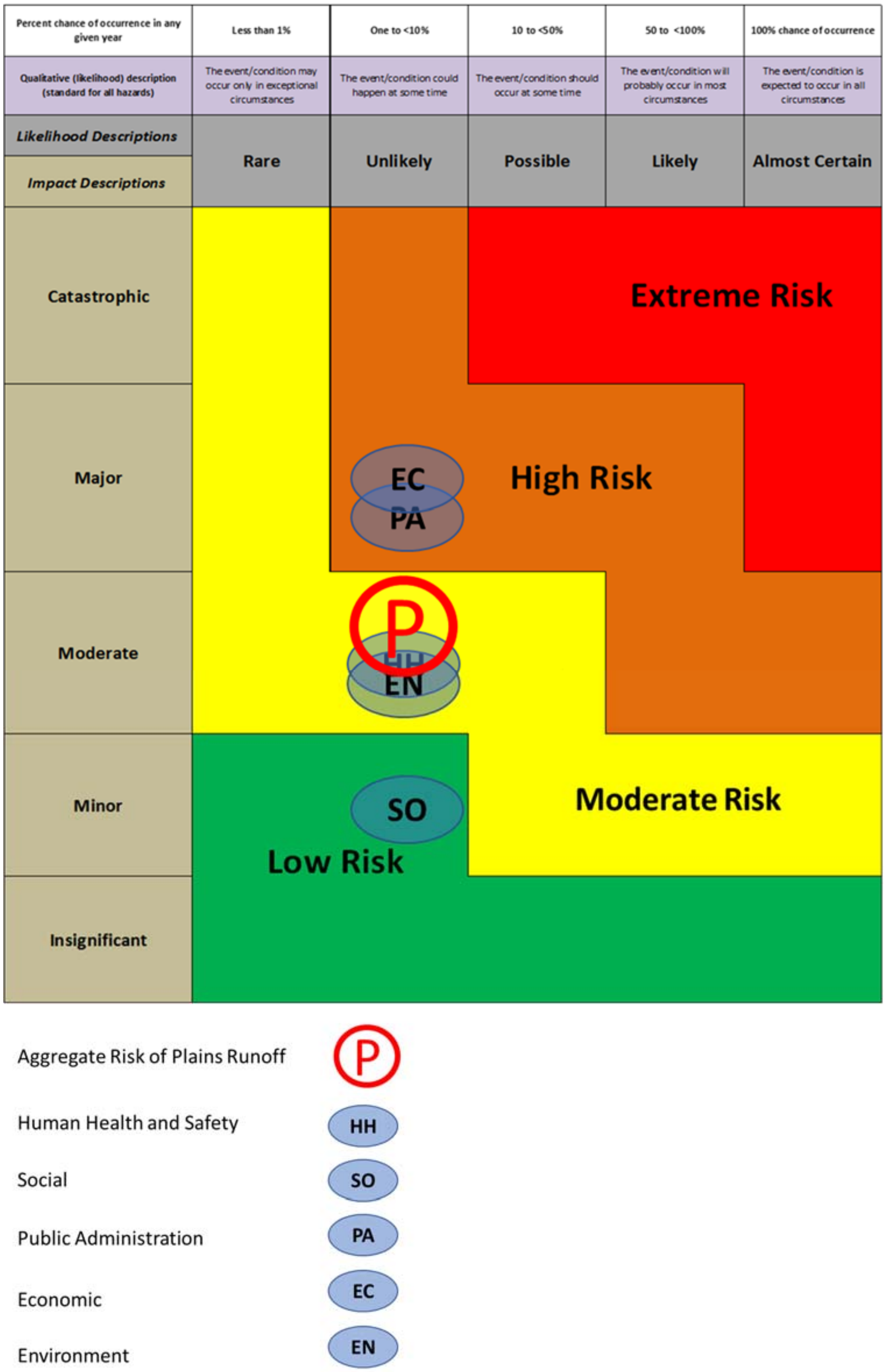


Figure 6.6 The risk of plains runoff flooding in Saskatchewan based on impact categories and percent chance of occurrence. The red circle with the P in the centre indicates the aggregate risk of plains runoff flooding across the provincially based impact categories for the worst-case scenario.

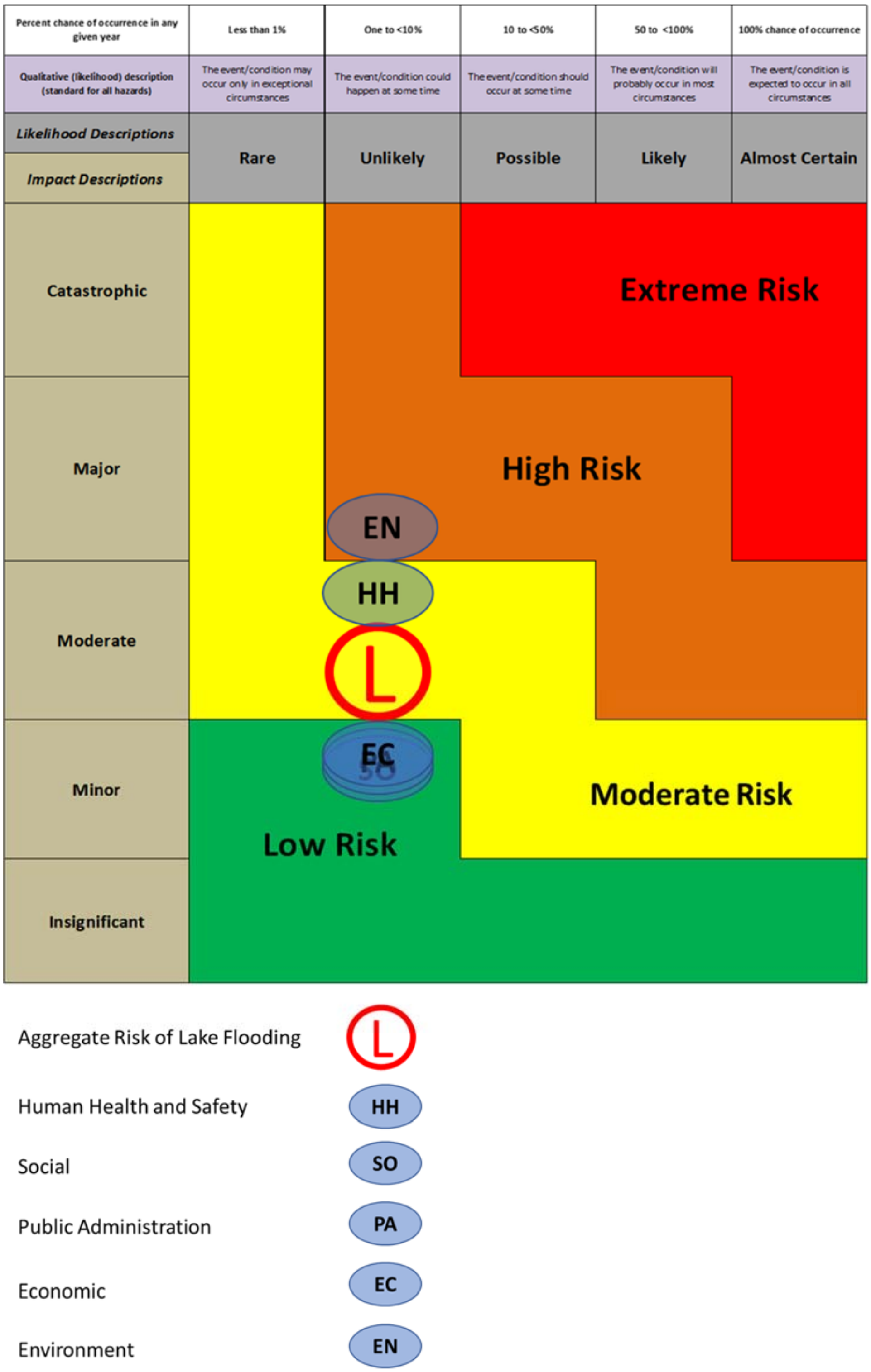


Figure 6.7 The risk of lake flooding in Saskatchewan based on impact categories and percent chance of occurrence. The red circle with the L in the centre indicates the aggregate risk of lake flooding across the provincially based impact categories for the worst-case scenario.

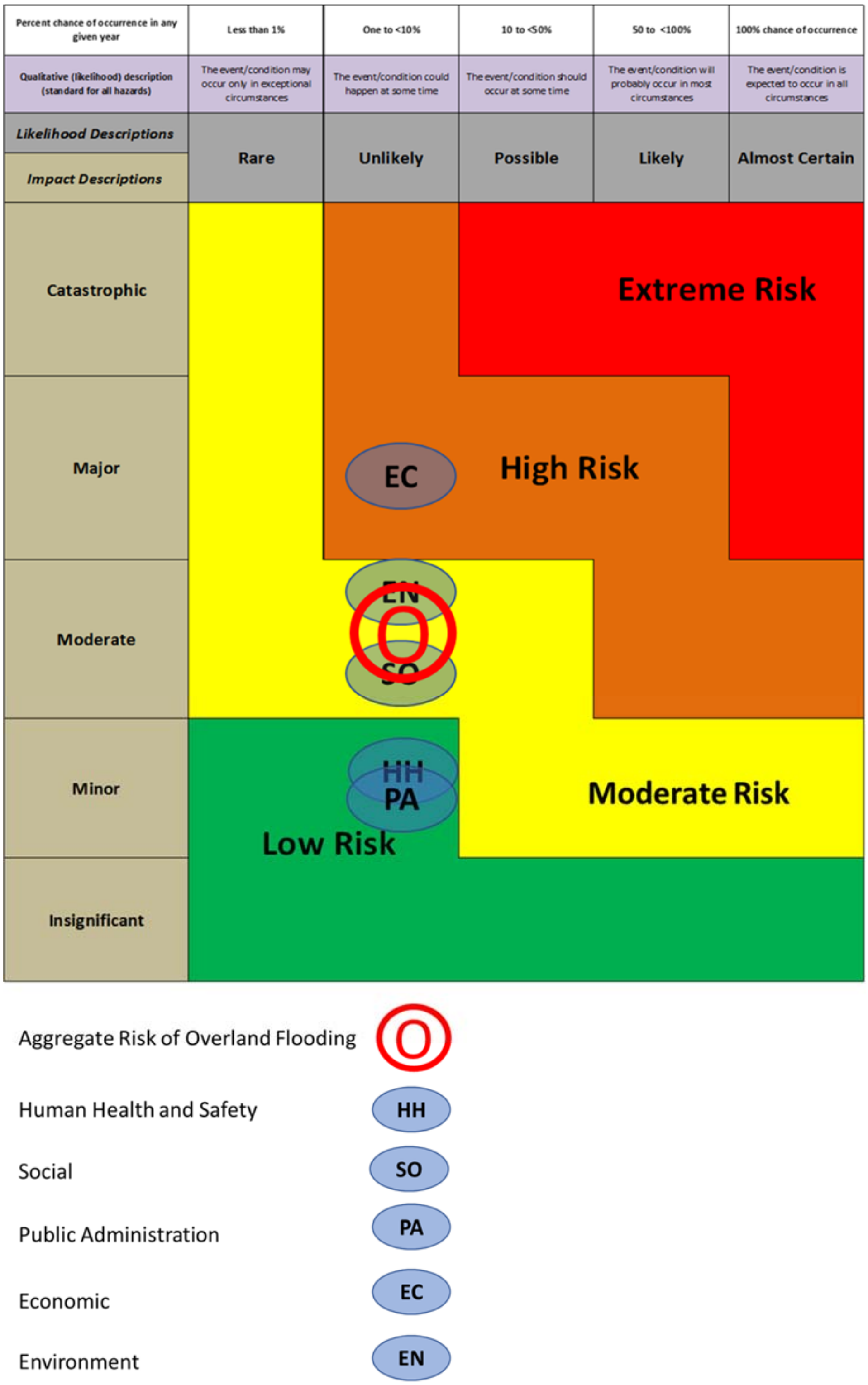


Figure 6.8 The risk of overland flooding in Saskatchewan based on impact categories and percent chance of occurrence. The red circle with the O in the centre indicates the aggregate risk of overland flooding across the provincially based impact categories for the worst-case scenario.

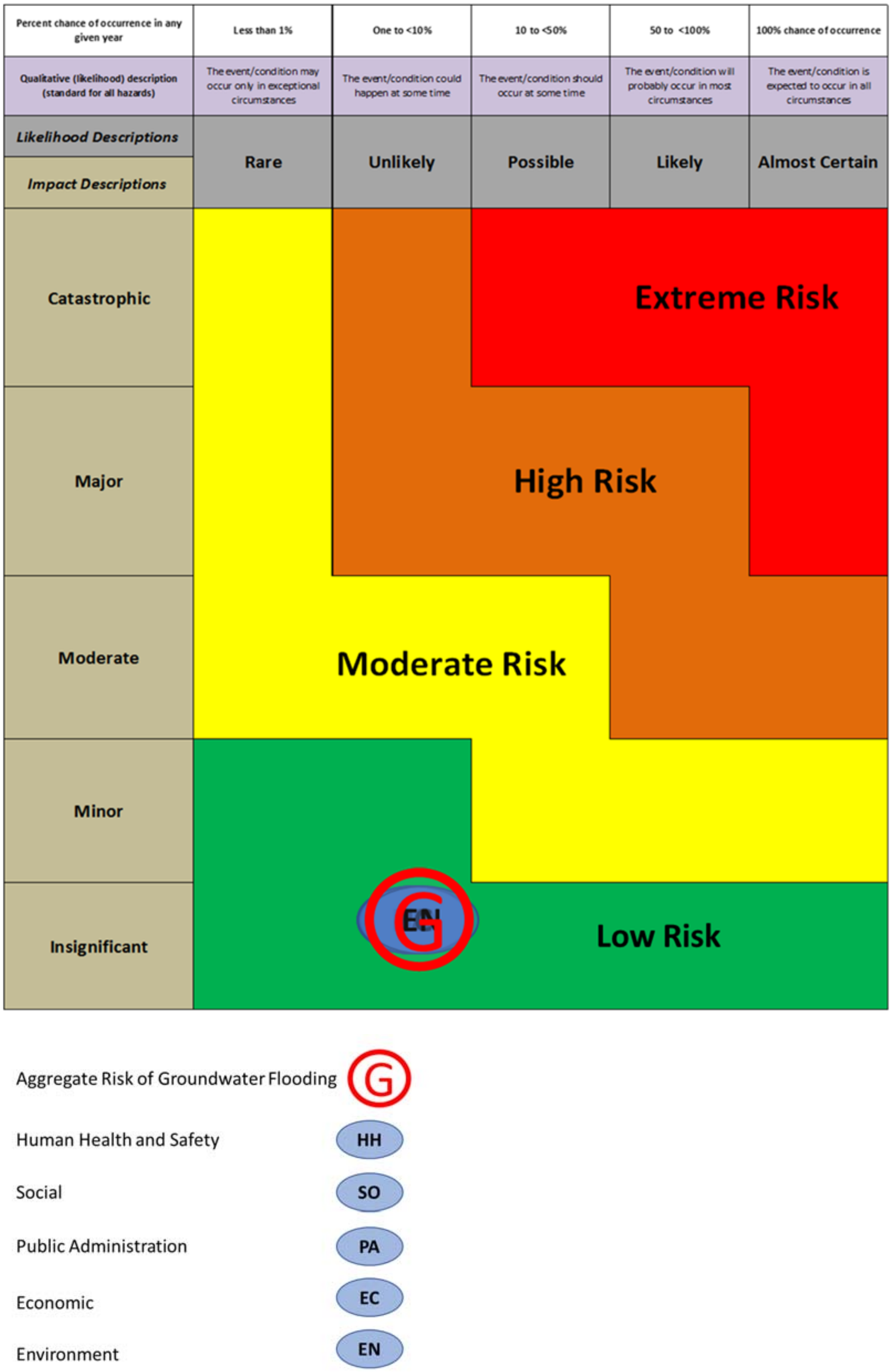


Figure 6.9 The risk of groundwater flooding in Saskatchewan based on impact categories and percent chance of occurrence. The red circle with the G in the centre indicates the aggregate risk of groundwater flooding across the provincially based impact categories.

Climate change scenarios support the likelihood of increased extreme weather events; hence, one would expect the consequences of the various modes of flooding to increase by some indefinable degree. As stated earlier in this chapter, types of floods that are currently rare in the province, such as mid-winter ice-jam floods, could increase. In a statistical sense, a flood that is currently a 1:100 event could become a 1:70 event, for example.

Assessment of Risk Reduction Measures

There are many measures that can be taken to reduce the risk associated with flooding in Saskatchewan. In a general sense, risk reduction measures can include reducing the hazard, reducing the exposure, and reducing the vulnerability (Shabman and Scodari 2014). Once measures are taken, the remaining risk to floodplain residents and assets is termed the residual risk. Residual risk will always exist, but risk can be significantly reduced.

Reducing the Hazard

Hazard reduction implies reducing either the quantity of water or the timing of water flows that may constitute a flood, or both. A common example is upstream storage or diversion of floodwaters. Dams are an obvious measure but floodwater may be diverted through other means such as dykes, storm channels, flow easements, or appropriate culvert sizing. Other options include restoration of wetlands, urban stormwater retention ponds, rain capture systems, and development of permeable urban surfaces. Hazard reduction measures that transfer the hazard to another geographic location may be valid, but require careful evaluation. Any structural measure aimed at reducing the hazard must be appropriately maintained to ensure that the measure is, indeed, reducing the hazard. Finally, temporary measures may also reduce the hazard.

Emergency Flood Damage Reduction Program

In February 2011 with forecasts of significant flooding, Saskatchewan instituted an emergency flood damage reduction program that included both permanent and temporary flood protection measures. Technical support and financial assistance were provided to communities and individuals for construction of dykes and berms, installation of culverts and gates, construction of permanent diversion works or channel improvements, and relocation of a principal residence. Temporary measures included assistance in pumping to reduce damage from overland flooding.

Over the years Saskatchewan has constructed a number of structures aimed at reducing the flood hazard. Rafferty Dam and the Regina and Lumsden dykes are examples. Communities have also taken some actions; stormwater detention ponds are now ubiquitous. Although some communities are taking steps to enhance permeability of new residential developments, none have bylaws that require that new developments do not increase runoff.

Reduce Exposure to the Hazard

Exposure reduction implies reducing the potential for people and assets to come in direct contact with the floodwaters. This is accomplished for the most part through floodplain mapping and appropriate zoning. Floodplain buyout programs can be used to replace at-risk assets with more appropriate use of floodplains such as parks and conservation areas. Mandatory flood insurance can also play a role in discouraging inappropriate development on a floodplain.

Under the Planning and Development Act, 2007, and regulations, all new official community plans and zoning bylaws must contain policies to address the management of lands subject to natural hazards, including flooding, slumping and slope instability. This includes the requirement that development be prohibited in the floodway of the 1:500 year flood elevation of any watercourse or water body and that new development in the flood fringe of a 1:500 year flood be flood proofed.

The former federal–provincial flood damage reduction program led to the mapping of many at-risk communities in the province. Unfortunately, the flood risk analysis and mapping have, with rare exceptions, not been kept up to date. As well, not all communities zoned their floodplains. The City of Moose Jaw has made a major effort to buy out floodplain properties over the years. Because of those purchases, the city's exposure to damaging floods has been significantly reduced. The effect of Hurricane Harvey on Houston, Texas, is the consequence of that city taking a hands-off approach to urban planning (Boburg and Reinhard 2017). The storm caused almost US$200 billion in damages, much of it in the Houston metropolitan area, and 82 fatalities.

Until very recently, flood insurance has not been available in Canada. The Canadian insurance industry has recently introduced a program but it is too soon to judge its effectiveness or its viability. The United States has a highly subsidized insurance scheme, but even then, the number of subscribers is relatively small.

Reduce Vulnerability to the Hazard

Vulnerability reduction implies reducing the likelihood that people and assets will be adversely affected by the flood hazard. Development of building codes and adoption of safe building elevations is a first step. Technical assistance and subsidies related to moving, raising or dyking at-risk structures would also help landowners. Preparedness actions, both at a community or individual level, such as flood forecast systems, evacuation plans, strategic equipment, and protection of critical infrastructure are also important.

Canada, unlike many developed countries, does not include flood-proofing measures in its model National Building Code. Although provinces can modify the code to meet regional requirements, none have done so with respect to flooding.

Saskatchewan specifies a safe building elevation that is 0.5 m above the 1:500 flood elevation. Given the uncertainty in the 1:500 flood level in many communities and concerns about wind and waves at some locations, the 0.5 m criterion could be considered as necessary but perhaps insufficient. Technical assistance is available to communities that have flooding problems, although not all communities seek advice, and provincial capacity is limited (Provincial Auditor 2015).

The Emergency Planning Act requires that every local authority in the province have an emergency plan. Such plans should cover both preparedness for and response to flood emergencies. While some Saskatchewan communities have good plans, others do not.

Conclusions

Many Saskatchewan communities are subject to known flood hazards. These include cities and towns as well as First Nations Reserves and resort villages. In recent years the effects of overland flooding in rural areas have been significant. Many of these at-risk communities and rural areas are found in the prairie ecozone of southern Saskatchewan. In general, however, the information required to determine a specific community-based flood risk is not available. Flood management in the province tends to rely on qualitative, rather than quantitative, assessments.

Because of the relatively frequent occurrence of flooding, flood disaster payments tend to represent the largest single payout from federal and provincial disaster relieve programs. These costs can be reduced through a combination of identifying and reducing the flood hazard, reducing the exposure to the flood hazard, and reducing the vulnerability to the flood hazard.

7. SEVERE DROUGHTS

E. Wheaton, V. Wittrock, and B. Bonsal

"Widespread drought is one of the most severe natural hazards to impact the prairies" (Anonymous Stakeholder in Corkal 2018).

Definition

Drought is a prolonged period of abnormally dry weather that depletes water resources for human and environmental needs. Drought is one of the most complex hazards and its importance is determined by its impacts and the effectiveness of adaptation (Bonsal et al. 2011).

The main types of drought are meteorological, agricultural, hydrological and socio-economical (Wilhite 2000, Maybank et al. 1995). Meteorological droughts are determined by the degree and duration of the dry period or time with inadequate precipitation. Agricultural droughts link the meteorological drought to agricultural impacts, often accounting for the soil and plant properties. Hydrological droughts are related to the effects of dryness on surface and sub-surface water supplies, such as streamflow, reservoir and lake levels, and groundwater. Socio-economic drought links the supply and demand of economic goods and services with the other types of droughts.

Description

"The Canadian Disaster Database identifies "prairie drought" as the number-one most costly disaster in Canada, recurring 4 times in the top 5 national disasters and 11 times in the top 20 national disasters during the period from 1900 to 2010" (Public Safety Canada, 2010).

The rationale for evaluating the risk of droughts is clear. Droughts are a severe threat to the economy, environment and society. Multi-year, large-area droughts are among the most costly natural disasters in Canada (Bonsal et al. 2011a). A good example is the Canada-wide drought of 1999–2005, which is one of the mostly costly of Canada's natural hazards at $5.8B (Cdn) in GDP, with an estimated loss of more than 41,000 jobs (Wheaton et al. 2008). Droughts are usually a greater threat for the Prairie provinces, especially Saskatchewan and Alberta; however, other areas across Canada also face water shortages and other impacts related to drought (Wheaton et al. 2008, Bonsal et al. 2004).

Droughts have major implications for society, economics, health and the environment. Droughts can have significant impacts on many sectors, including agriculture, forestry, industry, municipalities, recreation, and health (Bonsal et al. 2011a). The costs do not reflect the entire scale and range of harm due to droughts for several reasons, including knowledge gaps regarding damage to health (people and wildlife), damage to agricultural sustainability, such as soil erosion, and other continuing effects (Wheaton and Kulshreshtha 2017). Drought risk assessments are recommended to both better understand the drought hazard and to identify the factors and processes regarding the systems most at risk to drought and the reasons for this risk (UNISDR 2009).

Although extreme rainfall and ensuing flood hazards have been most noticeable in some recent years, drought hazards have the greatest impacts in Saskatchewan. Droughts tend to affect larger areas of our province and last longer than other hazards such as floods. Human activities and ecosystems require adequate and reliable water supplies. Therefore, droughts are serious threats to the economy, environment and society and are among Saskatchewan's and the world's worst hazards.

People are able to adapt to droughts, to a limited extent, to reduce their negative impacts to droughts and benefit from their positive impacts. However, past droughts in Canada have caused many challenges for adaptation, and several consequences were well beyond adaptation capabilities as documented for the severe drought of 1999 to 2005 (Wheaton et al. 2008). The potential for increased variability and worse droughts anticipated with continuing climate change will certainly increase the level of challenges (Bonsal et al. 2017). Therefore, considerable improvements are needed in understanding and monitoring droughts, and in adaptive capacities, planning, and action. The identification and understanding of drought hazards are critical for assisting Saskatchewan and Canada in developing plans and adaptation measures to effectively reduce the negative impacts of droughts and to take advantage of positive impacts.

It is widely recognized that drought is a complex hazard that is quite different in many ways from the other climatological and hydrological hazards, such as floods, windstorms, tornados, and hail. These differences include longer durations, greater areas, lack of easily identified start and end times, and multiple causes and impacts (Bonsal et al. 2011). Other differences include more cumulative effects, wider area of impacts, and often more difficult planning, preparations and responses (Wheaton ISGP 2015). Therefore, the planning and management of drought, as well as research, are a considerable challenge. For more complete details on data, methods, and various results see Wheaton et al. (2018).

Provincial Risk Statement

The level of provincial risk of drought depends on the type of drought, its severity, its location and area impacted and the time period the drought lasts. As mentioned previously, the main types of droughts are meteorological, agricultural, hydrological and socio-economical. Mitigation strategies to drought events have improved since the 1930s with the augmentation of various safety nets, ranging from crop insurance, to individual farmers creating water storage units (e.g., dugouts) that last at least two years (Wheaton et al. 2008), to cities imposing watering restrictions during drought years (Wittrock et al. 2001); nevertheless, drought events still result in a high degree of risk for the province.

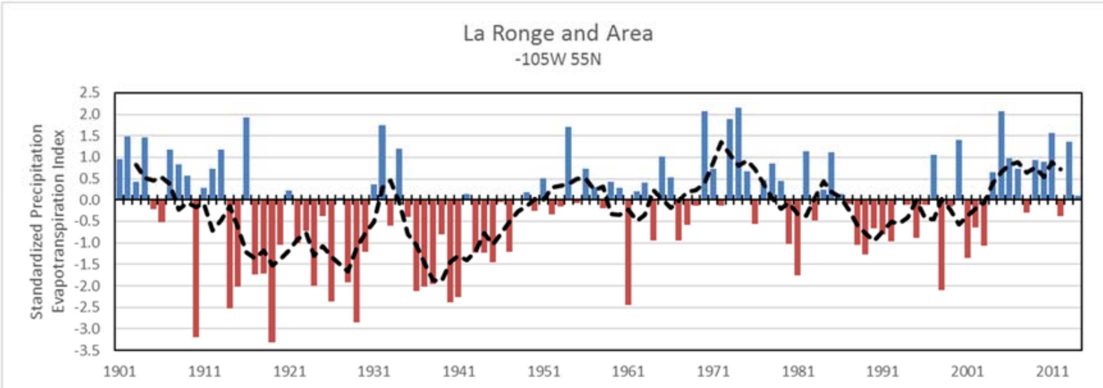
This high risk can be shown by the various impacts that resulted from the severe 1999–2005 multi-year drought event, with the most severe years occurring during the 2001–2002 period. Besides resulting in an estimated $1.6 billion loss in agricultural production in Saskatchewan, there were water shortages for large and small communities with the added costs of maintaining potable quality of water for both people and animals. Other effects included the potential that Alberta would not have met its Prairie Provinces Water Board agreement, high levels of stress in the agricultural community and large reductions in grass growth (Wheaton et al. 2008). These impacts were echoed in the stakeholder workshops (Corkal 2018).

The stakeholders identified that water quantity (both surface and ground water) and quality were primary impacts of drought. Water scarcity negatively affects human and animal needs in communities, and affects industry and economic activities. They also indicated that it's not just agriculture that is impacted by drought, but other sectors as well, including recreation, and consequently tourism, hydropower generation, and other water users, all of which may have competing interests (Corkal 2018). Impact assessments (e.g., Wheaton et al. 2008) support this finding, and give further details on ripple effects through other sectors of the economy.

Previous Significant Events

The years 1961, 1988 and 2001–2002 have been described as among the worst droughts in recent decades (e.g., Bonsal et al. 2011, Hanesiak et al. 2011). We examined their characteristics using the Standardized Precipitation Evapotranspiration Index (SPEI) (Vincente-Serrano et al. 2010). The SPEI is a water balance indicator calculated as the difference between precipitation and potential evapotranspiration. The SPEI was selected because it has several advantages over other drought and water balance indicators. The time interval selected for the SPEI was the "agricultural year" of September 1 to August 31 of the following year (SPEI-12, i.e., 12 months). The study area south of 54°N was used for the SPEI analysis. We focused on severe to exceptional droughts, that is, SPEI of -1.5 and less.

We examined the annual variations of the water balance indicator for the 1900 to 2014 period. The year 1961 was the worst single year for most of the analyzed locations (Figure 7.1). Other droughts included 1988 and 1999–2005. These more recent droughts were so severe that projects were completed to document their effects (Wheaton et al. 1989, Wheaton et al. 2008). Therefore, these years were selected for analysis of spatial patterns of previous severe droughts (Figures 7.2–7.5). One reason for assessing individual droughts as well as their frequency is to determine their spatial characteristics and variability. These characteristics and applied adaptation measures are significant, as they affect the extent and severity of the drought impacts. This information is vital for appropriate planning, preparation, and implementation of measures to decrease the negative impacts of droughts.


La Ronge and Area
-105W 55N
Standardized Precipitation Evapotranspiration Index
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
1901
1911
1921
1931
1941
1951
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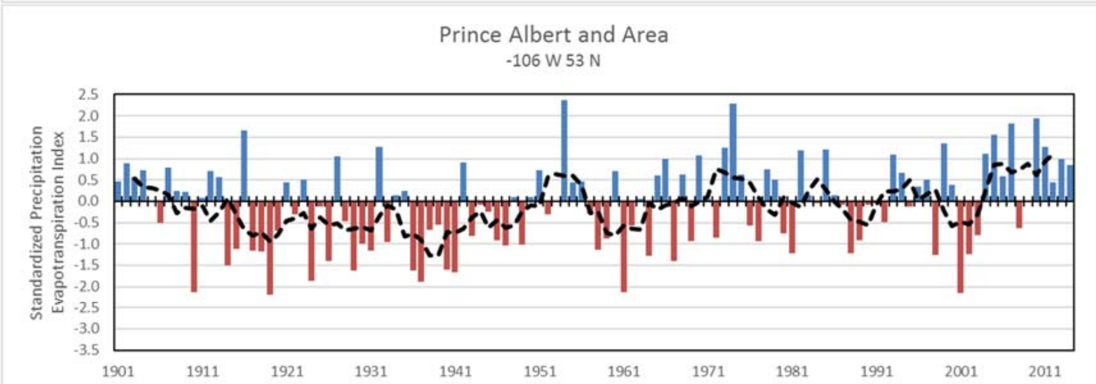
Prince Albert and Area
-106 W 53 N
Standardized Precipitation Evapotranspiration Index
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
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1901
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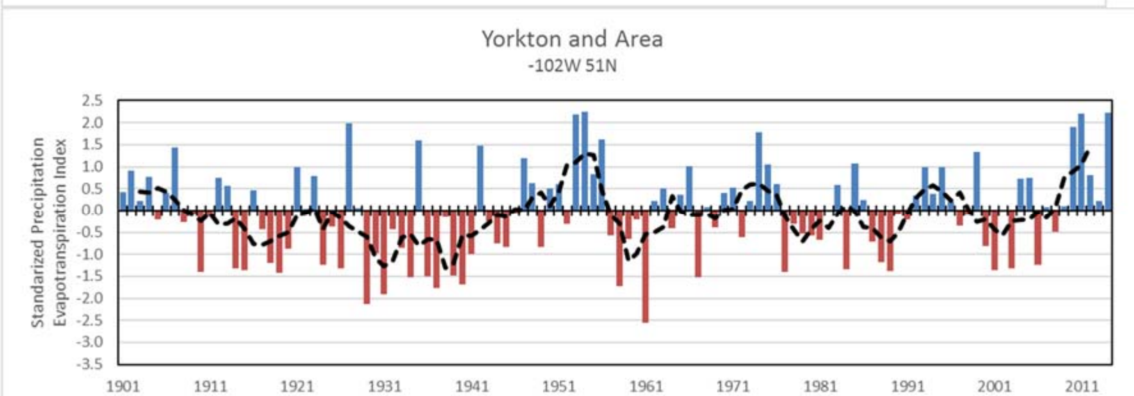
Yorkton and Area
-102W 51N
Standardized Precipitation Evapotranspiration Index
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
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1901
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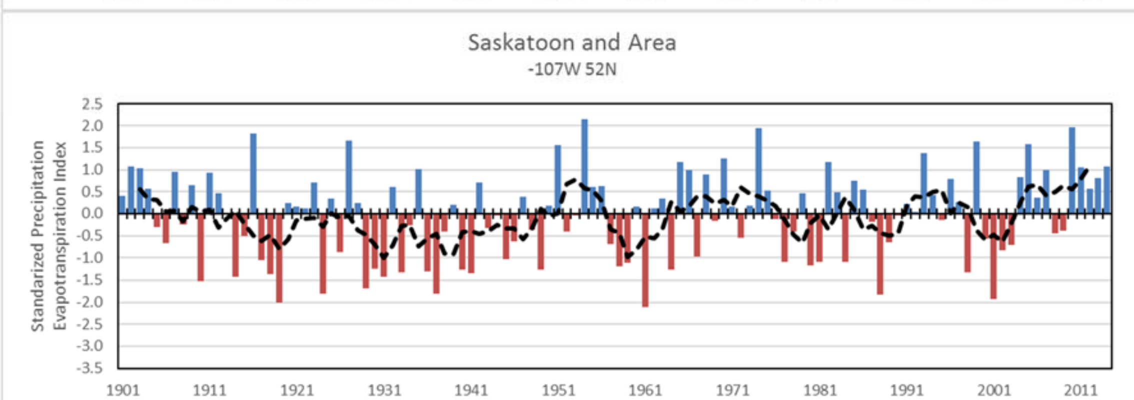
Saskatoon and Area
-107W 52N
Standarized Precipitation Evapotranspiration Index
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
1901
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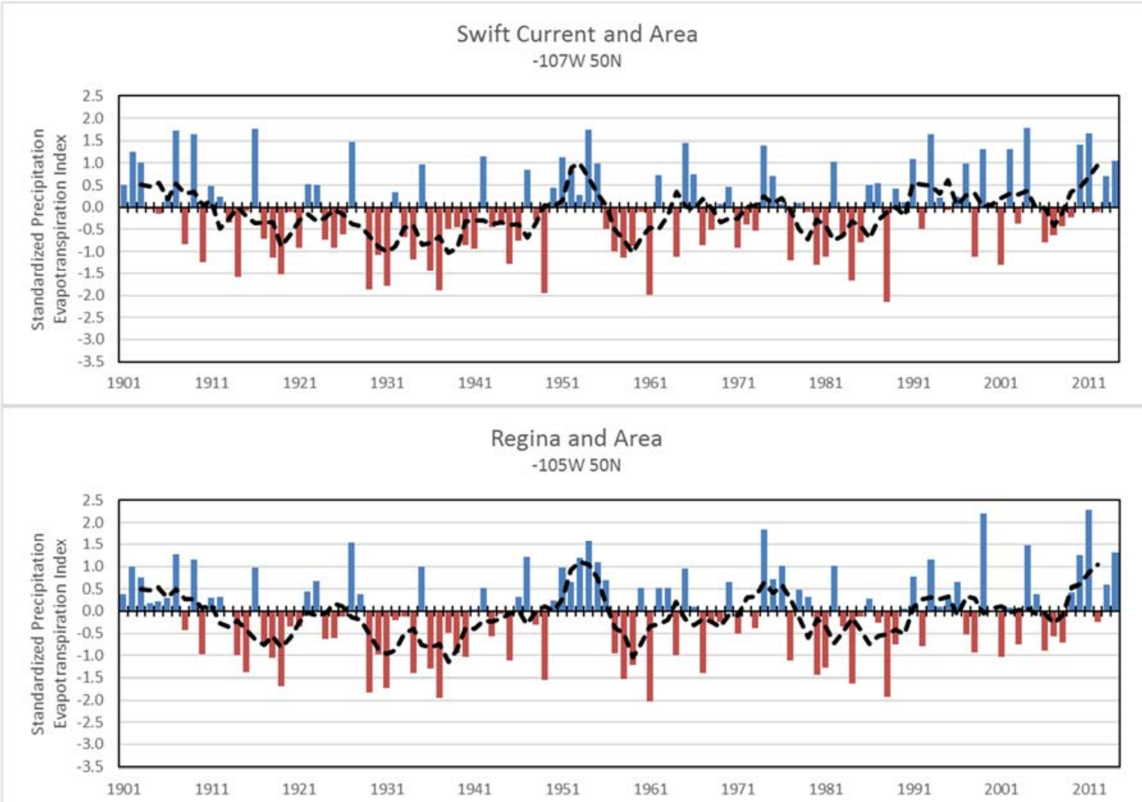


Figure 7.1 The time series of SPEI-12 values, 1900–2014, for the agricultural year for the grid cells including La Ronge, Prince Albert, Yorkton, Saskatoon, Regina and Swift Current. The blue bars indicate wetter conditions and the red bars indicate drier conditions. The black dashed line is the five-year running average over the 1900 to 2014 period. (SPEI data sources: Tam et al. 2016, Vincent et al. 2015, Tam et al. 2018)

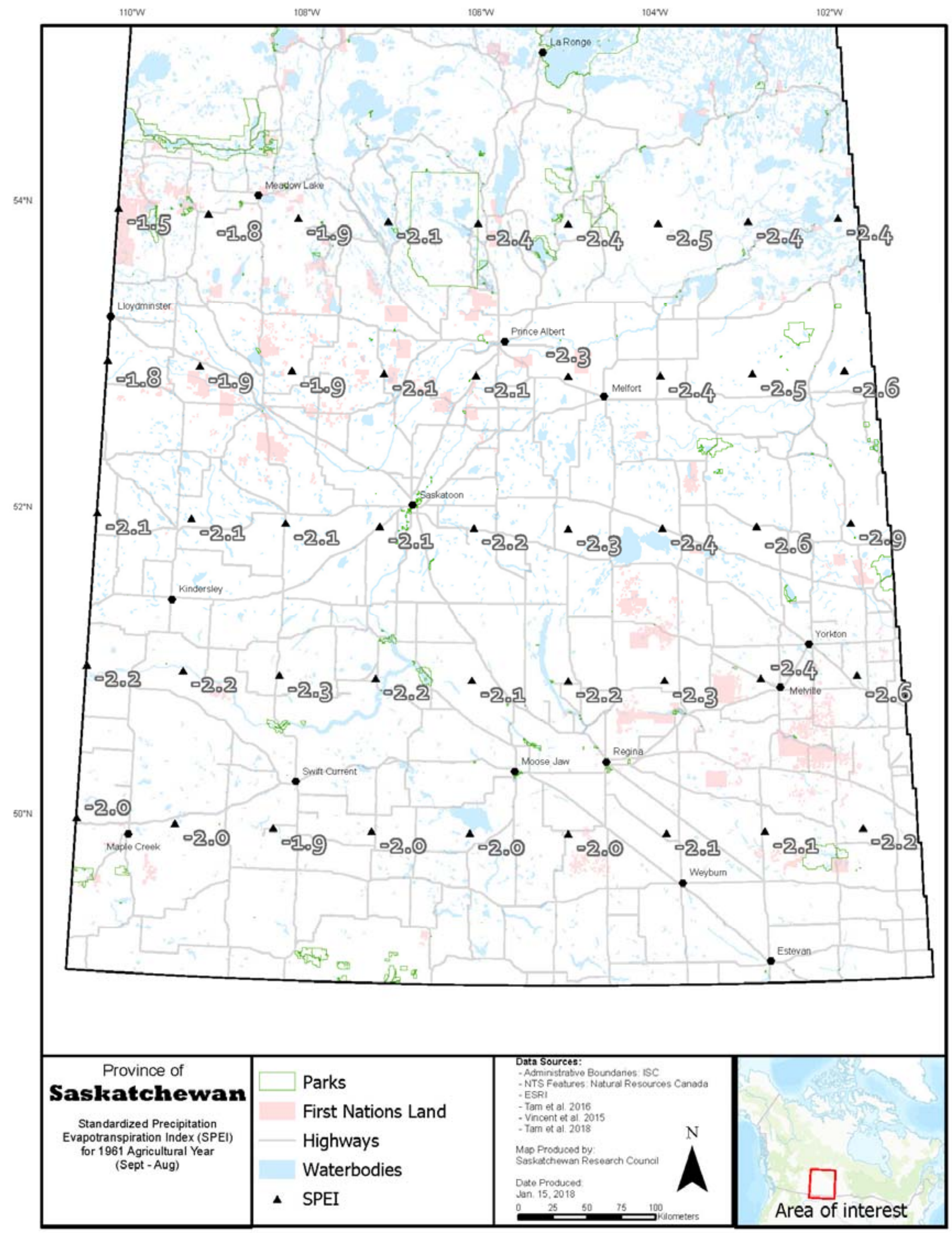


Figure 7.2 Spatial patterns of SPEI-12 months for previous main drought year of 1961 (SPEI data sources: Tam et al. 2016, Vincent et al. 2015, Tam et al. 2018)

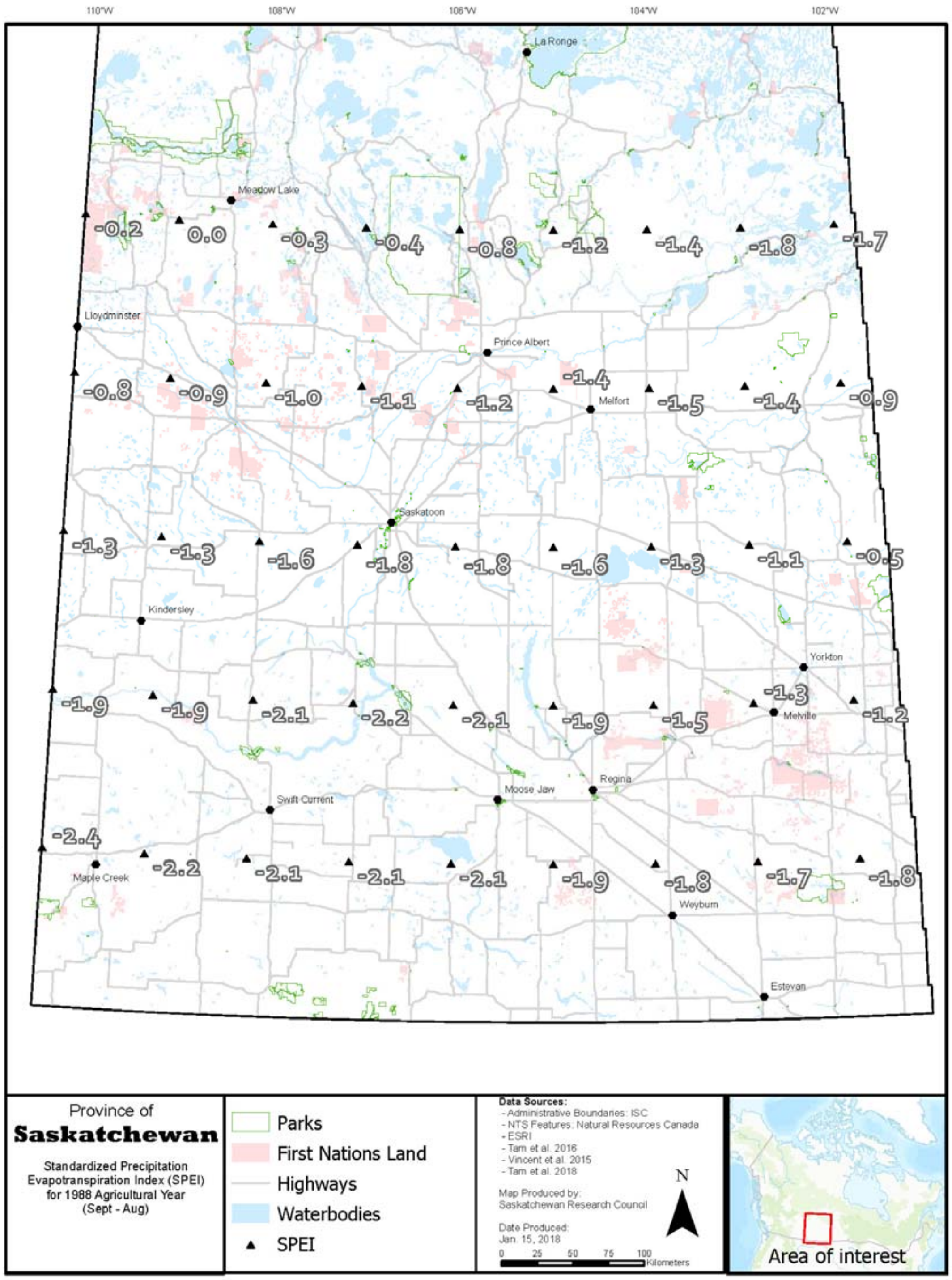


Figure 7.3 Spatial patterns of SPEI-12 months for previous main drought year of 1988 (SPEI data sources: Tam et al. 2016, Vincent et al. 2015, Tam et al. 2018).

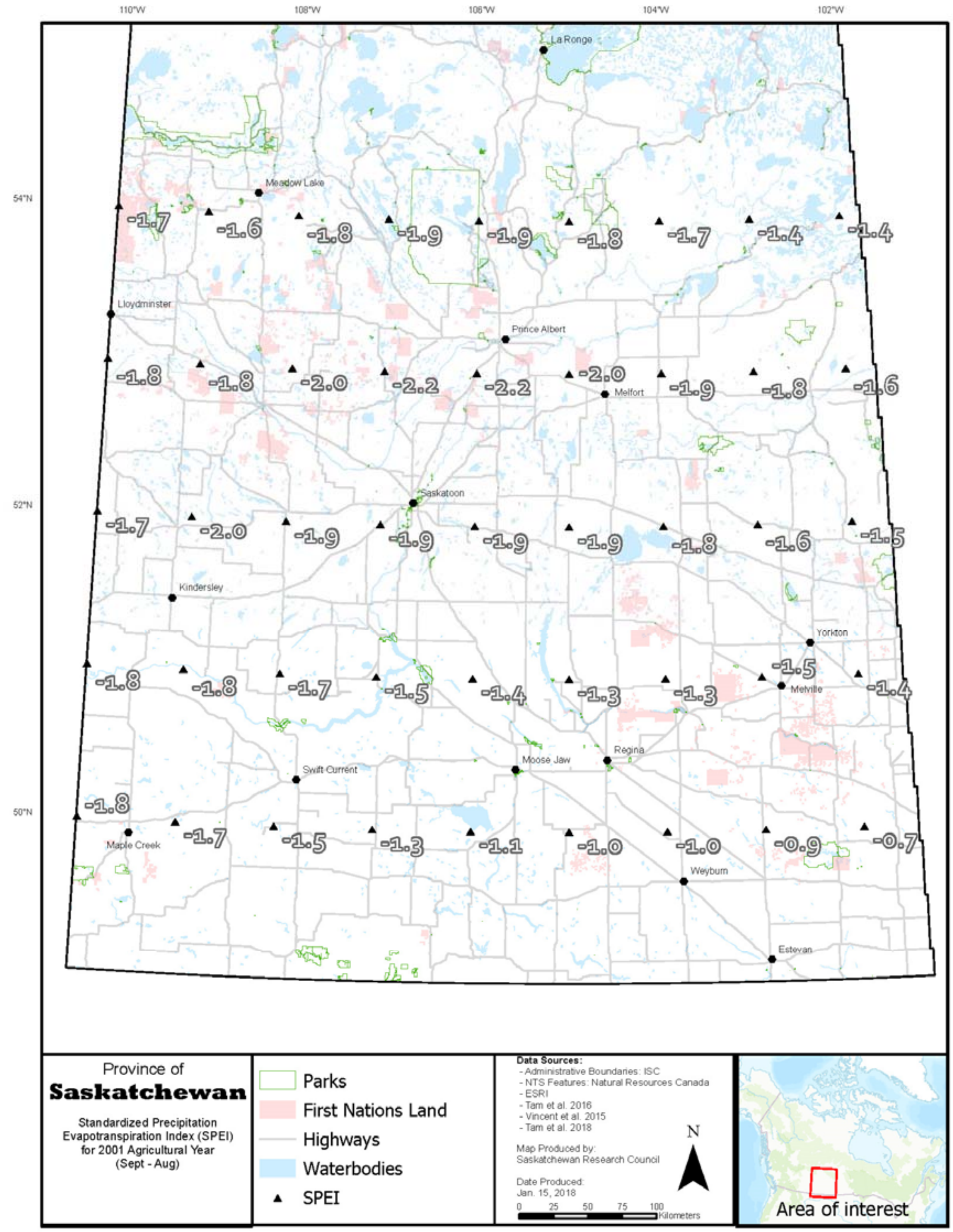


Figure 7.4 Spatial patterns of SPEI-12 months for previous main drought year of 2001 (SPEI data sources: Tam et al. 2016, Vincent et al. 2015, Tam et al. 2018)

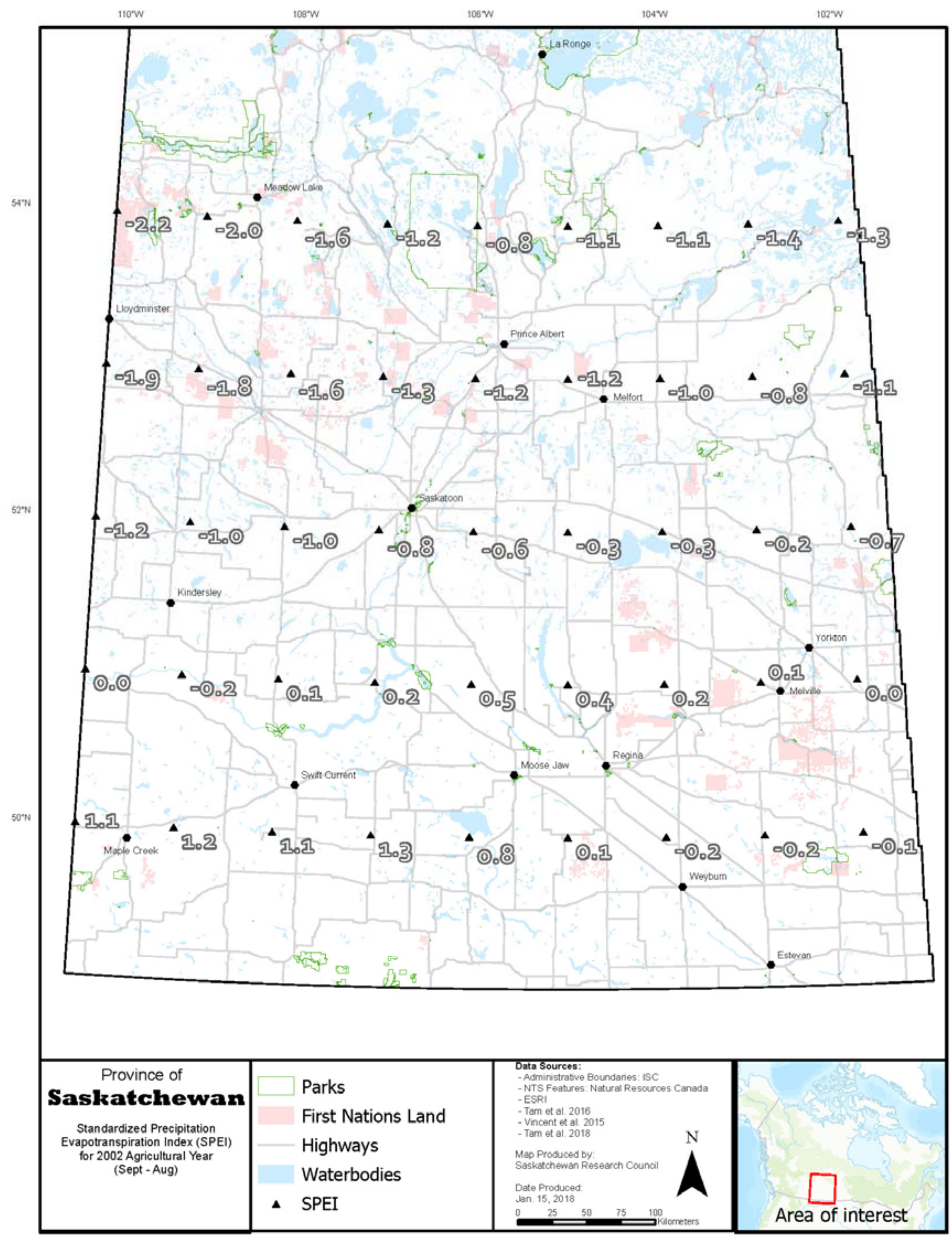


Figure 7.5 Spatial patterns of SPEI-12 months for previous main drought year of 2002 (SPEI data sources: Tam et al. 2016, Vincent et al. 2015, Tam et al. 2018).

In 1961, the entire study area was in the severe to exceptional categories of drought with values of SPEI-12 for the agricultural year at -1.5 and less. The worst droughts in 1961 were located in the central-east part of the study area, just northeast of Yorkton at -2.9, i.e., the exceptional category. The least severe droughts were in the far northwest, and in the southwest.

The worst condition during the drought of 1988 was rated extreme at -2.4, and was located in the southwest, a normally dry area of the province. Several grid cells in the northwest even escaped the drought as they had near-normal conditions. The transition from extreme drought to normal conditions in the west was fairly steep and the drought did not appear as uniform as in 1961.

The drought years of 2001–2002 also had contrasting spatial patterns. The worst droughts in 2001 were in the central north, just south of Prince Albert, with two grids at -2.2 or the extreme class. The best conditions were just drier than normal at -0.7 (mild drought) in the extreme southeast. However, drought conditions were widespread, with most of the other areas having droughts of -1.5 to -2.0, or in the severe class.

The next year, 2002, had a severe record-breaking rainstorm and flooding in June 2002 (Szeto et al. 2011), and several parts of the southwest reached SPEI values over 1.0 to a maximum of 1.3, or moderate excessive moisture conditions. The worst drought conditions had migrated even farther northward than in 2001, with the worst drought at -2.2 or extreme in the far northwest, north of Lloydminster. Several grid cells had drought worse than -1.5 (severe) or worse in the northwest.

Climate Change Implications

"***Analysis (of) results indicate that the 2015 extreme drought in western Canada was likely an outcome of anthropogenically influenced warm spring conditions and naturally forced dry weather from May to July***" (Szeto et al. 2016 p. S42).

"We are probably due for a much worse drought in the coming decades" (Anonymous Stakeholder in Corkal 2018).

Projected future changes of drought characteristics and changing drought risks are difficult to estimate, mostly due to the uncertainty regarding future precipitation and the current high variability, as well as changing adaptive capacities. However, a higher frequency and severity of future droughts is expected, especially in the Canadian prairie ecozone, as indicated in the many literature sources reviewed by Wheaton et al. (2013) and Wheaton and Kulshreshtha (2017).

"***Climate change is, therefore, an important factor to be considered in drought risk analysis***" (UNISDR 2009:13).

The effects of climate change on drought, such as for 2015, are already being indicated (Szeto et al. 2016) and future droughts are expected to become even worse (e.g., Wheaton et al. 2013, Wheaton et al. 2016, Masud et al. 2016, 2017, Bonsal et al. 2017). This section provides an overview of recent literature regarding future possible droughts in the Prairie provinces, with emphasis on Saskatchewan. A detailed review of results regarding possible future droughts was completed by Wheaton et al. (2016), and highlights are provided here.

Changing characteristics of drought severity, frequency, and maximum duration were estimated by PaiMazumber et al. (2013) for the Canadian Prairies (Figure 7.6). They found that six- and ten-month droughts would become more severe over southern Saskatchewan in the 2050s compared with the 1971–2000 period. The ten-month droughts are expected to increase by as many as four events in the 2050s. They point out several limitations of the modeling, including biases in the Canadian Regional Climate Model results, use of only precipitation change, and only one model. However, they identify the southern Prairies as a "hot spot" with high likeliness of severe and more frequent droughts (Figure 7.6). Therefore, they indicate that more efficient and numerous adaptation strategies are essential to deal with the impacts of such droughts.

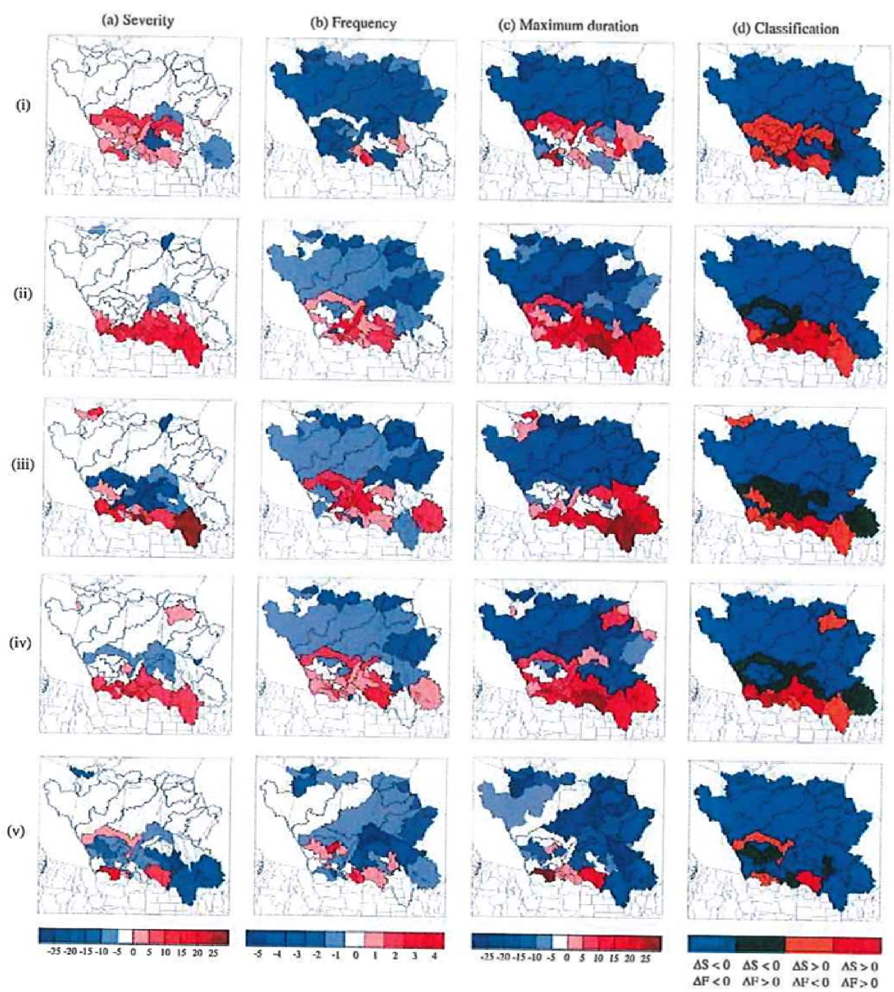


Figure 7.6 Projected changes to the a) severity (in %), b) frequency and c) maximum duration (months) of 10-month droughts at the watershed scale, and d) classification of watersheds based on projected changes to severity (S) and frequency (F) of 10-month droughts for the 47 watersheds located in the Canadian Prairies, for the five pairs of Canadian Regional Climate Model simulations for the 2041–2070 period. (PaiMazumber et al. 2013)

Many changes in the characteristics of drought were examined by Bonsal et al. (2013) covering three periods, the pre-instrumental, instrumental, and future periods in the study area of Alberta and western Saskatchewan. They found multi-year droughts to be more frequent in the future compared with the instrumental period (105 y). The length of drought was measured by the average number of consecutive summers with a negative Palmer Drought Severity Index (PDSI). During the instrumental period, summer droughts five years and longer have a frequency of approximately 2 per 100 years (2%). This frequency was found to more than double to about 4% in the future to 2100. The frequency of future droughts of 10 years or longer increases to just over 3%.

More recent work has emphasized these findings. Bonsal et al. (2017) assessed historical and projected future hydro-climatic variability and extremes over southern watersheds of the Canadian Prairies. Atmospheric patterns are important drivers of drought. The authors found patterns linked with extreme dry conditions to continue into the future (2041–2070) and to increase in frequency, in some cases.

The implications of future climate for water availability in nine major western Canadian river basins, including the Saskatchewan River Basin, was examined by Dibike et al. (2016). They projected decreasing water availability in summer for all these river basins in Western Canada except for the one farthest north. Some projections for the Saskatchewan River Basin showed among the largest widespread annual water deficit, with summer frequencies of deficits over 20% for the 2050s (Figure 7.7).

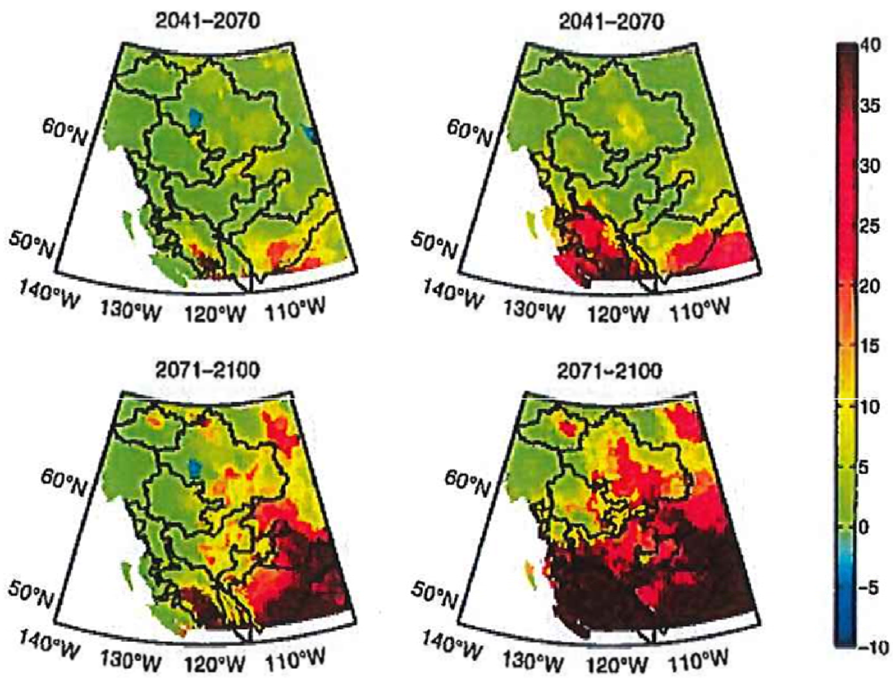


Figure 7.7 Ensemble mean percentage changes in the frequency of severe water deficit corresponding to the SPEI-12 (left) and SPEI-3 (right) between the baseline (1980s) and the 2050s (top) and 2080s (bottom) time periods corresponding to the RCP8.5 climate scenario (Dibike et al. 2016: Figure 10).

Summarized characteristics of future possible droughts in Saskatchewan include (Wheaton 2013, Wheaton et al. 2016, Wheaton and Kulshreshtha 2017):

- They have increased intensity of dryness, driven by increased evaporation potential. Drying likely overwhelms projected increases in average precipitation amounts.

- Droughts at least 6–10 months long increase in frequency by about an additional 4 events by the 2050s. The number of longer droughts doubles towards 2099.
- The number of droughts of at least five years doubles towards 2099.
- Decade-long droughts triple in frequency towards 2099.
- Storms with extreme precipitation are interspersed with droughts.
- Surprises result with the new combinations of climate variables.
- Worst-case scenarios of mega-droughts with even more intensity, frequency, duration and area are possible, but with low probability.

A warming climate increases the risk of both droughts and heavy rainfall events. Several factors, including basic theory, climate model simulations and empirical evidence converge to support this conclusion. The past alone is no longer a sufficient guide to the future. Confidence has increased that droughts and extreme rainfall events will become more numerous, widespread and/or more intense. A main conclusion is wet times get wetter and dry times get drier. Surprises are also likely as the climate destabilizes and storm patterns become more unusual. Globally, mid-continental and higher latitude locations such as Saskatchewan may be affected first and with most intensity.

Worst-Case Scenario

As indicated in the significant events section in this chapter, 1961 had the worst drought in the 1900–2014 period for several areas in Saskatchewan. A worst-case scenario for drought would be an SPEI drought level of 1961 but lasting for an extended period of time such as 10 years. Ten-year-long droughts have been documented to have occurred in the past in the Canadian Plains in both the instrumental and pre-instrumental periods (e.g., Sauchyn and Kerr 2016, Bonsal et al. 2013). Therefore, this type of drought was selected as a possible scenario for a worst-case event.

The possible impacts of such a future 10-year drought would be large scale hydrologic and agricultural droughts leading to a socio-economic type of droughts. Note that the impact levels shown in brackets and italics relate to the provincial risk matrix. Refer to the methodology section of the report for more information. The results of these long-term droughts could be very severe, including such consequences as people moving from one location to another similar to what occurred in Alberta and Saskatchewan in the 1930s (Marchildon 2007). The hydrological drought would result in major decreases in both quantity and quality of water that would affect industry and communities to the level of limited surface water availability and very poor water and air quality (*Human Health-major*). Droughts also have an impact on visibility due to blowing dust. These events are associated with traffic accidents and have been a contributing factor in road fatalities (Wheaton et al. 2008) *(Human Health – major to catastrophic).* As noted in Chapter 8, there is potential for injury and death due to wildfires (*Human Health -major to catastrophic*). A 10-year drought may result in widespread evacuations and regional psychosocial impacts, for both the people that evacuated and the people that stayed in their communities (*Social-major to catastrophic*). A 10-year hydrological drought would require specialized government responses at various levels with the potential for violating national and international agreements (e.g., water sharing agreements with the Prairie Provinces Water Board and the International Joint Commission) (*Public administration-catastrophic*).

"Low flows [in transboundary rivers] are challenging for interprovincial [and international] water sharing" (Anonymous Stakeholder in Corkal 2018).

The economic impacts of a 10-year drought could result in an economic decline of at least 5 percent of the GDP. The drought of 2001–2002 resulted in agricultural production losses in Saskatchewan of more than $1.6B (Wheaton et al. 2008); losses from a 10-year drought's economic decline would likely result in a GDP decline of much more (*Economic-catastrophic*). A 10-year drought impact on the environment can lead to deterioration of grassland and decreased grassland production and other ripple effects like grassfires on ecosystems, and plant mortality may facilitate invasion of exotic species (Thorpe 2011) (*Environment-moderate to major*). The return to a productive level of native species depends on a multitude of factors including timing of growing season precipitation and livestock grazing management (Thorpe 2011). The hydrological drought may also result in lack of available water supplies (Corkal 2018) that are a tool in extinguishing fires. This lack of surface water for usage in local fire fighting capability in Southern Saskatchewan may result in a larger burned area and have a *moderate impact* on the environment.

Existing Controls

"Develop more drought resistant [crops]…discourage the breaking of marginal lands. Develop best practice irrigation capacity…encourage novel forms of agriculture" (Anonymous Stakeholder in Corkal 2018*).*

Several adaptation measures are used for agriculture to adapt to drought; however, many are costly and disruptive. The documentation of adaptation measures is rare; therefore, work by Wheaton et al. (2008) and Wittrock et al. (2010) is a main source of information. An increased reliance on irrigation, where possible, was a primary adaptation to drought documented for the 2001–2002 drought. Increased irrigation, however, resulted in higher energy and labour costs. Other adaptation included small reductions in fertilizer and herbicide applications, fuel and labour. Many adaptations proved insufficient to deal with such an intense, large-area, and persistent drought, underlining Canada's vulnerability to such events (Wheaton et al. 2008).

The stakeholders in the consultations recommended proactive planning and revisiting drought preparedness planning (Corkal 2018). These stakeholders suggested a program similar to the FireSmart program utilized in the forested regions of the province but having the drought program focused on drought planning (Corkal 2018). The Saskatchewan Water Security Agency has an action item in its 25-year planning process to develop a coordinated provincial drought response plan that includes monitoring, preparedness, response and recovery approaches (Saskatchewan Water Security Agency 2012).

Many other adaptation strategies have been implemented. For livestock operations, these included transporting hay, using more unusual feed types, and using available public and private lands as well as cropland for grazing. Where and when these adaptation options were not successful, livestock lost weight, became sick, and some died. When so much livestock feed is affected so severely for so long, limits to adaptation are reached (Wheaton et al 2008).

The 2001–2002 drought spurred work to improve the understanding of the current adaptation processes and options in Canada, resulting in the Agricultural Drought Adaptation Project (ADA), summarized in Wheaton et al. (2007). Dynamics of the adaptation process were examined by analyses of print media. The most commonly mentioned types of adaptation options were in the categories of crops and livestock, followed secondly by water and economics. These types reflect the level of discussion and concern for the impacts of and the need for dealing with these effects. The total number of media articles during 1999 to 2006 was highest in August 2002, and declined very slowly afterwards. This timing seemed to indicate the peak of concern and effort.

The ADA work also examined "barriers and bridges" for adaptation to drought, as adaptation is most effective if it is practical, implemented, and facilitated, and has few barriers. Barriers documented for the Prairie Provinces included the need for better knowledge of water supplies and water used, lack of funds, lack of research, and difficulties in dealing with change. Effectiveness was further described through aspects such as residual negative impacts, positive impacts, opportunities, innovations, and maladaptation (Wittrock and Wheaton 2007). The ADA work documented many characteristics of adaptation, including the most frequently used options, their effectiveness, and space and time characteristics.

Government response and safety net programs partially offset the negative economic and social impacts from the 2001–2002 drought. These included crop insurance, the Rural Water Development Program, the Net Income Stabilization Account, the Canadian Farm Income Program, and the Livestock Tax Deferral Program. The provinces that received the highest payments from crop insurance in Canada (Wheaton et al. 2008) were Saskatchewan (over $1 billion), and Alberta (almost $800 million).

The challenges posed by the 2001–2002 drought were unusually severe, particularly for some sectors and for many regions. Therefore, many and a wide range of adaptation measures were used. However, because of the severity and extensiveness of the drought, losses mounted and could not be adequately dealt with, as evidenced by the lingering impacts and the costs. These findings have many implications for measures to deal with and to plan for future droughts.

As noted in Corkal (2018) and Johnston (2018) in this report, fires are seen as a risk to communities. Existing controls of these include emergency management systems such as Emergency Management and Fire Safety, Fire Commissioners, and Forest Fire Commissioners. Mutual aid agreements are beneficial to get assistance from others trained in specific emergency response (Corkal 2018).

Industries such as power generation utilize large amounts of surface water. During the drought of 1988, drilling deep water wells offset the lack of surface water but resulted in a major decline in groundwater level in the region (Wheaton et al. 1992).

Provincial Risk Analysis

"While floods get the media attention, they can be largely mitigated through proper planning and flood proofing. The bigger long-term risk is drought, which has been experienced in the past, but climate models suggest these could be longer and more severe in the future" (Anonymous Stakeholder in Corkal 2018).

The plausible worst-case scenario of a 10-year extreme drought event, as presented in the worst-case scenario section, results in the impacts ranging from moderate to extreme, depending on the type of impact, creating a high risk for the province. The frequency of the long-term (e.g., 10-year)

droughts is 1.0 per 100 years (1901–2005) (Bonsal et al. 2013) and in the risk matrix such droughts are classified as "*unlikely*" for occurrence.
The provincial-scale risk matrix heat map (Figure 7.8) shows that the aggregate risk of the worst-case drought scenario is "high risk." This is because of the potentially *catastrophic* impacts on the provincial economy, public administration and human health and safety, plus major to catastrophic impacts for the social impacts, and moderate to major for the environment. The risk matrix heat map (Figure 7.8) summarizes the worst-case scenario conditions. The red circle with the "D" in the center is the aggregate risk level of extreme drought conditions. The aggregate risk is the approximate average of all the impacts and likelihood description.

"We are probably due for a much worse drought in the coming decades" (Anonymous Stakeholder in Corkal 2018).

The frequency of long-term droughts in the future is projected to be even greater than during the instrumental and pre-instrumental periods (Bonsal et al. 2013). This increased frequency would likely shift the percent chance of occurrence of the impacts closer to the *possible* likelihood description and therefore into the ***extreme risk*** category on the risk matrix (Figure 7.8).

Conclusions

"We need to better understand our resilience to future drought and develop mitigation, adaptation or contingency plans. Drought is insidious, and it is easy to become complacent during 'normal' or wet periods such as we have experienced in recent years" *(*Anonymous Stakeholder in Corkal 2018).

This chapter included descriptions of the drought hazard in Saskatchewan, current and future possible impacts, adaptation, vulnerabilities, risk matrices. A reference/bibliography section is located at the end of the report. Risk assessment requires knowledge of the frequency of drought, impacts and adaptation. Vulnerability assessment uses knowledge of the exposure to drought, sensitivities, and adaptive capacities. These results have indicated areas of greatest exposure to drought and the nature of the changing characteristics of drought from the past into the future.

Many research recommendations can be made because drought is such a complex issue. A main focus for further analysis would be research regarding the characteristics of longer duration droughts, such as consecutive one-year droughts. Also, droughts tend to migrate and change in intensity over time. Further examination of the spatial and temporal patterns of drought migration would also be important for improved monitoring and adaptation to the impacts of drought.

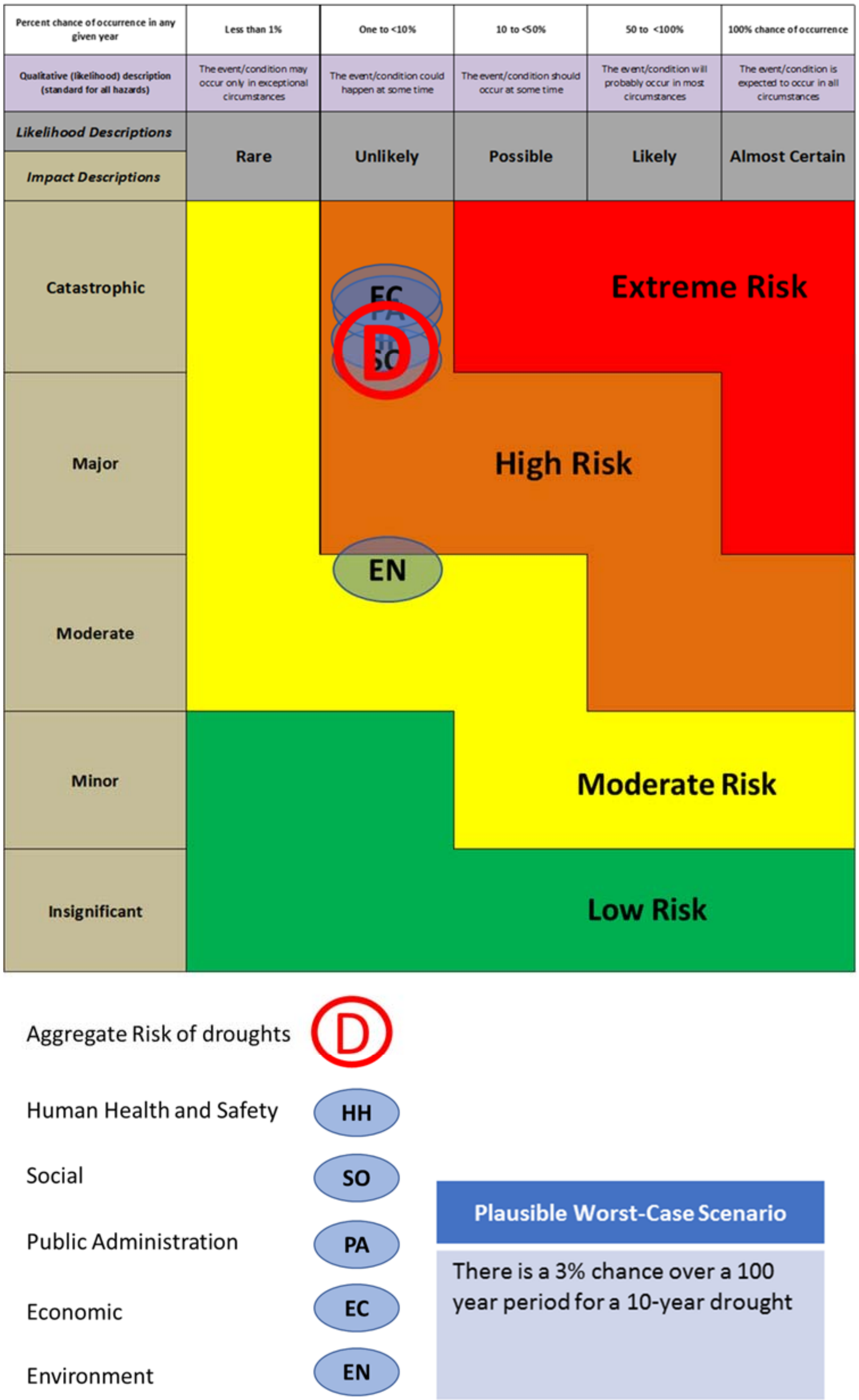


Figure 7.8 The risk of droughts in Saskatchewan based on impacts categories and percent chance of occurrence. The red circle with the D in the centre indicates the aggregate risk of drought across the provincially based impact categories for the worst-case scenario.

Ground crew fire fighters (photo source: Government of Saskatchewan)

8. FOREST FIRE AND GRASS FIRE

M. Johnston

"The ability to reduce the number of evacuations is paramount to human safety and this can only be done if we ensure that communities, industry and individuals incorporate the proper mitigation techniques to reduce wildfire risk and develop response zones around values at risk where wildfires suppression work can take place" (Anonymous Stakeholder in Corkal 2018).

Forest Fires

Description

Saskatchewan is over 50 percent forested, the majority of which is boreal forest (Brandt 2009). Boreal forests are well-known as fire-prone ecosystems (Johnson 1992). Fire is the major determinant of landscape pattern and forest age-class distributions, and strongly affects nutrient cycling and species composition. Nearly all tree species in the boreal forest exhibit adaptation to either surviving fires (e.g., thick bark) or rapidly reproducing after fire (e.g., resprouting from root stock in aspen, serotinous cones in jack pine that require the fire's heat to open). These adaptations mean that, generally, forest fires do not result in environmental damage. The exception is when fires are extremely intense and burn in areas with very shallow soils. In that case, important nutrients, especially nitrogen, may be lost, and it may take several decades for the forest to return (Johnson 1992).

Saskatchewan has one of the highest levels of forest fire activity in Canada. Figure 8.1 shows clearly that virtually all of northern Saskatchewan has experienced fire impacts in the past 25 years. On average, 50 percent of fires are human caused, but burn less than 10 percent of the total area. The remaining fires are caused by lightning. Between 1990 and 2015, there were an average of 598 fires each year (range 302–1266, Figure 8.2), and these fires burned an annual average of 530,201 ha (range 3,885–1,734,806 ha, Figure 8.3). The number of fires (Figure 8.2) and area burned (Figure 8.3) are often not strongly correlated. For example, 2010 experienced the highest recorded area burned since 1990 (1.7 Mha), yet the number of fires (570) was less than the average. The high variability in number of fires and area burned means that forest fire activity is extremely difficult to predict. A few days or a week of hot, dry windy weather can change the fire hazard from low to extreme.

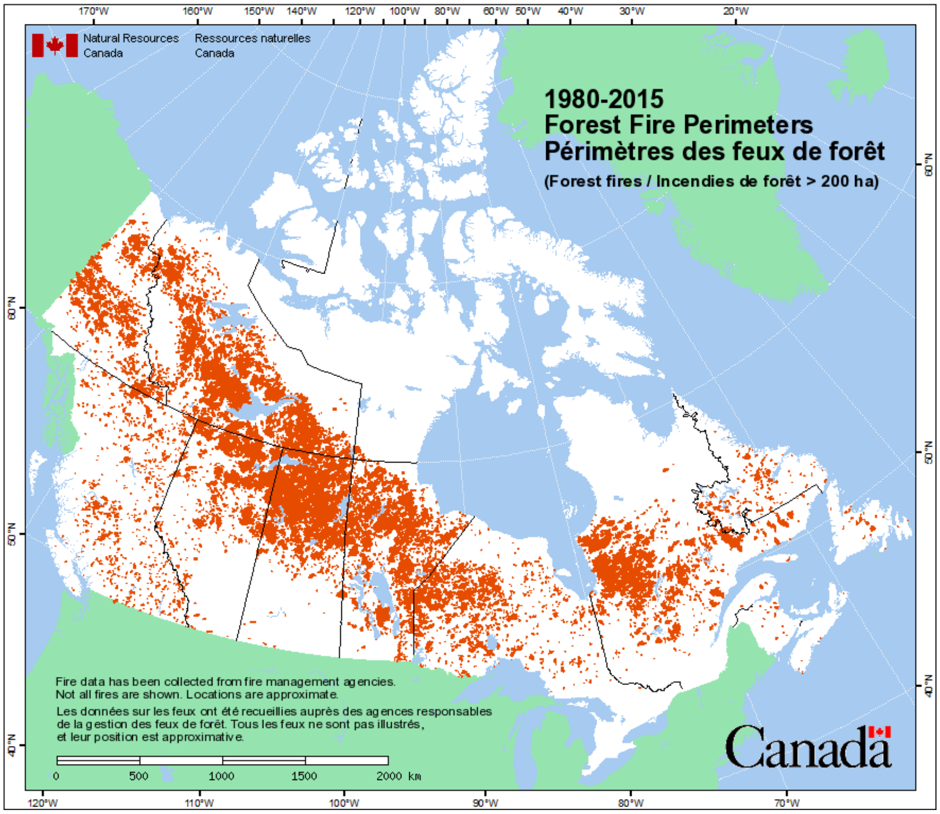


Figure 8.1 Fire activity across Canada, 1980-2015. (Canadian Forest Service ND)

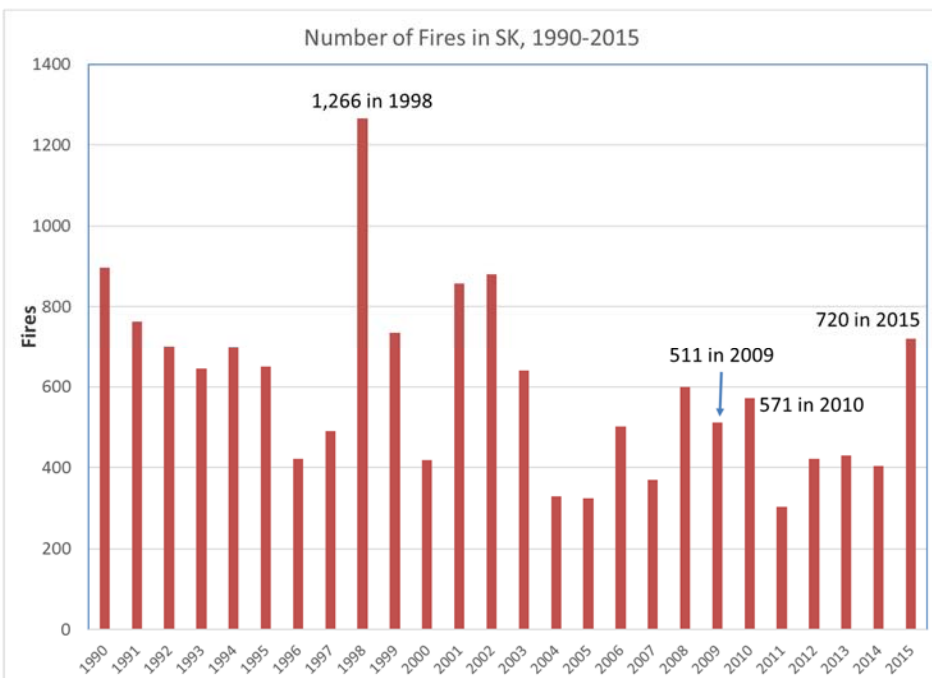


Figure 8.2 Number of forest fires in Saskatchewan, 1990–2015. (Data Source: Canadian Forest Service ND)

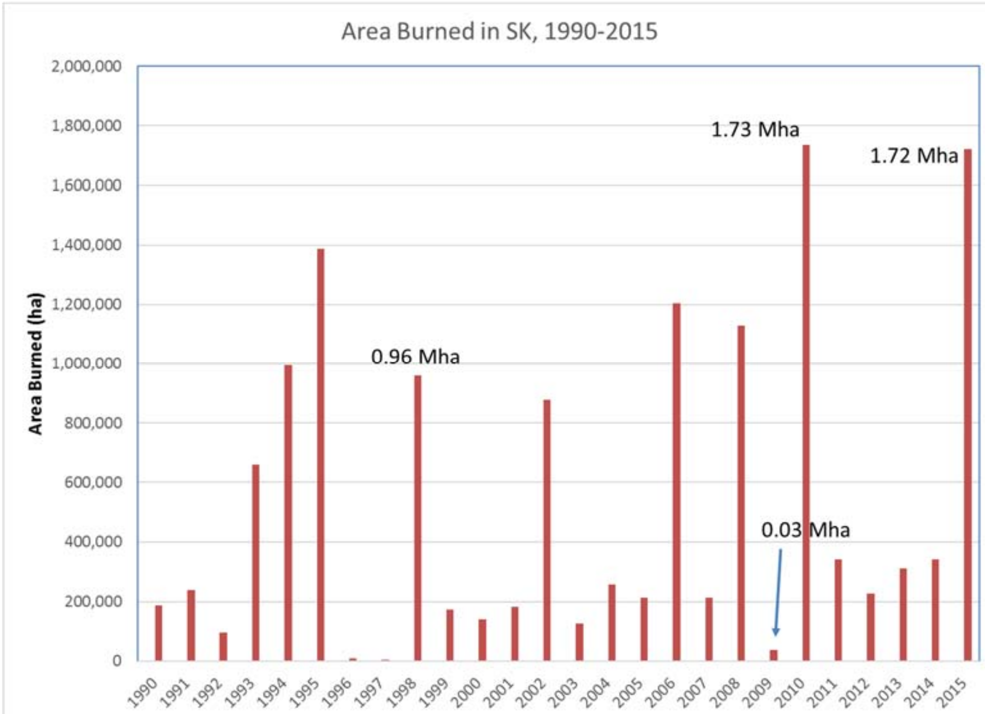


Figure 8.3 Area burned in forest fires in Saskatchewan, 1990–2015. (Data Source: Canadian Forest Service ND)

Provincial Risk Statement

Fires occur every year in Saskatchewan, varying from a few hundred to over a thousand fires per year. The area burned also varies widely, from a few thousand ha to nearly 2 Mha. All fires in Saskatchewan are monitored, but some may be observed, with no suppression action being taken when human life or communities are not threatened (Saskatchewan Ministry of Environment Wildfire Management Branch (WMB) 2017a). Fires in the boreal forest are generally not environmentally destructive, but may have negative effects on species at risk (e.g., impacts on woodland caribou habitat, Johnston 2014). However, forest fires often threaten human lives and property, and other values on the landscape such as valuable timber stands. These are collectively known by fire managers as "values at risk," and the fire managers' mandate is to protect these values to the maximum extent possible, with human lives being the highest priority. There are many Indigenous and non-Indigenous communities in the boreal forest that are often threatened by fire, either directly by a physical threat to loss of infrastructure, or indirectly due to health impacts like smoke, or civil disruption due to evacuation. These aspects are where fires represent a natural hazard risk to Saskatchewan communities.

Community evacuations are often carried out when fire is threatening a community's infrastructure, or when heavy smoke represents a health concern. The Canadian Forest Service maintains a Wildfire Evacuation Database (CFS 2017). Figure 8.4 shows the number of people evacuated in Saskatchewan since 1980. Evacuations vary widely; some years see no evacuations, while in 2015 over 10,000 people were evacuated from more than 50 communities in Saskatchewan's boreal forest.

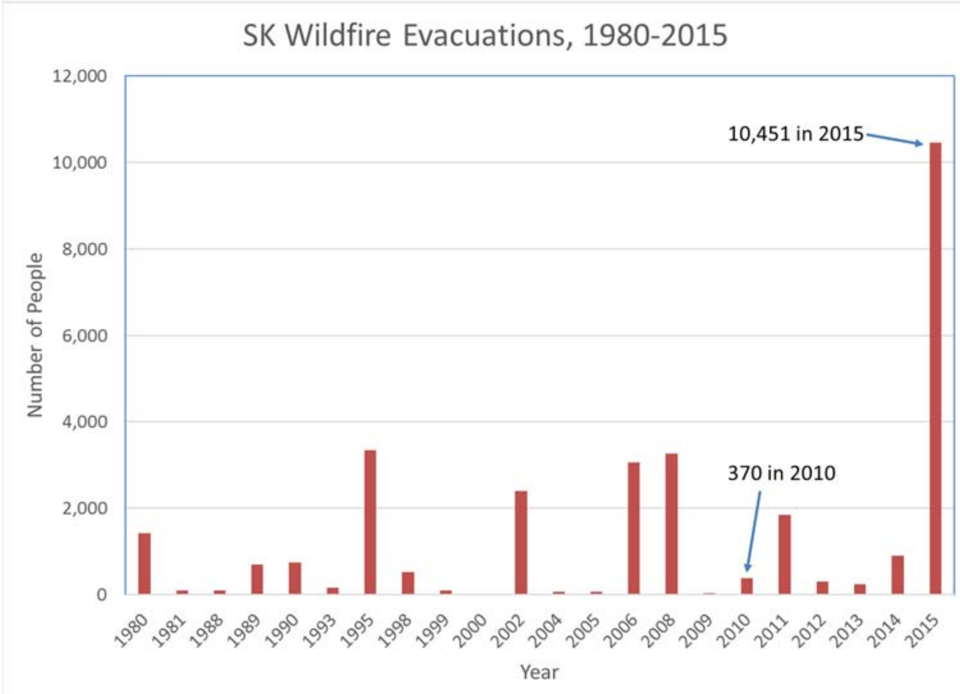


Figure 8.4 Wildfire evacuations in Saskatchewan, 1980–2015. (Data Source: Canadian Forest Service ND).

Previous Significant Events

The forest fire season of 2015 was one of the most severe for community and human impacts in the past several decades. In addition to the large number of evacuations (over 10,000 people), there were more than 250 occurrences of property damage, including cabins, vehicles, outbuildings, commercial properties, etc. Fortunately, there was no loss of life, although many communities were severely disrupted due to evacuations and road closures. In contrast, 2010 was the year with the highest area burned (over 1.7 Mha, Figure 8.3) but saw only 370 people evacuated (Figure 8.4). This highlights an important aspect of risk from fires: the size of the fire is not as important as its proximity to communities and the residents' ability to quickly evacuate. Other years with significant human impacts from fires were 1995, 2002, 2006 and 2008, with between 2,000 and 4,000 evacuations (Figure 8.4). For example, in 2002, a wildfire burned most of the community of Turtle Lake in northwestern Saskatchewan, with the loss of 56 houses.

Participants at the stakeholder workshops identified several issues affecting northern residents, especially during the 2015 fire season (Corkal 2018). In addition to items already mentioned (health impacts, stress related to evacuations), stakeholders identified difficulties with the incident command and communication systems established as fires became larger and more numerous. It was sometimes unclear who was empowered to make decisions, and residents sometimes received contradictory information about actions which affected them directly. An example is receiving contradictory information about road closures from law enforcement and Ministry of Highways. Residents perceived that government agencies were not communicating effectively among themselves and with local communities. Residents also feel strongly that community members should be allowed to stay and fight the fires rather than always being evacuated, although this would require appropriate firefighting training in preparation for active fire seasons.

Climate Change Implications

Climate change is expected to have significant impacts on forest fire activity in Canada's western boreal forest. Researchers have used future climate scenarios to calculate the indices of the Canadian Forest Fire Danger Rating System as an indicator of future fire conditions. The results suggest that there may be a doubling of area burned by mid-century and a three- to five-fold increase by the end of this century for western Canada (Balshi et al. 2009). Similar results for western Canada were reported by Boulanger et al. (2014), as shown in Figure 8.5. As with the historical occurrence of fire, Saskatchewan is expected to continue to be highly affected by forest fires through the end of the century. In Figure 8.5, area burned doubles by 2041–2070 and remains at this level through the end of the century. Number of fires doubles by mid-century and increases by three times by 2100.

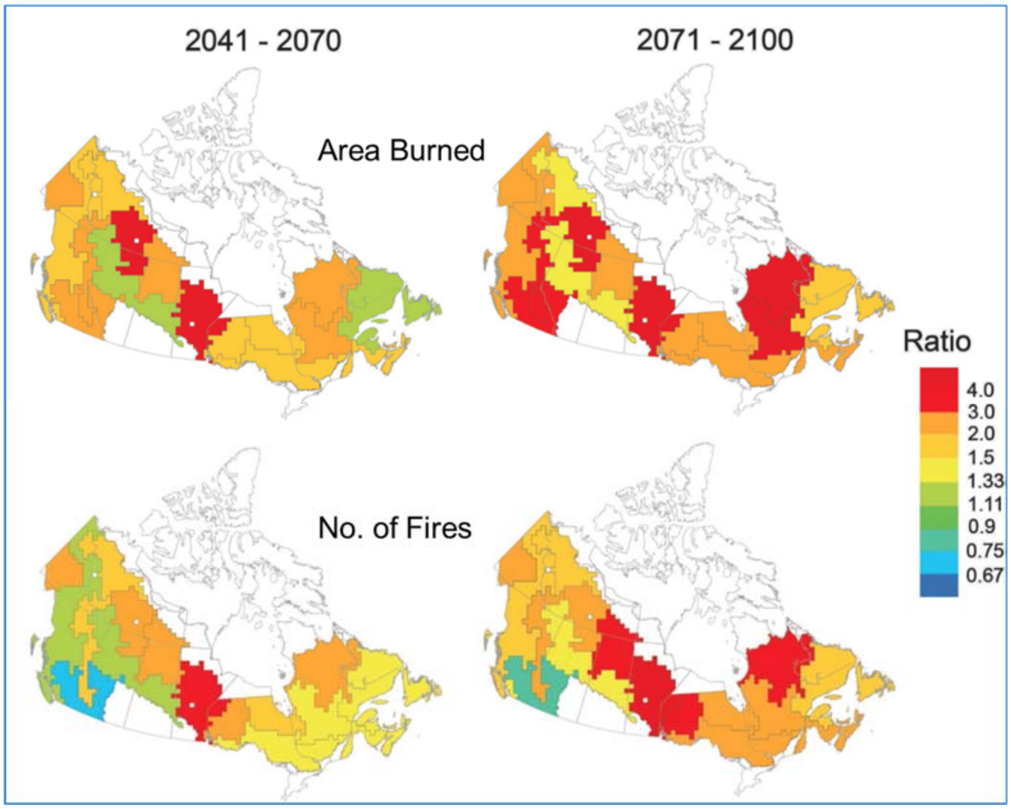


Figure 8.5 Ratio of future fire activity to that of the 1961–1990 baseline period for mid-century and late century. Area burned, upper figures; number of fires, lower figures. (Boulanger et al. 2014).

Worst-Case Scenario

Saskatchewan Ministry of Environment, Wildfire Management Branch (WMB), carries out an internal risk assessment every other year for its fire management program and completed the most recent one in Spring 2017. Part of the assessment was envisioning a worst-case scenario and evaluating the risks associated with the event. [Note that the impact levels shown in italics relate to the provincial risk matrix. Refer to the methodology section of the report for more information regarding this matrix.] The scenario is based on a human-caused fire (either accidental or purposely set). Initial control efforts were partially successful, but due to severe fire weather, the wildfire continued to grow. Impacts of this scenario are based on the forest fire season of 2015, when 1.72

Mha burned and over 10,000 people from northern communities were evacuated. Other major fire events, such as the Fort McMurray fire in 2016 (Alberta Agriculture and Forestry 2017) and the Slave Lake fire of 2011 (KPMG 2012), also illustrate the nature of these unlikely but severe events. Multiple public fatalities or long-term injuries are possible, either from the direct effects of the fire or indirectly, e.g., vehicle accidents during evacuations. It is likely that ambient air quality standards would be exceeded in some locations. Smoke is an important issue during forest fires, and many community members (e.g., elderly, asthmatics, infants) are vulnerable. It is likely that ambient air quality standards would be exceeded in some locations (*Human Health, major impact*). If large-scale evacuations are undertaken, civil disruption and effects on quality of life would be likely (*Social, moderate-major impact* depending on length of evacuation). Infrastructure is significantly affected with loss of buildings and vehicles but will be recoverable (*Economic, moderate impact*). Key business sectors (e.g., tourism, mining, forestry) are significantly affected with medium-term profit reductions (*Economic*, *moderate*). Provincial and municipal government bodies would encounter a reduction in the ability to deliver core functions and experience time delays and increased cost (*Public Administration, major impact*). Environmental impacts are generally *minor*, with some localized severe burning impacts that reduce forest productivity and reduce wildlife habitat for species at risk (*Economic, minor to moderate*).

Existing Controls

Saskatchewan Ministry of Environment, WMB, has several programs and activities that make up its wildfire management program (WMB 2017a). Fire prevention education is key to reducing human-caused fires, which make up about 50 percent of all fires in the province. This is increasingly important as forest-based communities continue to develop and the wildland–urban interface expands (Johnston 2017). WMB manages and delivers the provincial FireSmart program. Most provinces have a FireSmart program, which is made up of two main components. The first is Wildfire Hazard Assessment, in which residents or community members asses the hazard in and around their property. This includes risks from vegetation (e.g., tall grass or trees too close to buildings), and building materials or practices that promote structural fires (e.g., cedar shake roofs, opening under decks where embers can ignite a fire). The second component is hazard mitigation, and provides guidance on vegetation management near structures, on structural options (e.g., fireproof roofing materials) for reducing fire risk to buildings, and on surveying of community infrastructure such as roads for community evacuation, greenbelts that do not readily burn, and water supplies for fire suppression. WMB has legislated responsibility for fire management on Crown land and includes fire detection, preparedness and suppression in its operations. The updated Wildfire Act came into force in 2015 and the accompanying Wildland Urban Interface (WUI) Code being developed to accompany the act designates FireSmart for new WUI developments as mandatory in Saskatchewan. The Act also designates industry Wildfire Preparedness Plans as mandatory for any commercial operation in the provincial forest. Detection is based on public reporting, detection aircraft and ground patrols, and a system of high-resolution cameras that have been installed in fire tower locations. Preparedness includes bringing firefighting crews on at the beginning of the April to October wildfire season. The crews are distributed among 12 Forest Protection Areas that cover all of Saskatchewan. WMB maintains a fleet of aircraft for aerial firefighting made up of ten land-based and amphibious airtankers supported by seven smaller Bird Dog guide aircraft. Aircraft are generally active during the wildfire season, but may be mobilized at other times. In addition, Saskatchewan is part of the Canadian Interagency Mutual Aid Resources Sharing Agreement that moves fire equipment and personnel between provinces as needed. This system is managed by the Canadian Interagency

Forest Fire Centre in Winnipeg. It is important to note that there have been no fatalities among the public due to wildfires in Saskatchewan. However, a few deaths have occurred related to wildland firefighting aircraft operations.

Forest fire suppression costs (including pre-suppression preparation) averaged about $55M between 2004 and 2016, and varied from $35M to about $60M (Figure 8.6, WMB 2017b). However, the exception was the severe fire season of 2015, in which suppression costs, amounting to $124M, were more than double those of the long-term average. Figure 8.6 shows the costs for 2004 to 2016. Other high-cost years were 2006 and 2008, which also saw large area burned (Figure 8.3) and significant evacuations (Figure 8.4). Interestingly, the area burned in 2010 was larger than that in 2015, yet the suppression costs were about average. This again illustrates the point that where wildfires occur (i.e., proximity to communities) is often more important than the amount of area affected.

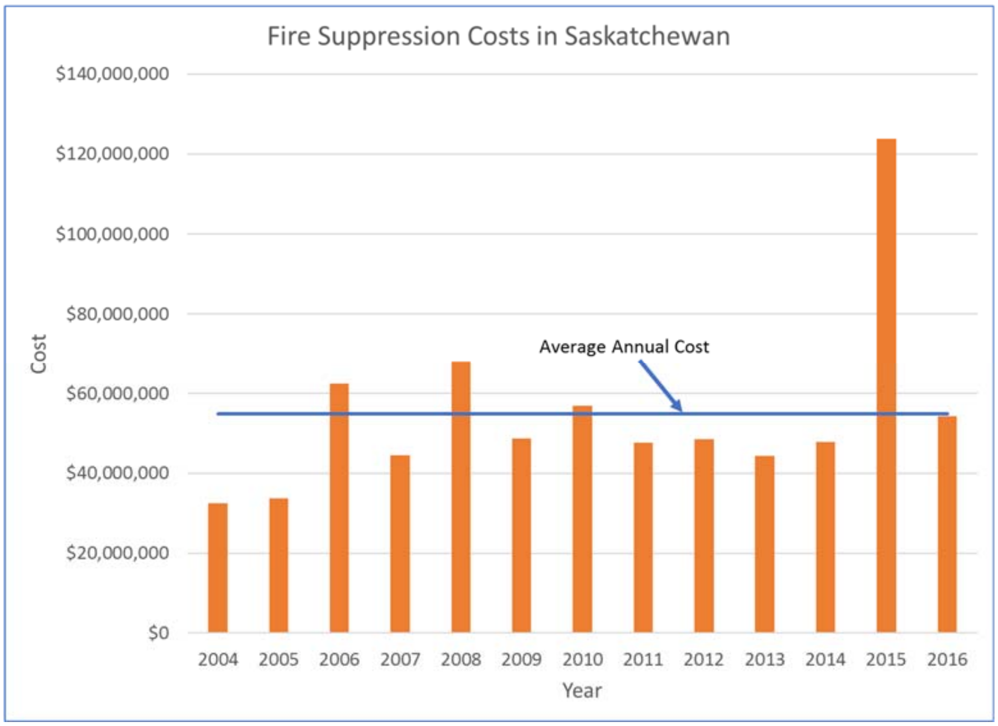
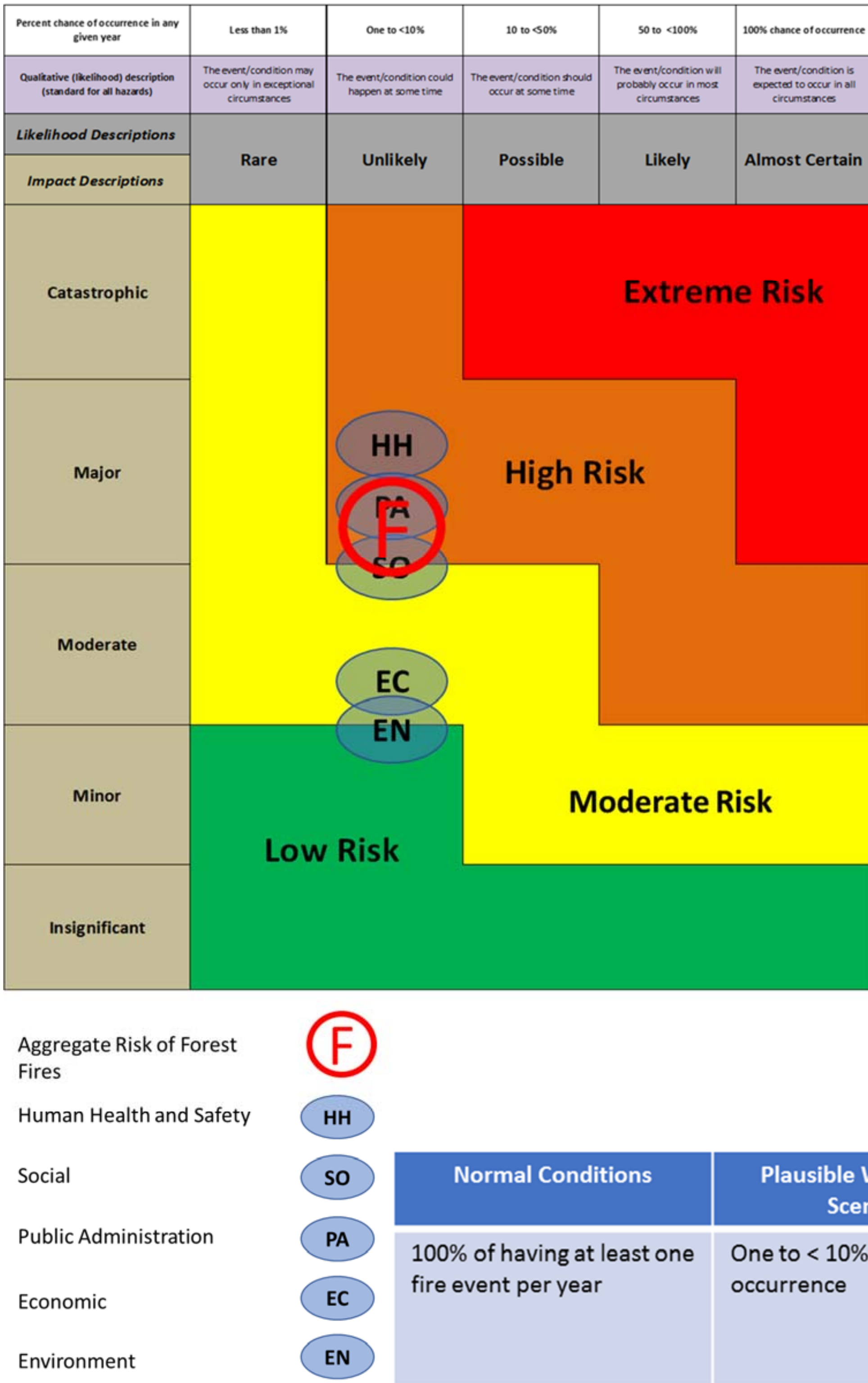


Figure 8.6 Cost of fire suppression in Saskatchewan, 2004–2016. (Data Source: WMB 2017b)

Provincial Forest Fire Risk Analysis

Forest fires occur every year in Saskatchewan, and most events have insignificant impacts on values at risk (the large blue circle on the lower right corner of the risk matrix heat map in Figure 8.7). Most wildfires occur far from communities, and due to the fire adaptation of boreal species, environmental impacts are minor and generally positive. Analysis of fire data from across Canada has shown that about 3 percent of wildfires escape suppression and develop into large fire events that account for 97 percent of the area burned (Stocks et al. 2003). It is these few escaped fires that represent the highest risk, if they occur close to communities or major values at risk (e.g., industry or public infrastructure). The risk matrix heat map in Figure 8.7 summarizes the worst-case scenario (see above section) developed by the provincial Wildfire Management Branch in its internal risk assessment completed in spring of 2017. It's based on the occurrence of a human-caused wildfire located close to major values at risk that escapes initial attack and grows quickly due to severe fire weather. Multiple public fatalities or long-term injuries are possible, either from the direct effects of the fire or indirectly, e.g., vehicle accidents during evacuations (*high risk*). Smoke is an important issue during forest fires, and many community members (e.g., elderly, asthmatics, infants) are vulnerable. It is likely that ambient air quality standards would be exceeded in some locations (*high risk*). If large-scale evacuations are undertaken, civil disruption and effects on quality of life would be likely (*high risk)* depending on length of evacuation. Infrastructure is significantly affected, with loss of buildings and vehicles, but will be recoverable (*high risk*). Provincial and municipal government bodies would encounter a reduction in the ability to deliver core functions and experience time delays and increased cost (*high risk*). Key business sectors (e.g., tourism, mining, forestry) are significantly affected, with medium-term profit reductions (*moderate risk*). Environmental impacts are generally *low risk*, with some localized severe burning impacts that reduce forest productivity and reduce wildlife habitat for species at risk (*low risk*). The red circle in the centre of the worst-case scenario indicates the aggregate risk of the forest fires across the impacts categories, which is **moderate to high risk**.



Normal Conditions	Plausible Worst-Case Scenario
100% of having at least one fire event per year	One to < 10% chance of occurrence

Figure 8.7 The risk of severe forest fires in Saskatchewan based on impacts categories and percent chance of occurrence. The red circle in the centre with an F indicates the aggregate risk of forest fires across the impact categories for the worst-case scenario.

Grass Fires

"…Forest fringe and northern communities face the greatest risk from wildfires, but with continuous cropping being the standard, we have seen an increase in the number and size of prairie fires in the last few years also" (Anonymous Stakeholder in Corkal 2018).

Description

Grass fires have been a feature of the prairie landscape in Saskatchewan for hundreds of years. Indigenous people used fire in the prairies to improve bison forage quality, drive bison herds to hunting locations, reduce insect outbreaks, for signalling and as an offensive or defensive tactic during warfare (Rannie 2001). Early explorers describe a fire in 1866–1867 that burned from the South Saskatchewan River to the Red River in Manitoba (Rannie 2001). More recently grass fires have resulted in community evacuations, road closures and loss of cattle. Once it dries, grass is extremely flammable, and the flat prairie topography allows winds to blow without interruption across the landscape. Rate of spread is extremely fast and can catch communities unaware.

The data for grass fires are not as comprehensive as those for forest fires. Under the provincial Wildfire Act (Sections 3(2) and 11(1)), fire suppression on private land is the responsibility of municipal governments, although provincial resources will be mobilized when needed. The involvement of many municipalities means there is no standardized way of reporting grass fires or maintaining statistics on cause, size, impacts, etc. The data gathered for this assessment were taken from a database of 9-1-1 dispatches as reported to the Emergency Management and Fire Safety, Ministry of Government Relations. The caveat with these data is that grass fires fall into a general dispatch category called "Outside Fire," and may or may not turn out to be a grass fire once the emergency responders reach the location, i.e., it could be a structural fire or a vehicle fire instead.

Figure 8.8 shows the number of Outside Fire Dispatches by month for the years 2011 to 2017 (note that the data for 2017 are complete only up to April). Two points are apparent: the most important months for grass fires are April and May, likely because the grass is still dead from the previous year, and the snow has just disappeared. Second, the years 2015–2017 have seen a significant increase in reported fires as compared to the preceding years. However, the period of record is short for these data and it is not possible to draw any firm conclusions about whether there is a trend in the number of grass fires. In addition, this could be an artefact of increased reporting or another reason for the increase in numbers.

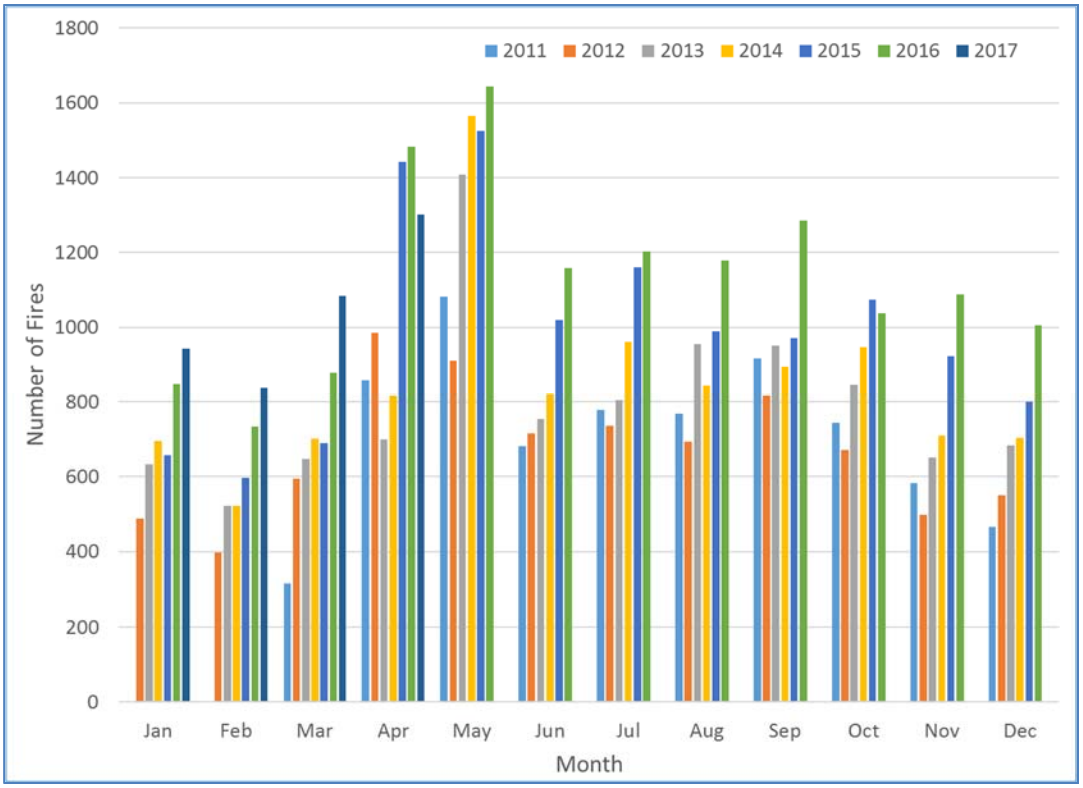


Figure 8.8 Number of Outside Fire Dispatches by month for 2011–2017. Note that the data for 2017 only extend to April. (Data Source: Emergency Management and Fire Safety, Saskatchewan Ministry of Government Relations 2017).

Provincial Risk Statement

Grass fires are a common occurrence in the prairies and residents have developed ways to mitigate their effects over many years. However, grass fires can spread extremely quickly due to the fine fuels which dry rapidly, and the prevalence of strong winds on the prairies. Another factor adding to the risk of grass fires is the difficulty of establishing fire breaks in areas with continuous cropping and large areas of natural grasslands. Stakeholders identified the need for better integration among local and provincial firefighting agencies (Corkal 2018). In addition, much of the firefighting capacity in rural areas is made up of volunteers who may be overtaxed during large fire events, and similarly other local emergency management responders may have difficulty managing large fire events. In the dry potions of southern Saskatchewan, water supplies may be limited or depleted, and this often occurs during drought events when the likelihood of fires is highest.

Previous Significant Events

A grass fire in September 2017 burned approximately 1,500 ha in southeastern Saskatchewan (SwiftCurrentOnline 2017). In October 2017, 750 cattle were killed and over 1,000 people were evacuated from several communities in western Saskatchewan near Leader as a grass fire grew to 30,000 ha (CBC 2017a, b, CKRM 2017). In this fire, one person was killed due to a vehicle accident, and two local residents were severely injured while fighting the fire (Global News 2017).

Figure 8.9 shows the locations of 2016 Crown Land "ditch" fires along provincial highways. WMB is responsible for wildfires on all Crown Lands in Saskatchewan, including ditch rights of way.

These fires may become 'grass fires' if they escaped containment along the roadway. WMB does not keep track of southern grass fires.. Fires were widespread throughout southern Saskatchewan but generally had minor impacts as compared to the events described above.

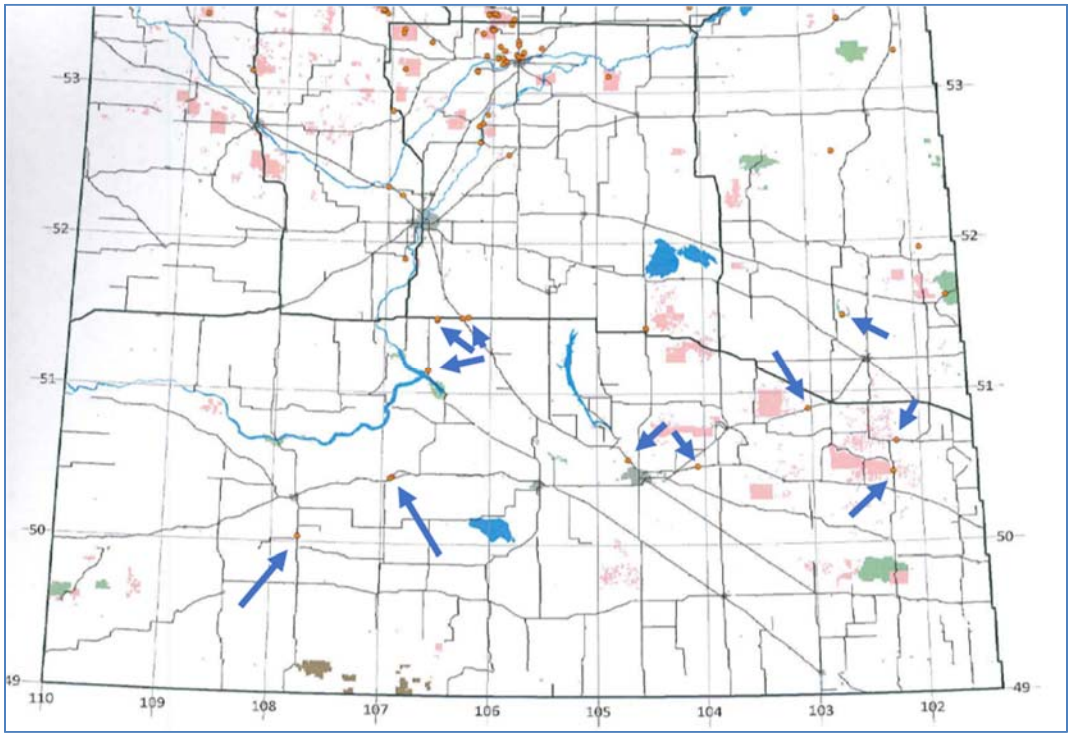


Figure 8.9 Location of ditch fires in Saskatchewan in 2016. (Wildfire Management Branch Saskatchewan Ministry of Environment 2017a).

Climate Change Implications

The expectations for Saskatchewan under climate change are for increased temperatures, increased evapotranspiration and continued variability in precipitation. The net effect of these factors is a generally drier prairie vegetation community, making it more susceptible to fire ignitions and faster rates of spread once a fire is established. However, a dampening effect on grass fires is the fact that grass biomass accumulation may be less under a hotter drier climate, which would provide less fuel for fires, reducing the intensity. It will be a matter of which factors turn out to be more important, which can not be predicted at this time.

Worst-Case Scenario

The worst-case scenario is one in which a major grass fire (> 1,000 ha) moves across the prairie landscape, similar in scope to those described in Rannie (2001). Similar grass fire events occurred in the fall of 2017 (SwiftCurrentOnline 2017, CBC 2017a,b, CKRM 2017, Global News 2017) and helped define the wort-case scenario. [Note that the impact levels shown in italics relate to the provincial risk matrix. Refer to the methodology section of the report for more information regarding this matrix.] Structures are lost, livestock are killed, crops destroyed, small prairie towns are evacuated and roads closed. Fatalities may occur, either directly from the fire or resulting from related activities, e.g., vehicle accidents (see GlobalNews 2017). Municipal firefighting resources are severely strained or overwhelmed. Provincial firefighting assets are requested but may be unavailable as they deal with other high-priority events on Crown land, or may be unavailable if grass fires occur in early spring before the provincial system is activated. Multiple public fatalities or long-term injuries are possible, either from the direct effects of the fire or indirectly, e.g., vehicle accidents during evacuations. Smoke is an important issue during grass fires, and many community members (e.g., elderly, asthmatics, infants) are vulnerable. It is likely that ambient air quality standards would be exceeded in some locations (*Human Health, major impact*). If large-scale evacuations are undertaken, civil disruption and effects on quality of life would be likely moderate to major (*Social, moderate-major impact* depending on length of evacuation). Infrastructure is significantly affected, with loss of buildings and vehicles, but will be recoverable. Key business sectors (livestock, crop production) are significantly affected at the local level, but provincial-scale economic impacts are minor (*Economic, minor-moderate impact*). Provincial and municipal government bodies would encounter a limited reduction in the ability to deliver core functions (*Public Administration, minor impact*). Environmental impacts are generally minor (*Environment, minor impact*).

Existing Controls

According to the provincial Wildfire Act (Sections 3, 10, 11 and 12), the Province is responsible for fire management on Crown land, while rural municipalities (RM) are responsible for fire management for fires wholly or partly within the RM. However, RMs can request assistance from WMB, and the Province can unilaterally act to supress fires on RM land if the RM's efforts are deemed to be inadequate or if the fire threatens Crown land. RMs vary widely in their capacity to suppress fires and often band together to fight severe fires, as happened in southwestern Saskatchewan in September 2017 (SwiftCurrentOnline 2017).

Provincial Grass Fire Risk Analysis

The risk matrix heat map shown in Figure 8.10 is similar to that of Figure 8.7 for forest fires. Many of the impacts are important at the local level, e.g., loss of crops or livestock, but at the provincial scale these impacts are likely to be minor, except for possible multiple fatalities. Multiple public fatalities or long-term injuries are possible, either from the direct effects of the fire or indirectly, e.g., vehicle accidents during evacuations. Smoke is an important issue during grass fires, and many community members (e.g., elderly, asthmatics, infants) are vulnerable. It is likely that ambient air quality standards would be exceeded in some locations (*Human Health, high risk*). If large-scale evacuations are undertaken, civil disruption and effects on quality of life would be likely (*Social, moderate to high risk*, depending on number of people evacuated). Infrastructure is significantly affected, with loss of buildings and vehicles, but will be recoverable. Key business sectors (livestock, crop production) are significantly affected at the local level, but provincial-scale economic impacts are minimal (*Economic, low to moderate risk*). Provincial and municipal government bodies would encounter a limited reduction in the ability to deliver core functions (*Public Administration, low risk*). Environmental impacts are generally minor but almost certain (*Environment, low risk*). The aggregate risk associated with grass fires is considered to be ***moderate***.

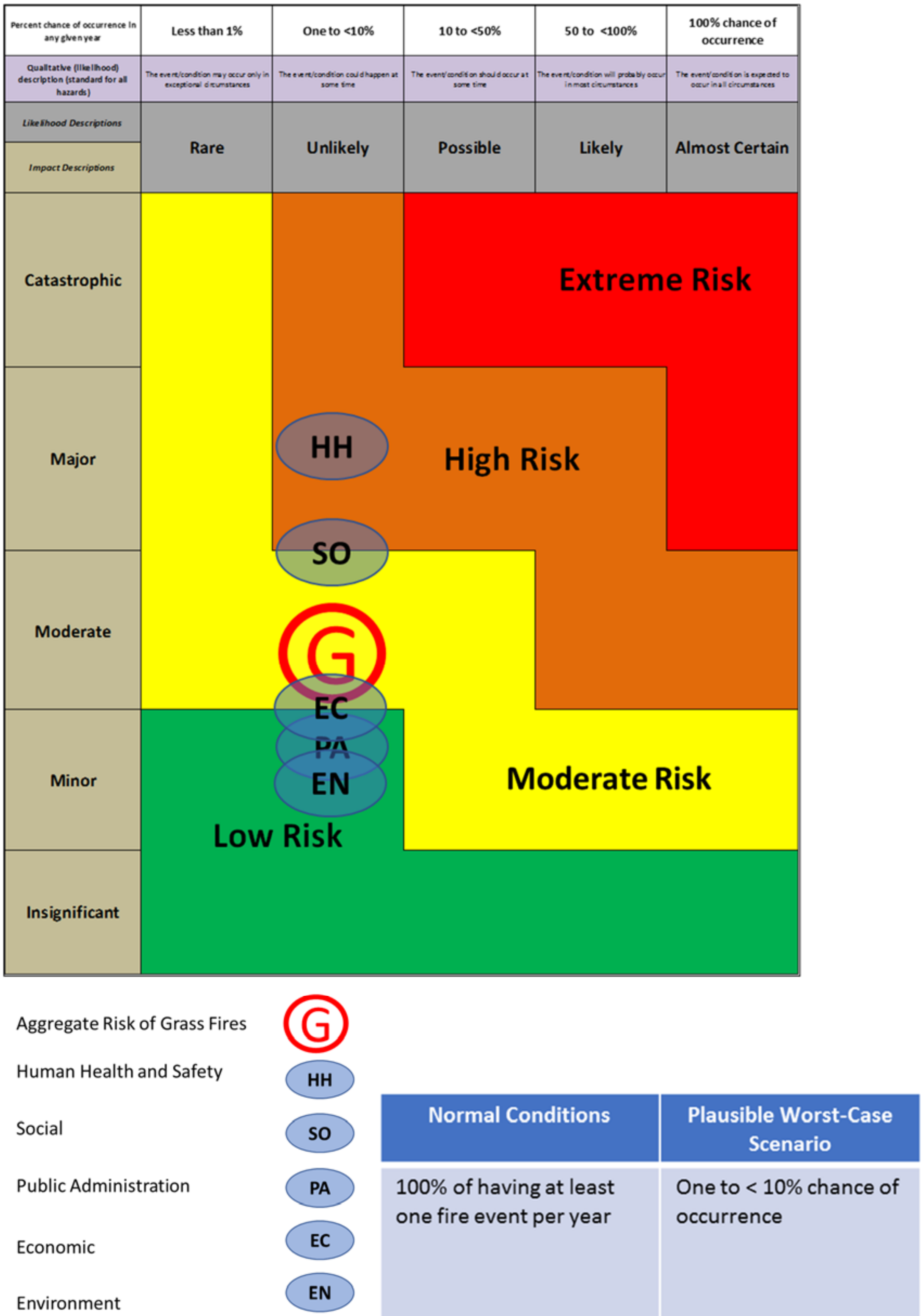


Figure 8.10 The risk of severe grass fires in Saskatchewan based on impacts categories and percent chance of occurrence. The red circle in the centre indicates the aggregate risk of grass fires across the impact categories for the plausible worst-case scenario.

Conclusions

Saskatchewan experiences forest and grass fires virtually every year. Forest fires are a natural part of the environment and play a positive role in ecosystem function. However, when forest fires threaten human life or property or other values at risk, they constitute a natural hazard. Forest fires have the potential for destroying infrastructure and other values on the landscape, e.g., valuable timber stands. They also can disrupt communities through evacuations, smoke impacts and road closures. Controls in place include public education, FireSmart practices, detection and fire suppression. Saskatchewan is a member of the Canadian Interagency Mutual Aid Resources Sharing Agreement, which provides for resource sharing among Canadian fire management organizations. Climate change may bring an increase in fire activity, particularly along the drier southern portions of the boreal forest. Recommendations include the need for increased FireSmart activities in northern communities, and increased public education on the need to limit human-caused fires.

Grass fires are also common in Saskatchewan, primarily in the south. Grass fires can be very dangerous, spreading quickly under windy conditions. Rural municipalities have primary responsibility for fire suppression on private land, but are supported by provincial firefighting resources when needed. Grass fires can threaten infrastructure, crops and livestock, cause evacuations and health effects from smoke, result in road closures, and disrupt communities. Climate change will likely bring hotter, drier conditions which will promote more fire during the fire season, although grass biomass may be less under warmer, drier conditions. Recommended actions are increased wildfire training for municipal firefighting organizations and better record-keeping of the incidence of grass fires.


Aftermath of tornado (Photo Source: Government of Saskatchewan)

9. SELECTED SEVERE CONVECTIVE SUMMER STORMS

V. Wittrock

Definitions

Severe convective storm (severe thunderstorm) – more than 50 mm of rain in one hour, more than 75 mm of rain in three hours, hail larger than 2 cm in diameter, winds greater than 90 km/h (including plough winds) and/or a tornado (Paul 1999).

Hail – precipitation in the form of lumps of ice mainly associated with thunderstorms. Hail ranges in size from small pea to cherry to as large as a grapefruit or softball. Hail occurs most frequently during the summer when thunderstorm activity is present (ECCC 2017).

Tornado – tornadoes are nature's most locally destructive storm (Wheaton 1998). A tornado is a rotating column of air that extends from a cumuliform cloud to the ground. The pressure in a tornado often results in the formation of funnel clouds that extend fully or partially from the cumuliform cloud to the ground. A tornado is typically visible by rotating debris near the ground. A tornado can be thousands of metres wide and have a lifespan of minutes or hours (ECCC 2017). Tornadoes are classified using the Fujita, or F-scale, which was originally developed in the midwestern United States (Wheaton 1998). Environment Canada introduced the Enhanced Fujita Scale (EF-Scale) in 2013 to measure the intensity of wind damage (Environment Canada 2013) (Appendix 10.1).

Windstorm – sustained winds of speeds that pose a significant threat to public safety and property. Wind warnings occur in Saskatchewan when winds are 70 km/h or more sustained wind and/or gusts to 90 km/h or more (ECCC 2017).

Description

Summer convective storm conditions can last from April to October but the most severe generally occur in June, July and August. This is the period when humidity and warm temperatures generate convective storms that traverse the province (Paul 2007). These convective storms can become severe and result in heavy rain, hail, strong winds and tornadoes (Paul and McInnis 2001). The available data covers the period 1880 to 2007 and many of the reported events contain all of these conditions (EC 2012). The 2008 to 2016 data is less complete but is incorporated in the analysis where applicable.

Provincial Risk Statement

Every summer, Saskatchewan has convective storm events somewhere in the province. Between 1880 and 2007, Saskatchewan had approximately 7000 severe weather events documented by Environment Canada (EC 2012). The majority of the storm events produce minor to moderate impacts on a relatively localized scale. However, public concern is usually significant in the face of the severe convective storm events because of both the financial and human health potential impacts (Corkal 2018). This concern could stem from the observation that severe storms can be more debilitating to smaller communities than to larger ones (McInnis 2001).

Convective storm tracks have been assessed by different researchers to determine if there is a pattern. McInnis (2001) analyzed five severe convective storms between 1979 and 1996 and their associated weather events (hail, wind, tornado, rainfall intensity), as well as the associated damage (Figure 9.1 and Appendix 9.2). Figure 9.2 is an illustration developed by Paul (2007) that shows the various storm tracks that included crop insurance claims for assorted reasons, including hail damage, as well as tornado sightings. Most of these convective storms travelled through southern Saskatchewan, resulting in widespread damage.

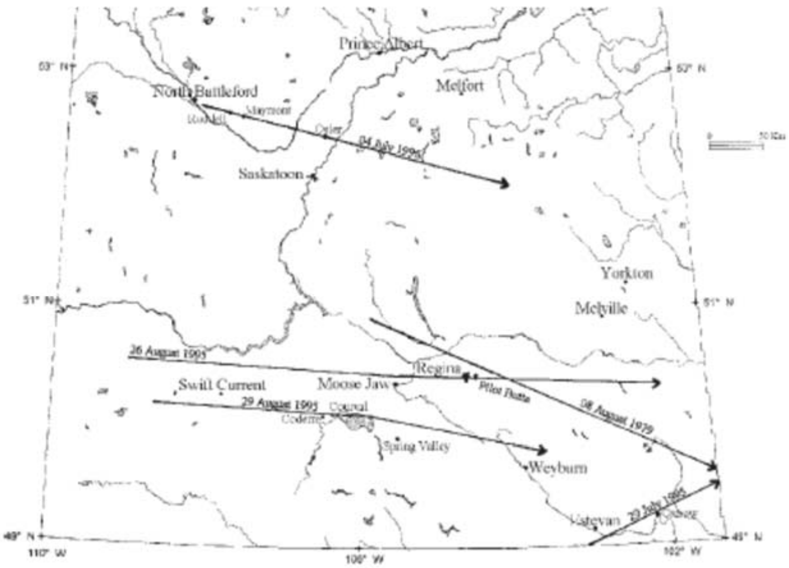


Figure 9.1 Hail damage and storm tracks for five selected storms between 1979 and 1996 (McInnis 2001)

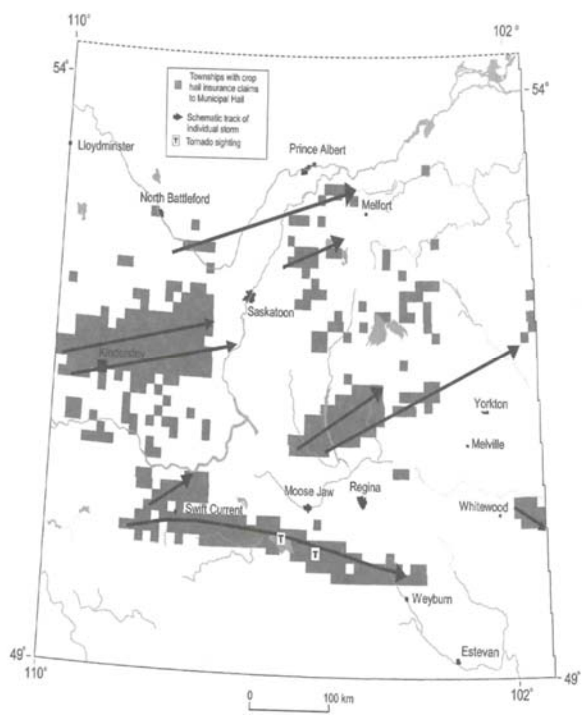


Figure 9.2 Selected severe thunderstorm trajectories across Saskatchewan (Paul 2007)

Tornado

In Canada, the highest tornado risks are in southern Saskatchewan, southern Manitoba and southwestern Ontario (EC 2011b). Saskatchewan had 1143 tornado sightings for the 1880–2007 period (Table 9.1). The majority of the reported tornados are in the south-central portion of the province (Figures 9.3 and 9.4). Most of the tornados are short lived and produce little to no damage (F0 and F1 category). Saskatchewan has had larger tornados (F2 and F4) that have resulted in severe damage, loss of life and multiple injuries (EC 2012). Recent years (2008–2016) continued the trend of having the greatest number of tornados in the F0 and F1 categories. One F3 tornado occurred on 2 July 2010, 5 km SW of Semans and moved northeastwards through Kawacatoose First Nation, resulting in one injury, five homes being destroyed and 15 more homes incurring significant structural damage.

Table 9.1 Tornado occurrence and associated damage scale rating (data: Environment Canada 2012, EC 2008 to 2014, ECCC 2015 and 2016)

Fujita Scale	F4	F3	F2	F1	F0	Unclassified
Occurrences (1880-2007)	3	27	136	317	606	54
Occurrences (2008-2016)	0	1	4	16	62	27

The deadliest tornado to hit Saskatchewan was the Regina Cyclone of 30 June 1912, categorized as an F4. This tornado touched down 16 km southwest of Regina, killing two people with a third reported as missing, and destroying 18 farmyards. The tornado moved towards the northeast towards Regina. In Regina, the tornado resulted in another 28 deaths, at least 300 people injured, and 200 homes and half of Regina's businesses destroyed. It narrowly missed hitting the Legislature, moved across Wascana Lake and cut a swath through the city extending from Albert Street to Cornwall Street. The tornado exited Regina on the north end of town after crossing the railroad tracks and overturning trains (Figure 9.5). The estimated damage was $4 million (EC 2012). This same weather system affected several other communities including Hague, Palmer, Cupar, Bladworth and others (Figure 9.6), with the scale of these smaller tornados reported as either F0 or F1. In addition to multiple reports of tornado activity in the various communities, this convective weather system included reports of strong winds and heavy rain (EC 2012).

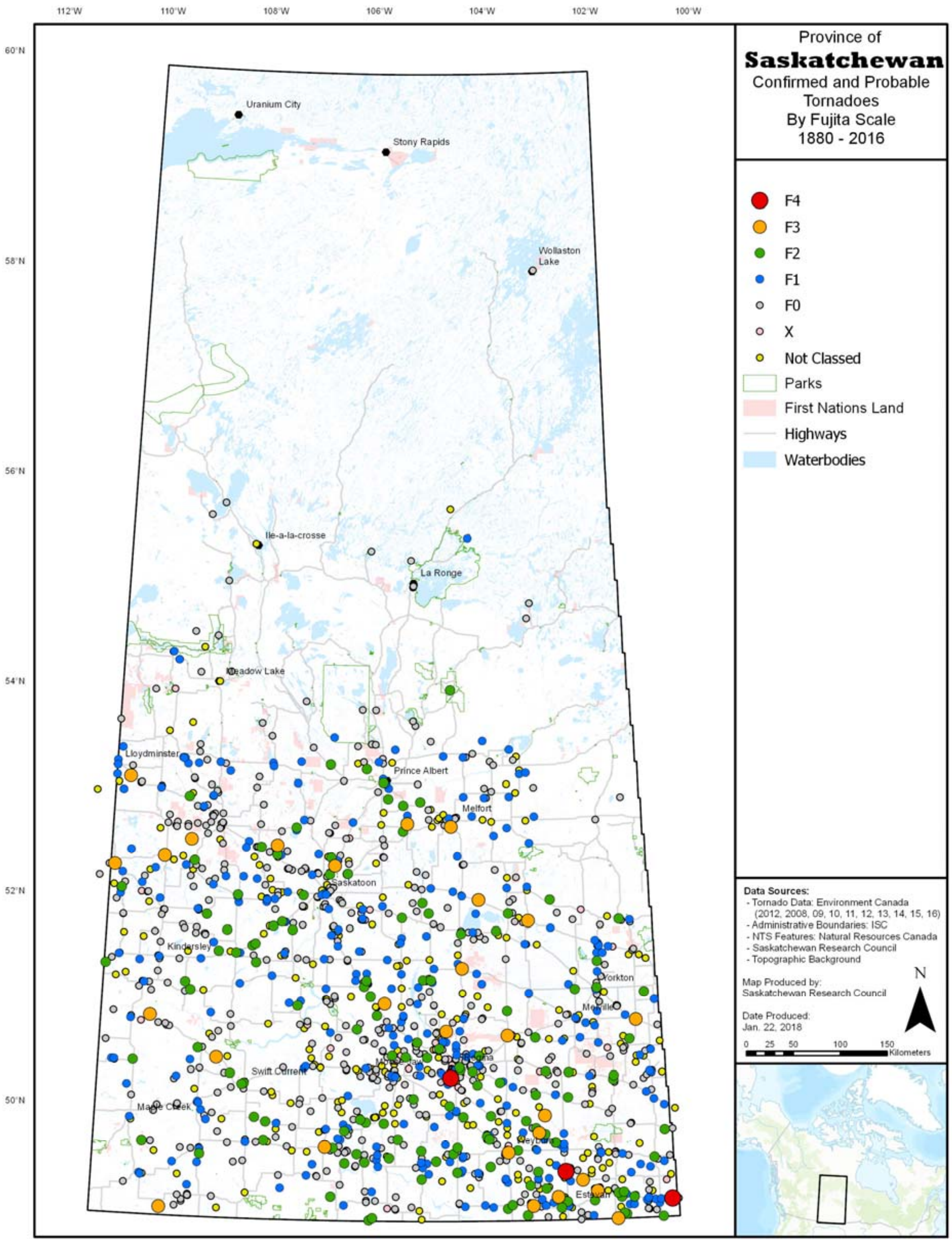


Figure 9.3 Tornado occurrences and associated damage scale ratings (data sources: EC 2012, McDonald 2008 to 2012, Cummine 2013 and 2014, Cummine et al. 2015 and 2016)

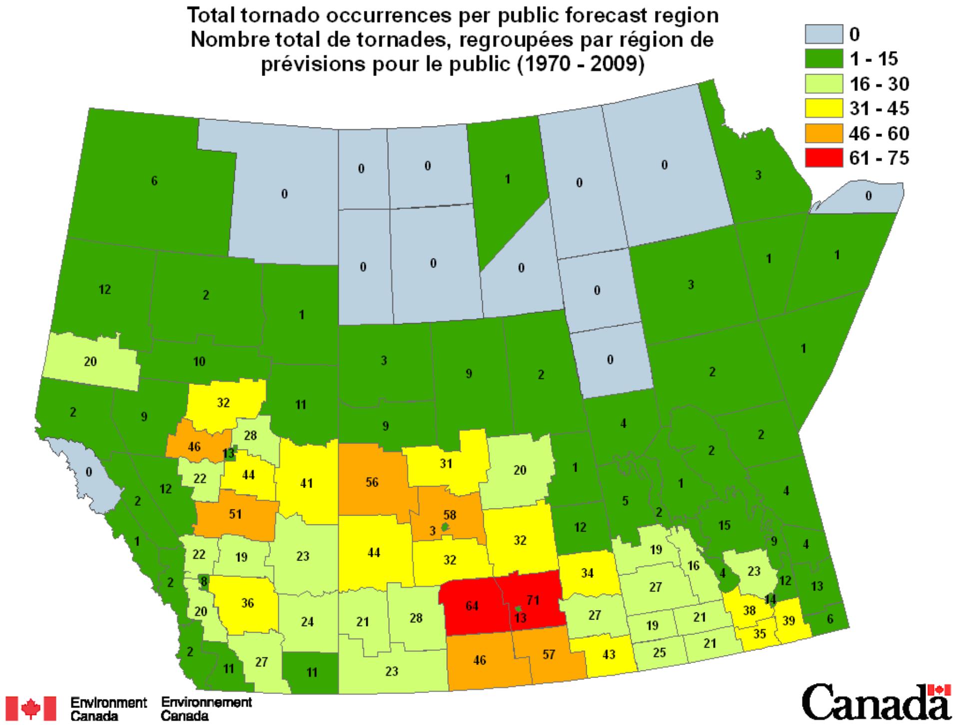
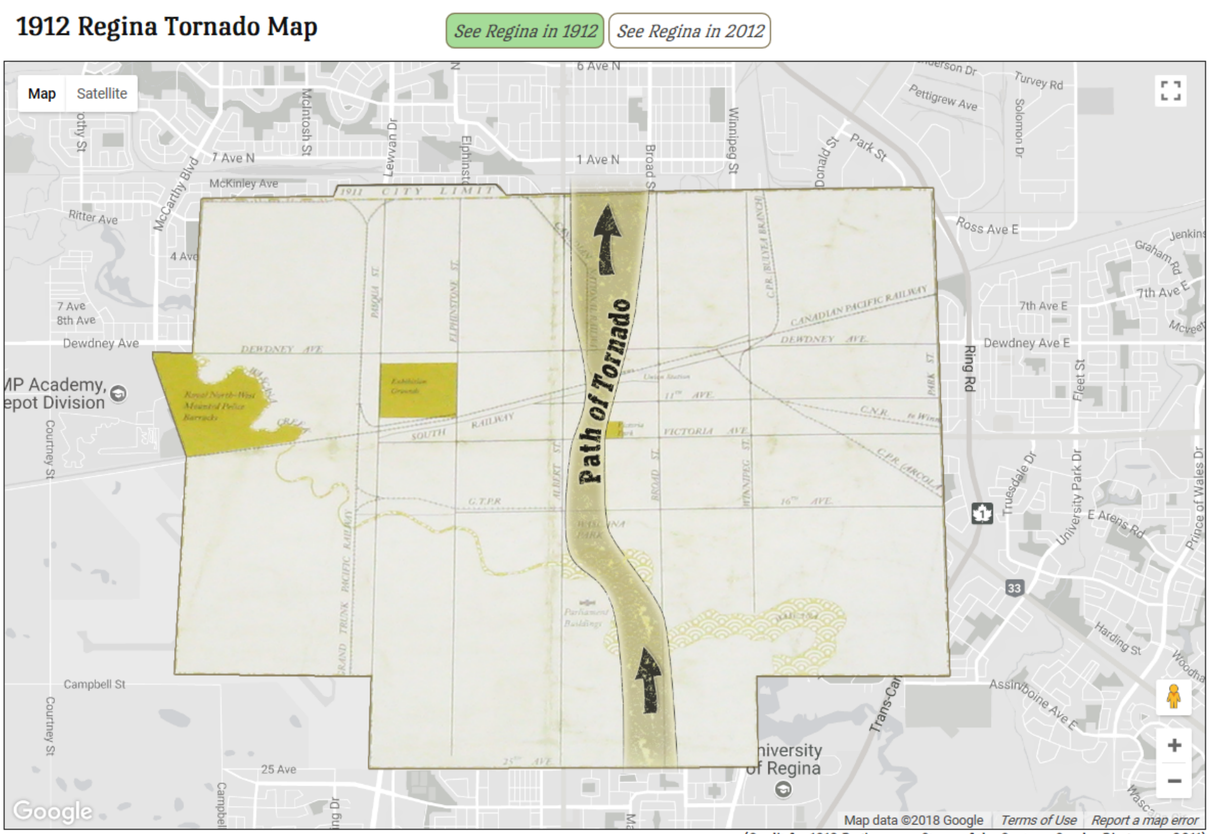


Figure 9.4 Total tornado occurrences (1970–2009) (EC 2011a)



(Credit for 1912 Regina map: Storm of the Century, Sandra Bingaman, 2011)

Figure 9.5 Path of the 30 June 1912 Tornado through Regina (image source: CBC 2018)

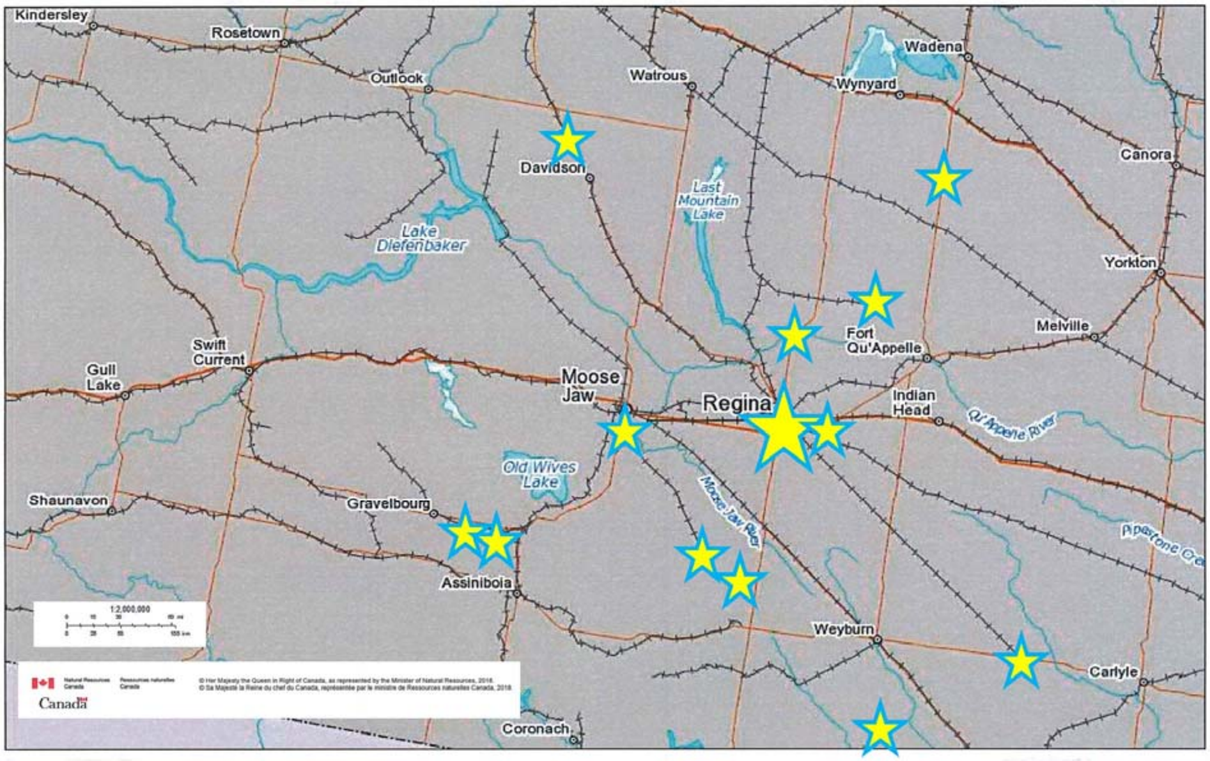


Figure 9.6 Communities affected by the severe convective storm events of 30 June 1912 (data: EC 2012)

Hail

Most regions in Saskatchewan receive between one and two days with hail every year, according to the 1971–2005 average (EC 2011a). Between 2008 and 2016, over 600 hail storms were recorded around the province, with the largest number in 2008 and the lowest in 2009 (Table 9.2). The largest number of severe hail events are located in the east and southeast portion of the province (Figure 9.7). These events cause widespread damage to the agricultural sector and property, resulting in large insurance claims and/or income loss. In addition, there is also the potential for impact on human life (EC 2011a). The greatest monetary losses in convective storms are from hail (Paul 1984). For example, the 8 August 1979 convective storm with hail resulted in nearly $30M of crop loss (Paul 1984). In recent years, agricultural payouts due to hail crop damage reached ranged from $121 million in 2011, $159 million in 2012 (Canadian Underwriter 30 Oct 2012) and $124 million with more than 11,000 claims in 2016 (Piller 18 Oct 2016). It has been found that three to four percent of the prairie grain crop is damaged or destroyed because of hail on average every year (Paul 1984).

Table 9.2 Number of hail events (2008 to 2016) (data: EC 2008-2014, ECCC 2015 and 2016).

	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Hail episodes	99	30	93	61	68	66	63	52	77	609

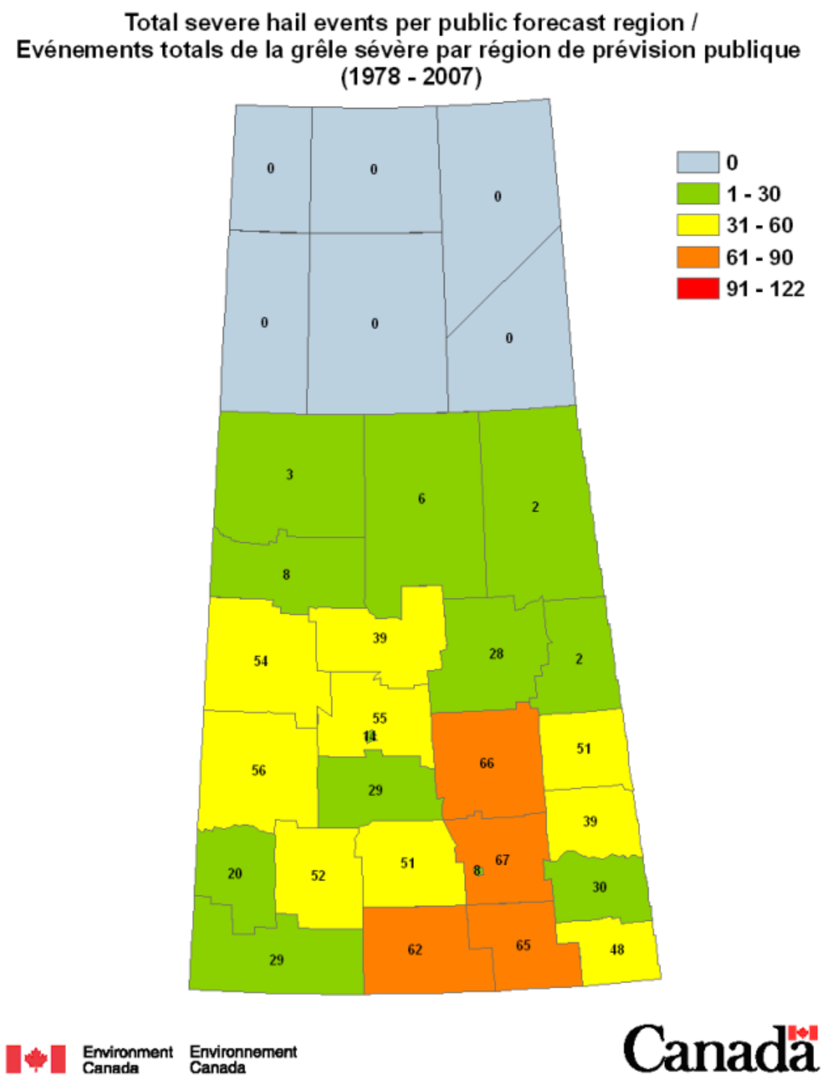


Figure 9.7 Total severe hail events (1978–2007) (EC 2011a)

Windstorm

The southern part of Saskatchewan has between five and 10 days with winds at least 63 km/h or stronger (Figure 9.8). These winds can cause a variety of impacts, including damage to trees, power lines and structures, and have resulted in injury and deaths (EC 2011a). Summer convective storms have resulted in almost 200 reported wind events between 2008 and 2016 (EC 2008 to 2014; ECCC 2015 and 2016). The greatest number was in 2014, with 35 events (Table 9.3).

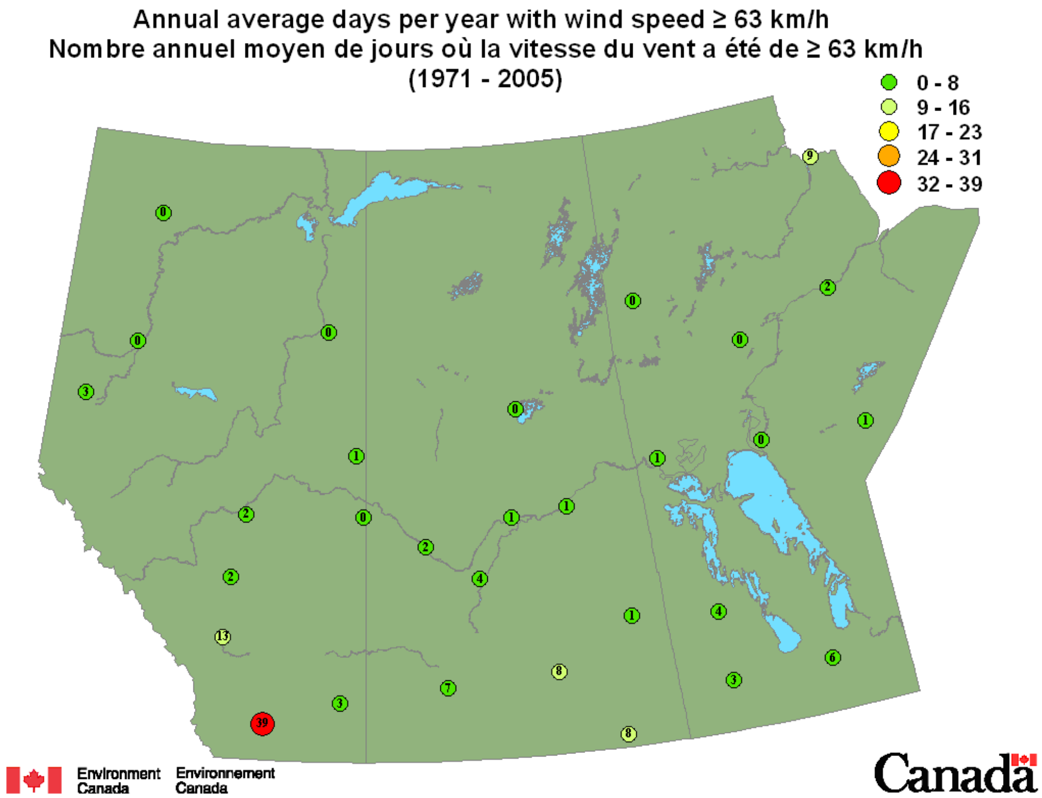


Figure 9.8 Annual average days per year with wind speed ≥ 63 km/hr (1971–2005) (EC 2011a)

Table 9.3 Wind events that were ≥ 63 km/h between 2008 and 2016 (data: EC 2008-2014, ECCC 2015 and 2016)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Number of events	24	17	13	33	28	20	35	9	19	198

Most convective storms have more than one significant weather type associated with them. They usually have strong winds, heavy rains, hail and occasionally tornados, all of which have various levels of damage, including casualties or injuries (Table 9.4).

Table 9.4 Selected convective storm events in Saskatchewan (Paul 2007, Paul 1984, Lundqvist 1999, Environment Canada 2012)

Date	Event	Location	Characteristics, damage, and casualties
30 June 1912	Tornado, strong winds, heavy rain	Regina and area	30 deaths; at least 300 injured; $4 million damage
17 July 1923	Tornado	Lumsden area	8 people injured; damage to buildings
1 July 1935	Tornado, plough wind, hail	Weyburn, Carlyle, Estevan area	Tornado, plough winds and baseball sized hail; damage to buildings, killed poultry, flash flooding
9 August 1944	Tornado, strong winds, heavy rain, hail, lightning	Kamsack	3 deaths, 44 injured, tornado, 400 buildings damaged or destroyed
8 August 1979	Hailstorms	Saskatchewan	$25–30 million in crop hail loss
8 August 1979	Tornadoes	Regina	$8 million in building damage, many minor injuries
11 August 1982	Hailstorm	Saskatoon	$6 million in damage
14 August 1982	Hailstorm	Prince Albert	$8.5 million in damage
19 June 1989	Tornado, hail	Central Saskatchewan	Building and crop damage, power failures
26 August 1995	Thunderstorm, strong winds, hail	Southern Saskatchewan	Building and crop damage, losses estimated to be in excess of $20 million
18 August 1996	Plough wind, hailstorm	Weyburn	$150,000 in damage
16 June 2005	Wind, rain, tornado, hail	25 miles SE of Swift Current	Multi-million-dollar crane destroyed, wind turbine blades destroyed (Centennial wind farm), farm buildings damaged

Climate Change Implications

Climate change alters atmospheric circulation and weather patterns such as the jet stream, affecting the location, frequency and duration of extreme events (Walsh et al. 2014 a). Scientific evidence indicates that the probability and severity of certain types of extreme events has increased and will increase due to climate change (Walsh et al. 2014a). The Intergovernmental Panel on Climate Change (IPCC) has low confidence in establishing any observed trends in small spatial-scale phenomena such as tornadoes and hail due to data inconsistencies, inadequacies of monitoring systems, and the inability of climate models simulate such weather phenomena (IPCC 2012, Seneviratne et al. 2012).

It remains a significant challenge to reliably derive information from climate model outputs on changes in extreme weather hazards (EC 2011b). The atmospheric processes that lead to production of severe weather phenomena like thunderstorms, hail and tornadoes usually occur over relatively small spatial scales that span only one kilometer to tens of kilometers. In contrast, global climate models (GCMs) are usually in the order of a hundred kilometers, and regional climate models (RCMs) have a grid scale with a 25- to 50-km range (Diffenbaugh et al. 2008, EC 2012). GCMs and a high-resolution (25 km horizontal grid resolution) RCM have been used to examine the large-scale meteorological conditions that can lead to the development of severe thunderstorms. The findings suggest that the projected warmer atmosphere will have a higher moisture-holding capacity that will be conducive to the development of more severe thunderstorms; nevertheless, the initiation mechanisms for these storms need to be considered before any conclusions on future changes in severe thunderstorms can be made (Trapp et al. 2007). More research is needed to understand how climate change will affect severe thunderstorms, hail and tornadoes because, while some of the risk factors increase with the changing climate, other factors may decrease (Walsh et al. 2014b).

Worst-Case Scenario

A worst-case scenario of severe summer weather event would be an EF5 tornado with heavy rain and hail going through Regina and a hail event extending large distances through the agricultural zone. An EF5 tornado occurring in southern Saskatchewan is probable (Figure 9.9). Regina had an F4 in 1912, so an EF5 is not unthinkable, especially with the town of Elie, Manitoba, having Canada's first EF5 in 2007. [Note that the impact levels shown in italics relate to the provincial risk matrix. Refer to the methodology section of the report for more information regarding this matrix.] A supercell convective weather system that incudes an EF5 tornado, heavy rains, strong winds and hail having a direct hit on a large urban center like Regina and surrounding communities is possible (Figure 9.9). Such an event would result in multiple deaths (*Human Health - catastrophic*). If a tornado equivalent to the 1912 tornado F4 followed the same path in Regina today, approximately 150 people would die, with more than 1,000 injured and at least 13,000 left homeless (Martin 2012). Irreparable damage of at least $82 million to high-value structures would occur (Martin 2012), and decrease quality of life for communities and the surrounding area (*Social-major to catastrophic*). Such an event, especially if it affects Regina and the surrounding communities as it did in 1912 (Figure 9.6), would result in multi-municipal, provincial and national specialized response being required (*Public Administration-major*). Major damage and impact on critical infrastructure would occur, as would the potential for destruction of high-value property like the Legislative Building(s) (*Economic-major to catastrophic*). An EF5 tornado and the other associated weather could also result in potential added environmental and secondary economic damage, as well as an influence on human well-being. This could happen if the tornado had a direct hit on a train in downtown Regina, as was the case in 1912, but this time with the train carrying dangerous goods. The type of dangerous good affected by a potential break of the rail car has varying levels of influence on the environment, whether the substance results in fire and explosion or becomes a toxic gas or a liquid that leaks into waterways (*Environment-major to catastrophic*). In addition, if certain industries such as the steel processing plant and the oil refinery were destroyed, that would result in even larger damage and potentially greater loss of life and higher injury count (*Environment, Economic-major to catastrophic*).

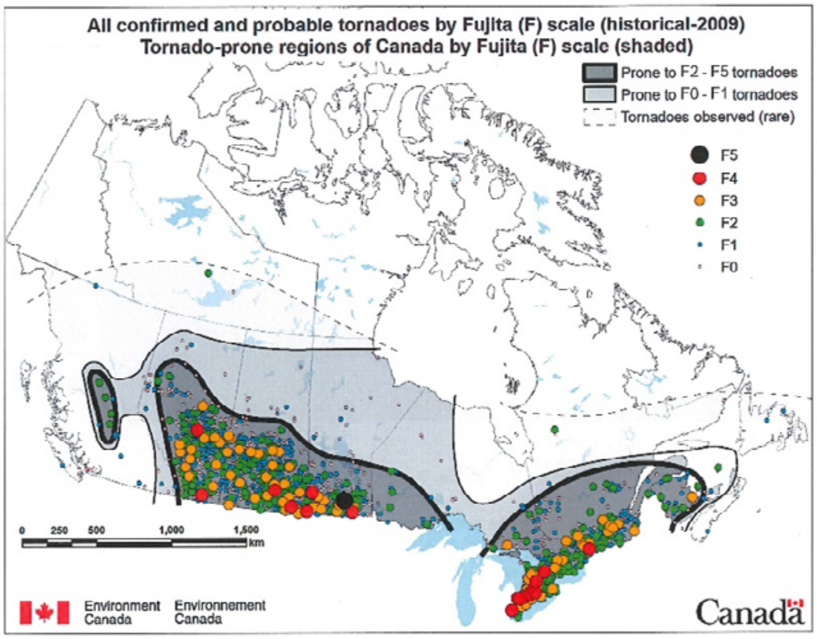


Figure 9.9 F0-F1 and F2-F5 tornado prone areas as well as a "rare occurrence" area, with all known Canadian tornadoes from 1792 to 2009 (Sills et al. 2012).

In addition to the impact of the tornado, there would be widespread hail damage to more than 80 percent of the buildings in Regina and widespread flooding due to the heavy rainfall. The hail will also destroy crops in the region, resulting in extensive crop insurance claims and damage to the crop land. The potential impacts would include quality of life impacted for up to 10 years for some people; a need for municipal, provincial and federal response to such an event; major damage and impact on critical infrastructure; and potentially major damage to the ecosystem, depending on where the tornado occurred.

A recent example of a large tornado hitting a large Prairie city is the Edmonton tornado (F4) that occurred on 31 July 2007. It killed 27 people, injured 600, left hundreds homeless and caused at least $300 million dollars in damage (Riebe 2017). The system also produced hail stones as large as tennis balls (Riebe 2017).

Existing Controls

Environment and Climate Change Canada (ECCC) is the federal agency tasked with providing public weather alerts. Every extreme weather event has a specific criteria that needs to occur for ECCC to issue watches and alerts. In addition, every region in the country has different criteria based on the region's average weather conditions. Appendix 10.3 contains a list of the public weather alerts criteria geared towards Saskatchewan. Summer weather events, especially tornadoes and hail, are unpredictable to locate in their actual zone of influence, but warning/alerts are issued indicating the potential. In addition to this system, the Povince has an emergency public alerting program, called SaskAlert, that provides critical information on various emergencies in real time. While EC is the lead agency for issuing weather advisories, SaskAlert will pick up EC's weather alerts that have the potential to affect life and safety and distributes these advisories and warnings through the SaskAlert System (Government of Saskatchewan 2017).

Tornadoes are the extreme weather event category that has resulted in the largest loss of life in Saskatchewan (Table 9.1). Given the deadly nature of this severe type of storm, Environment Canada put together a map that identifies tornado-prone areas across Canada (Figure 9.9).

The Province assists with alerting the public regarding road conditions through its Highway Hotline (Saskatchewan Ministry of Highways and Infrastructure 2017). It has various warning criteria, ranging from summer driving conditions, to "travel not recommended," for a variety of factors including visibility. The road may be closed for various reasons, e.g., poor visibility, water on road, or road washed out, as was the case with the TransCanada Highway in June 2010.

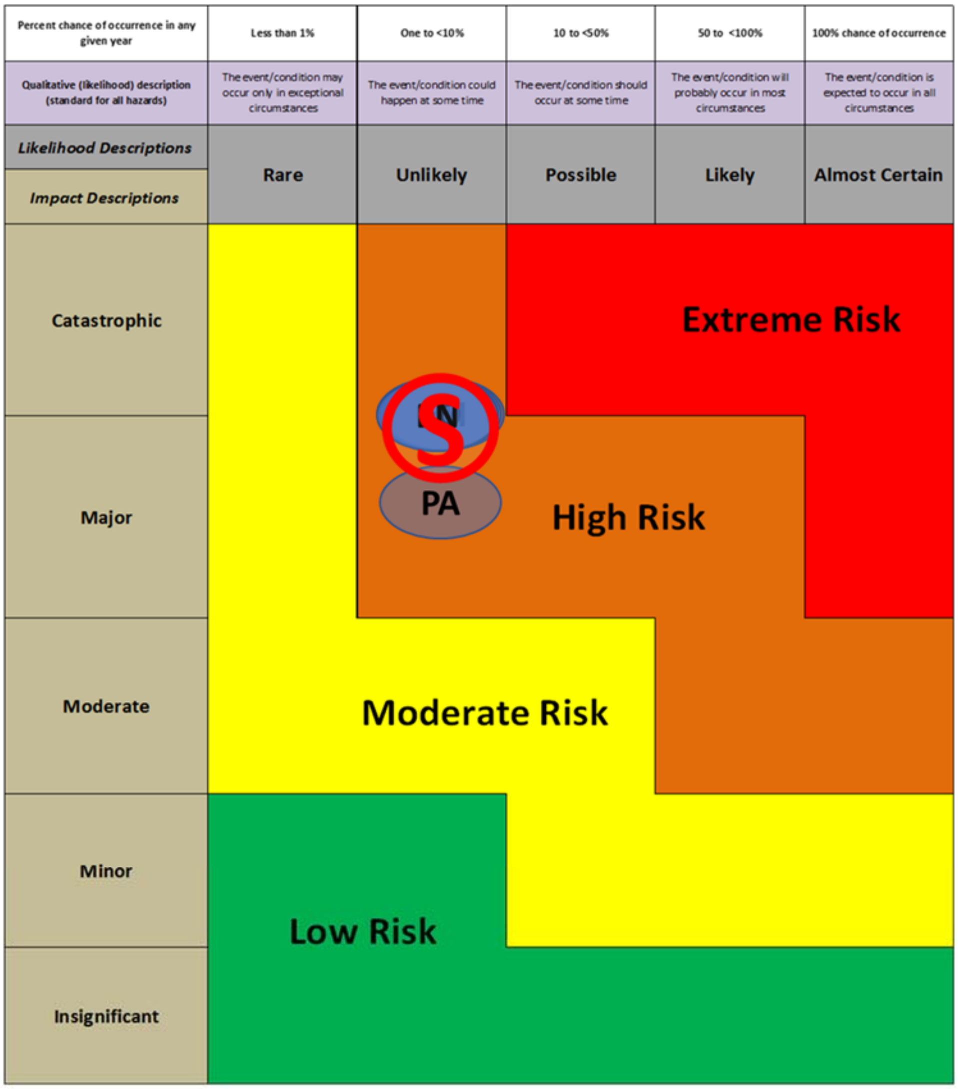
The provincial and federal governments have various controls in place to provide assistance after an extreme event. For example, the Saskatchewan Crop Insurance Corporation (SCIC) assists farmers with recouping some of their losses when extreme weather events such as drought, excessive rain, flooding, etc., occur. While drought events resulted in the largest claims to SCIC, excessive moisture, hail, and wind were also reasons for SCIC to issue insurance payouts to farmers (SCIC ND). In urban settings, insurance-covered events such as hail and windstorms and do not differentiate between climatological seasons, and thus all claims are usually combined (i.e., hail and wind event occur at the same time) (SGI ND). An example of a large insurance payout is for an event that occurred in Regina and surrounding area in July 2013 that was associated with wind, hail, and excessive rain, resulting over 7,000 claims (Richter 7 Aug 2013).

Provincial Risk Analysis

Saskatchewan is certain of having a convective weather event somewhere in the province during the year. Every summer, most regions of the province will have between 20 and 30 thunderstorms, of varying intensity and varying levels of excessive rain, hail, wind and tornadoes associated with them (Environment Canada 2012). However, when worst-case scenario events occur (see previous section), the impact on human health and the economy could be *catastrophic* (multiple deaths and destruction of critical infrastructure), the impacts on social and public administration could be *major to catastrophic* (extended evacuation of communities, irreparable damage to high-value structures and multi-municipal, provincial and national specialize response) and *moderate to major* impact to the environment (regional damage capable of remediation) (Figure 9.10). A convective weather system that includes an EF5 tornado and the accompanying heavy rain, hail, and high winds would result in the province facing a **high risk** scenario.

Conclusions

Summer convective storms are the leading cause of fatalities and injuries in the province of all the natural hazards examined in this project. These storms can lead to major economic losses and insurance claims, especially from hail events. While tornadic activity with EF3s or higher is relatively rare in the province, it does occur and has had catastrophic impacts. Therefore, the federal government severe weather forecast system is important to keep the citizens of the province as safe as possible.



Summer Convective Storms	Plausible Worst-Case Scenario
Convective storms that include hail, strong winds, tornadoes and excess rainfall	There is an unlikely chance (one to < 10 % chance of occurrence) of an EF5 tornado and associated severe convective weather

Figure 9.10 The risk of severe convective weather in Saskatchewan based on impact categories and percent chance of occurrence. The red circle with the S in the centre indicates the aggregate risk of summer convective storms across the provincially based impact categories for the plausible worst-case scenario.

Impacts on roads from winter snow storm (Photo Source: J. Wheaton)

10. SELECTED SEVERE WINTER STORMS

V. Wittrock

"How would we respond should large numbers of people experience loss of electricity and/or heat during a blizzard that restricted the ability to travel and the ability of emergency personnel to respond?" (Anonymous Stakeholder in Corkal 2018).

Definitions

Blizzard – When winds of 40 km/hr or greater are expected to cause widespread reductions in visibility to 400 metres or less, due to blowing snow, or blowing snow in combination with falling snow, for at least 4 hours (ECCC 2017a).

Freezing Rain – rain or drizzle which falls in liquid form and freezes on impact with the ground or other objects, forming a coat of ice (ECCC 2017a and EC 2011b).

Windstorm – sustained winds of speeds that pose a significant threat to public safety and property. Wind warnings occur in Saskatchewan when winds are 70 km/h or more sustained wind and/or gusts to 90 km/h or more (ECCC 2017a).

Winter storm (snow storm) – when severe and potentially dangerous winter weather conditions are expected, including (ECCC 2017a):

- A major snowfall (25 cm or more within a 24-hour period); or
- A significant snowfall (snowfall warning criteria amounts (Appendix 11.1)) combined with other cold weather precipitation types such as: freezing rain, strong winds, blowing snow and/or extreme cold.

Description

Saskatchewan winters can last six to seven months in the northern portions and four to five months in the south, although considerable variation occurs year to year and region to region (Paul 2007). Winters tend to be dominated by cold, dry stable air (Paul 2007). Normal winter weather includes a variety of precipitation types, including snow, rain, and freezing rain (EMO 2012), whereas winter weather extremes refer to blizzards, snowstorms, and freezing rain and can include all three events. The precipitation type depends on the distribution of temperature with height in the lower atmosphere and at the earth's surface (EMO 2012). Snowstorms and blizzards can occur from September to May. They are storm events in which the dominant form of precipitation is snow. The available data covers the period 1880 to 2007, and many of the reported events contain occurrences of all of these events (Environment Canada 2012).

Provincial Risk Statement

Saskatchewan has extreme weather in every season. In many cases extreme weather events overlap and are not entirely season dependent. It has been found that when severe storms affect the various parts of Saskatchewan, depending on their intensity and type, these severe storms can be more debilitating to smaller communities than to larger ones (McInnis 2001). Their impacts on the province depend on the location, time of year and intensity. The majority of the storm events produce localized minor to moderate impacts, but public concern is usually significant in the face of the events. The stakeholders at the workshops indicated that some of the "other," more "top-of-mind" natural hazards included wind events that were part of the blizzards (Corkal 2018). There was also a regional component, with freezing rain being of concern in the more southern regions (Corkal 2018).

Blizzard/Snowstorm

Blizzards and heavy snowfall are hazardous due to their impact on all transportation systems (EC 2011b). In addition, long-duration blizzards that are associated with high winds may result in power and communication outages (EC 2011b). Blizzard hours are greatest in the southern portion of Saskatchewan, decreasing farther northward (Figure 10.1). The information in the map is based on extrapolated information with numerous caveats, including limited data, resulting in the need to use extrapolated data to estimate the number of blizzard-like hours that could be expected during the 1953–1997 period.

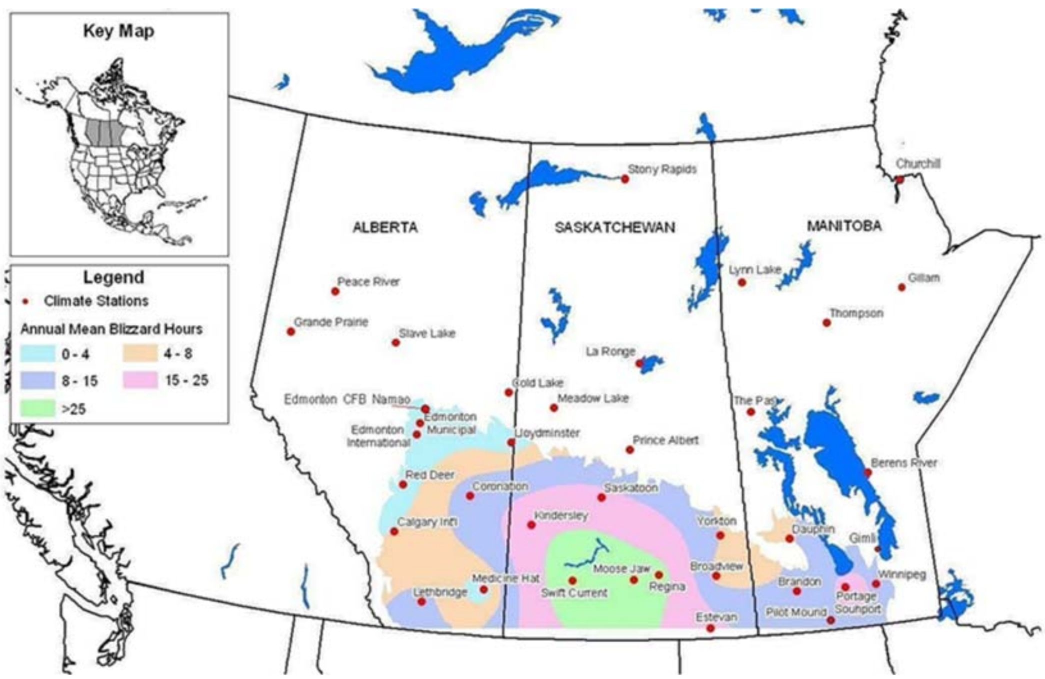


Figure 10.1 Annual mean number of blizzard hours on the Prairies (1953–1997) (Lawson 2011)

Regina and Swift Current have the largest number of blizzards (Table 10.1) recorded over the 1953–1997 period, while the lowest numbers were in Prince Albert and northwards. The duration of these events was from less than 5 hours to longer than 70 hours, with the majority of blizzards lasting 15 hours or less (EC 2011a).

Table 10.1 Total number of blizzards over 44 years (Jan 1953–Dec 1997) (data source: EC 2012)

Regina	Swift Current	Saskatoon	Yorkton	Prince Albert	La Ronge
98	92	24	25	12	0

Blizzards do not necessarily need an abundance of snow to occur. The greatest amount of snowfall generally happens on the eastern and northern portions of the province (Figure 10.2), but Saskatchewan rarely receives heavy snowfall days (25 cm) (Figure 10.3). Heavy snowfall days usually occur in the eastern and northern sides of the province.

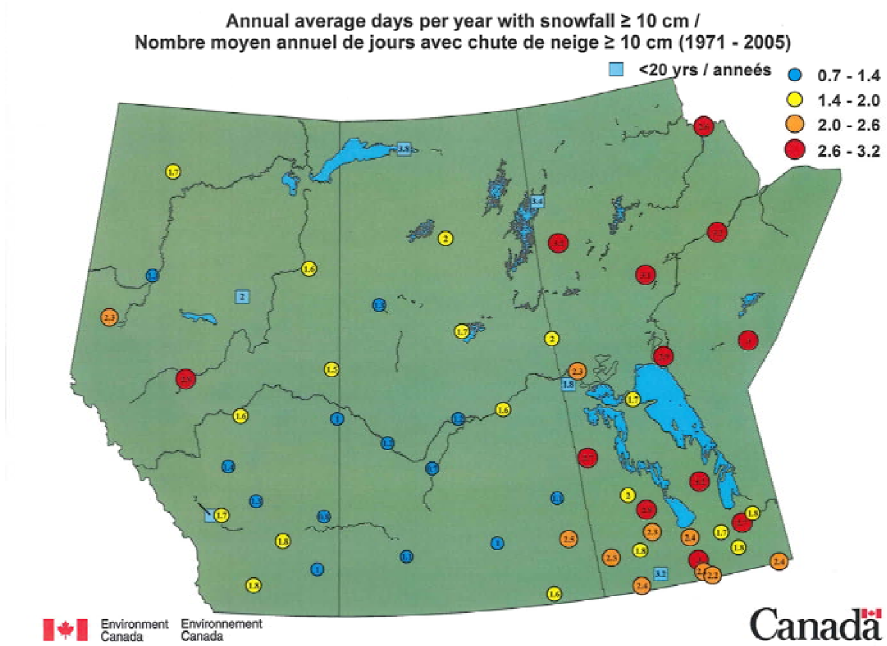


Figure 10.2 Annual average days with snowfall ≥ 10cm (1971–2005) (EC 2012)

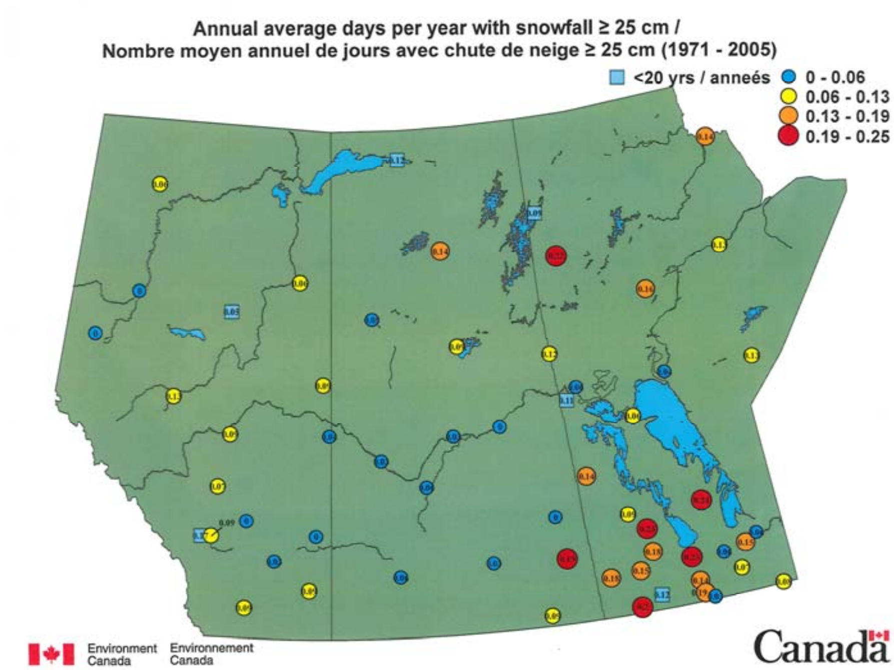


Figure 10.3 Annual average days per year with snowfall ≥ 25 cm (1971-2005) (Environment Canada 2012)

Saskatchewan has had at least nine major snowstorm and blizzard events since 1906 that have resulted in fatalities, infrastructure damage, vehicular accidents, and roads and rail lines closed, as well as business and school closures (Table 10.2).

Table 10.2 Selected blizzard and snowstorm events in Saskatchewan (Paul 2007, Paul 1984, Wheaton 1998, Lundqvist 1999, Environment Canada 2012, Climenhaga 2017, Environment and Climate Change Canada 2017)

Date	Event	Location	Characteristics, damage, and casualties
November 1906	Blizzards	Southern Prairies	One blizzard after another; record low temperatures; killed herds of cattle
January 1947	Blizzard	Southern Saskatchewan	10-day blizzard followed by extreme cold temperatures, buried trains, roads blocked for 10 days, damaged telephone infrastructure, food and fuel supplies became critical
December 1955	Blizzard	Central Saskatchewan	Heavy snow, strong winds
December 1964	Blizzard	Southern Saskatchewan	Heavy snow, strong winds, cold temperatures, three deaths, animals perished
11 January 1975	Blizzard	Southern Saskatchewan	Extreme windchills, cold temperatures
February 1978	Blizzard	Southern Saskatchewan	Storm lasted four days with heavy snow, strong winds, snow drifts. Schools closed, livestock perished, power outages in rural areas.
17 October 1984	Snowstorm	Southern Saskatchewan	Reduced visibility, numerous vehicular accidents.
December 1990	Blizzard	West-central Saskatchewan	Extreme windchills, cold temperatures
10 January 2007	Blizzard	Saskatoon and area	Heavy snow, strong winds, snow drifts, four deaths due to stranded vehicles, business and school closures, ~$1million cleanup costs for City of Saskatoon

Freezing Rain

Freezing rain is another severe winter weather event for Saskatchewan during the winter season. Freezing rain can result in slippery coatings on roads and bridges that can lead to traffic accidents. In addition, depending on the severity of the freezing rain event, it will cause extensive damage to vegetation and tree limb breakage and outages in electrical distribution and communication systems (EC 2011b).

Saskatchewan can have on average between one to more than 10 days of freezing rain (Figure 10.4). These events can occur from September to May. Most locations in the province will have at least one freezing rain event each year to as many as 26 (Table 10.3).

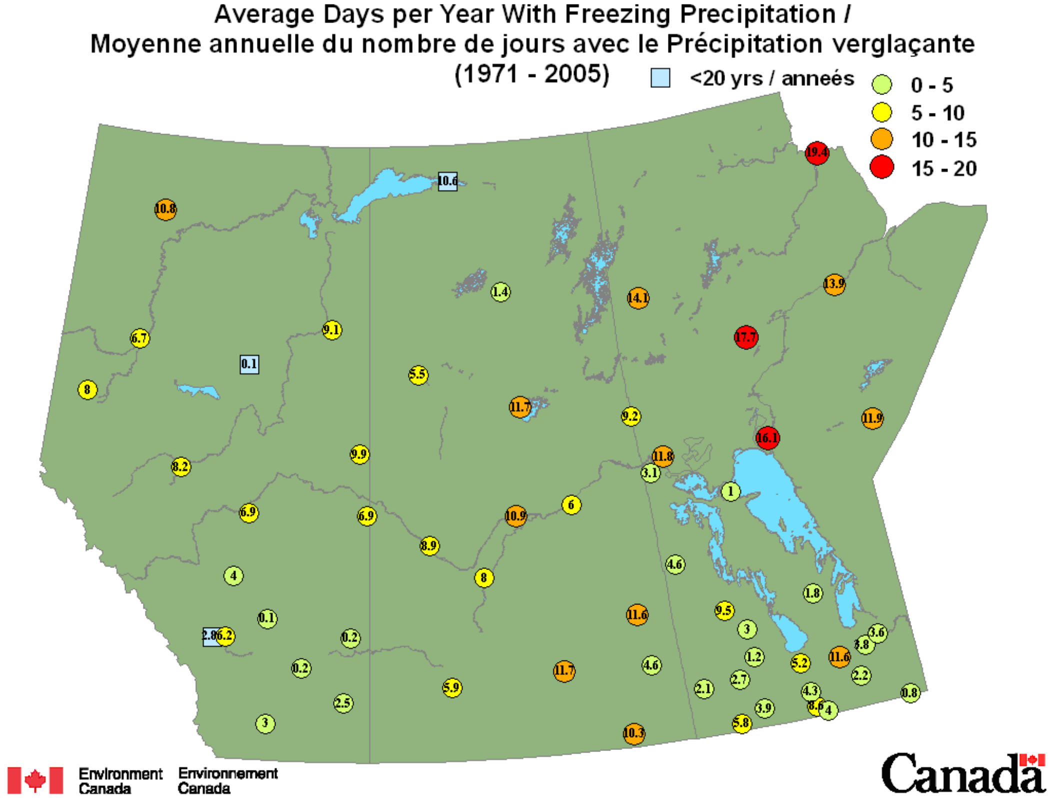


Figure 10.4 Average days per year with freezing precipitation (1971–2005) (EC 2012)

Table 10.3 Annual maximum and minimum freezing precipitation events and associated year(s) at selected communities in Saskatchewan (data: EC 2012)

	La Ronge	Prince Albert	Saskatoon	Yorkton	Swift Current	Regina
Maximum	24	21	16	22	16	26
Year	1983	1998	1983	1997	1983	1983
Minimum	2	2	0	3	1	1
Year	1978 & 1979	1976	1994	2000	1978 & 1980	2002

High Wind Speeds

High wind speeds occur in all seasons in Saskatchewan and, depending on the season, can have a variety of impacts. The southern part of Saskatchewan has between 5 and 10 days with winds at least 63 km/h or stronger during the year (Figure 10.5). These winds can cause a variety of impacts, including damage to trees, power lines and structures, and have resulted in injury and deaths (EC 2011a).

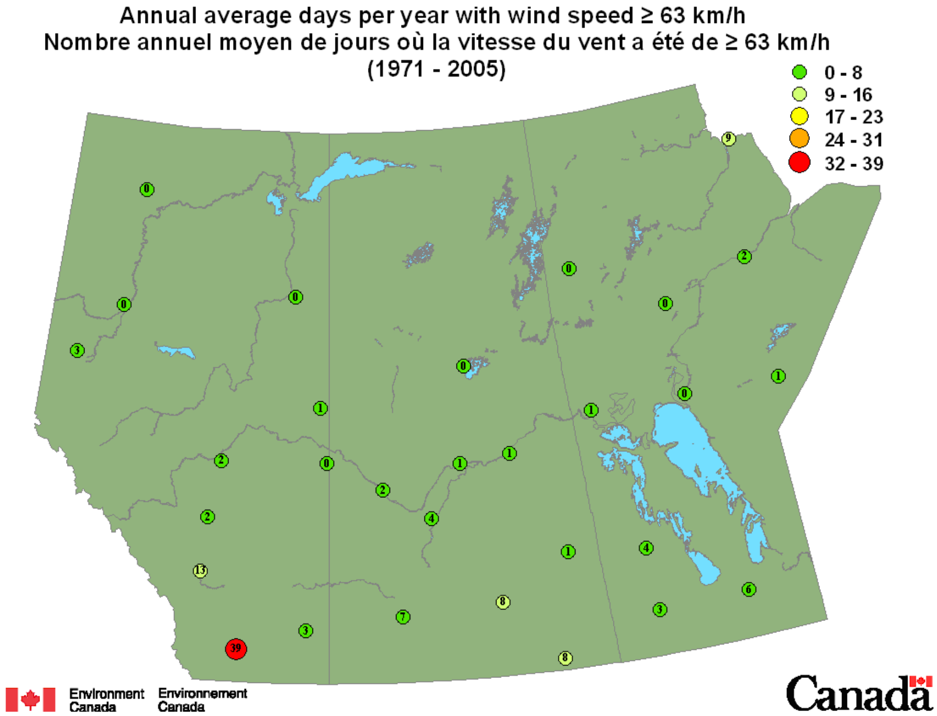


Figure 10.5 Annual average days per year with wind speed ≥ 63 km/hr (1971–2005) (EC 2011a)

Climate Change Implications

Climate change alters atmospheric circulation and weather patterns such as the jet stream, affecting the location, frequency and duration of extreme events (Walsh et al. 2014a). The probability and severity of certain types of extreme events has increased and will increase due to climate change (Walsh et al. 2014a).

Models tend to project a reduction of winter cyclone activity through the mid-latitude but the exact geographical pattern of the cyclone frequency anomalies exhibits large variations (Seneviratne et al. 2012), and the number of the most intense winter storms could potentially increase (EC 2011b). Winter storm tracks appear to have shifted slightly northward (Seneviratne et al. 2012, Walsh et al. 2014b). An ensemble of IPCC AR4 Global Climate Model data (Environment Canada 2011c), as shown in the number of days per year with snowfall ≥ 10 cm (Figure 10.6), indicates that in all locations in Saskatchewan, the number of days with snowfall will decrease in the 2050s (2041–2070) when compared to 1971–2000. The number of more intense snowfalls (days per year with snowfall ≥ 25 cm) may increase in the western portion of the province in the 2050s (Figure 10.7).

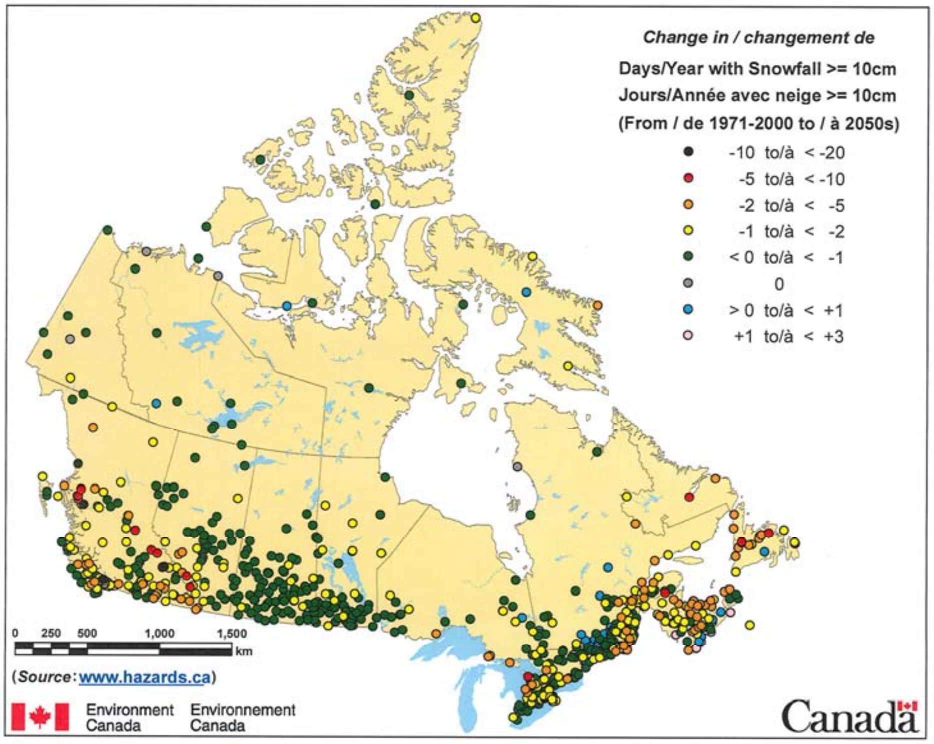


Figure 10.6 Change in days per year with snowfall >= 10 cm from 1971–2000 to the 2050s (Environment Canada 2011b)

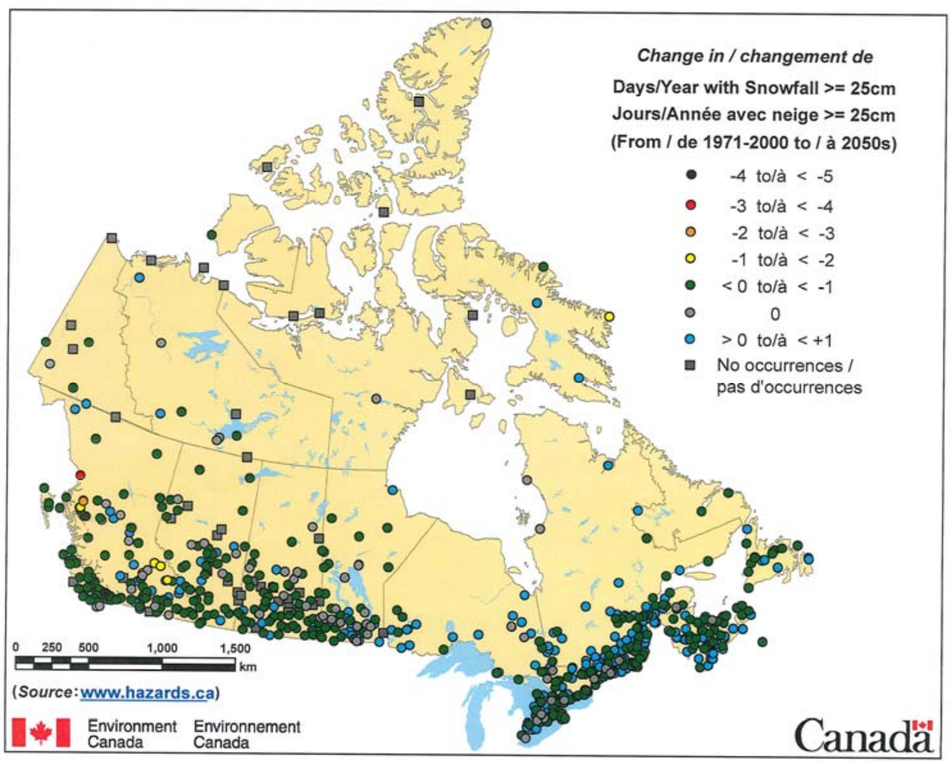


Figure 10.7 Change in days per year with snowfall >= 25 cm from 1971–2000 to the 2050s (Environment Canada 2011b)

Worst-Case Scenario

A worst-case scenario for a severe winter weather event would be a large weather system that covers the agricultural zone, starting with freezing rain that would coat all outside surfaces like power lines, roadways and sidewalks, and trees with thick ice; and, as the temperature falls, the freezing rain would be followed by blizzard conditions that last for a similar length as what occurred in February 1978 (at least 60 hours) (Appendix 11.2). These conditions would result in extremely dangerous road conditions to the point of roads being closed for days to more than a week. There would be widespread power outages due to utility lines being severely damaged by freezing rain that affects the power distribution system and, in urban areas, by ice-covered tree limbs falling on the lines, and by high winds and blizzard conditions. The continued severe winter weather conditions would make it unsafe to repair the infrastructure. These conditions could result in multiple fatalities (vehicular traffic fatalities, lack of heat supply in rural settings, carbon monoxide poisoning, fire, hypothermia etc.) (*Human Health-major*). This type of storm would lead to short- term (less than 5 years) disruption in quality of life and some damage to localized culturally significant objects (*Social-minor to moderate*); disruption of critical infrastructure, such as power lines, could require multi-municipal, provincial and federal response (*Public Administration-moderate to major*). An example of an extensive winter power outage in Canada occurred in Ontario, Quebec and New Brunswick during the ice storm in 1998 that resulted in extreme damage to the high-voltage lattice towers. This led to power crews from multiple provinces and the USA assisting with the repairs (Lecomte et al. 1998). This level of winter storm would result in the disruption of at least two critical infrastructures (e.g., power, roadways, emergency personnel, possibly water supply due to lack of electricity). The potential exists for regional damages that could last for more than two years (e.g., building collapse due to snow buildup, especially to aging infrastructure) (*Economic-major*). The storm would also have a negative impact on the agricultural community, especially livestock producers. The 1998 ice storm resulted in major losses of both livestock and poultry (Lecomte et al. 1998). This type of plausible worst-case scenario of a winter severe weather event has an immediate environmental impact and a delayed environmental impact. During the event, there would likely be only localized environmental damage (such as trees damaged due to the ice, wind and snow pack) The resultant regional damaged vegetation would take a number of years to be re-established (*Environment-moderate*). The spring snowmelt could result in widespread flooding due to the large snowpack (*Environment-moderate*).

Existing Controls

Environment and Climate Change Canada (ECCC) is the federal agency tasked with providing public weather alerts. Every extreme weather event has a specific criterion that needs to occur for ECCC to issue watches and alerts. In addition, every region in the country has different criteria based on the region's average weather conditions. Appendix 11.1 contains a list of the public weather alert criteria geared towards Saskatchewan.

Winter severe storms like blizzards and freezing rain events are usually forecast well in advance (EMO 2012). Winter storm warnings issued at least 12 hours before occurrence are not uncommon (EMO 2012).

The Province assists with alerting the public regarding road conditions through its Highway Hotline (Saskatchewan Ministry of Highways and Infrastructure 2017). It has various warning criteria, ranging from good winter driving conditions, to "travel not recommended," for a variety of reasons, including poor visibility, icy roads, and road closures. The road may be closed due to visibility, impassable due to snow buildup, or covered in water due to extreme flooding. In addition to this system, the Province has an emergency public alerting program, called SaskAlert, that provides critical information on various emergencies in real time. While EC is the lead agency for issuing weather advisories, SaskAlert will pick up EC's weather alerts that have the potential to affect life and safety and distributes these advisories and warnings through the SaskAlert System (Government of Saskatchewan 2017).

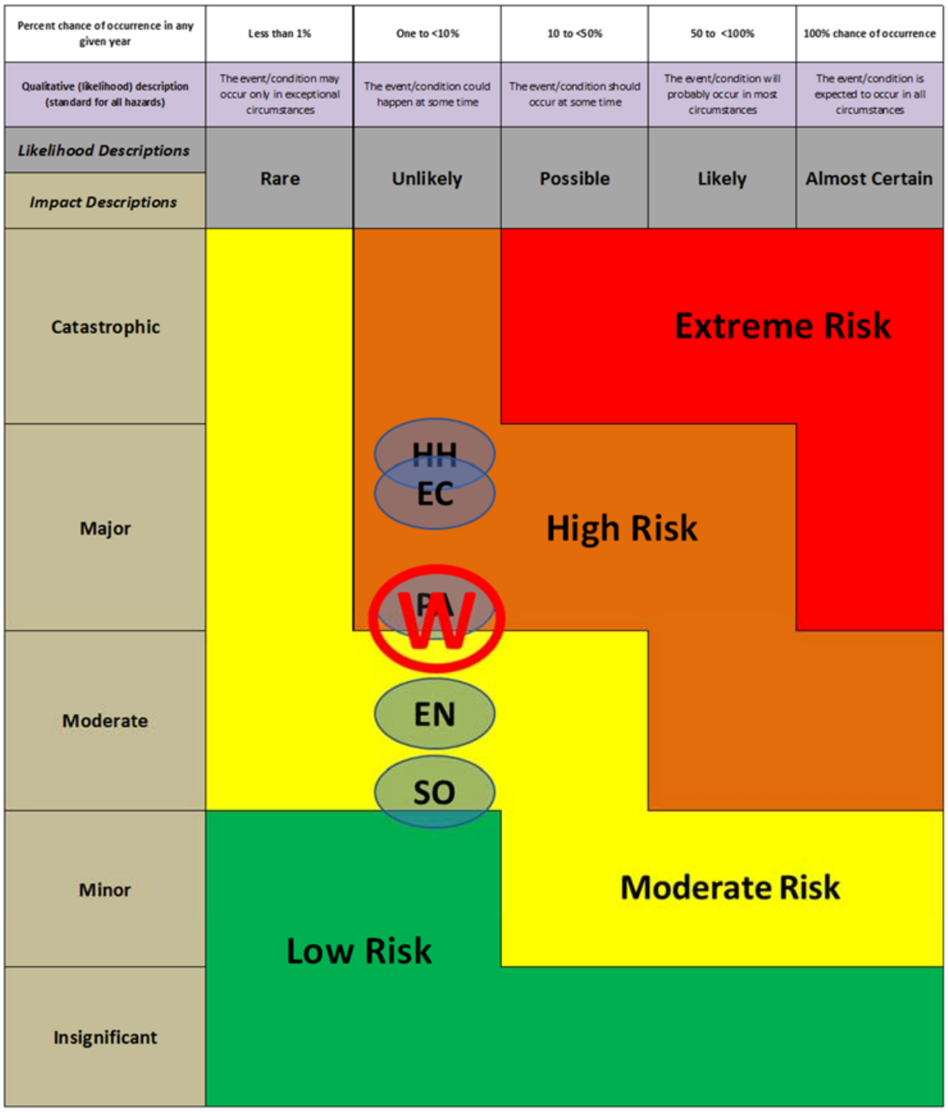
Communities also have existing controls in place. For example, in December 1995, the power for the Wadena, Kelvington, and Archerwill region was out for more than 30 hours. This outage wasn't due to a major ice storm, but rather to the weight of hoarfrost built up on trees and power lines over a matter of weeks. In addition, the outside temperature was nearly -30°C. Communities opened up their community halls to allow residents to seek warming shelters; volunteer firefighters went door-to-door assisting at-risk citizens; and social media was used to notify local residents of the community plans (Wadena-Admin 2015). The upside in this scenario was that it was safe to travel to the shelters.

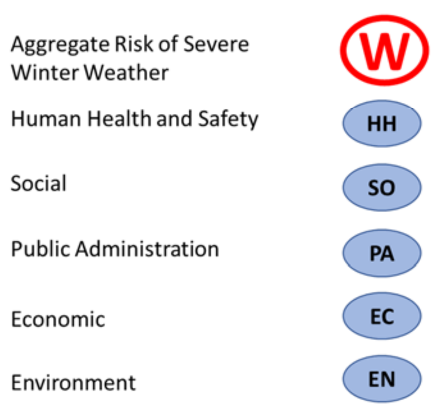
Provincial Risk Analysis

Saskatchewan is certain of having some type of extreme winter weather every year, somewhere in the province. Severe winter weather can have impacts in the plausible worst-case scenario that ranges from *moderate* (Social, Environment and Public Administration) to *major* (Public Administration, Economic and Human Health) with a one to less than 10 percent chance of this plausible worst-case scenario occurring, resulting in an aggregate provincial risk level of **moderate to high** (Figure 10.8).

Conclusions

This chapter includes descriptions of selected winter severe storms. Blizzards and freezing rain events can result in loss of life, businesses and schools closing, and infrastructure badly damaged; the resulting economic impact is major in nature. This leads to a moderate to high risk level for the province of Saskatchewan under a worst-case scenario. As with summer convective storms, the federal government has the responsibility for forecasting these extreme weather events but the Province also utilizes the provincial Ministry of Highways and Infrastructure to alert people of road conditions.





Severe Winter Weather	Plausible Worst-Case Scenario
Winter storms include freezing rain, heavy snow, blizzard conditions and high winds	There is an unlikely change (one to < 10 % chance of occurrence) of having the plausible worst-case scenario occur.

Figure 10.8 The risk of severe winter weather in Saskatchewan based on impact categories and percent chance of occurrence. The red circle with the W in the centre indicates the aggregate risk of severe winter weather across the provincially based impact categories for the plausible worst-case scenario.

11. EARTHQUAKES

V. Wittrock and R. A. Halliday

Definition

Natural Resources Canada (NRCan 2016a) describes an earthquake as what occurs "*when rocks break and slip along the earth. Energy is released during an earthquake in several forms, including as movement along the fault, as heat, and as seismic waves that radiate out from the 'source' in all directions and cause the ground to shake, sometimes hundreds of kilometres away*."

Description

Earthquakes can occur anywhere but are most often associated by slow deformation of tectonic plates. Because of the cooling and heating of the rock below the plates, the resulting convection causes the adjacent overlying plates to move and deform. The rates of plate movements range from two to twelve centimetres a year. If the accumulated stress exceeds the strength of rock making up the brittle zones of the tectonic places, the rocks can break, thus releasing the stored energy in the form of an earthquake (NRCan 2016a).

Saskatchewan lies entirely on one tectonic plate. Earthquakes in this province, therefore, are the result of intra-plate seismicity. Most Saskatchewan earthquakes are associated with the more structurally disturbed regions of the underlying Precambrian formation in southern Saskatchewan's Williston Basin. Of particular interest is the salt solution structure known as the Regina-Hummingbird Trough that extends south from Regina to the international boundary (Horner and Hasegawa 1978).

Although the majority of earthquakes are natural, human activities have caused earthquakes. These activities include mining where an underground region collapses or rockbursts occur, oil recovery, and the filling of large reservoirs behind dams. Large underground explosions, like nuclear explosions, also cause earthquakes (NRCan 2016a). The focus of this section is on naturally occurring earthquakes.

Earthquakes are measured according to both magnitude and intensity. The intensity scale of an earthquake describes the effects of the earthquake at a given location, on natural features, industrial installations and human beings. This is measured on a 12-point scale called the Modified Mercalli Intensity Scale (NRCan 2016a) (Table 11.1).

Table 11.1 Modified Mercalli Intensity Scale (after NRCan 2016a and EMO 2012)

Scale	Description
I	Shaking not felt except under certain conditions
II	Weak shaking, no damage. Felt indoors by only a few people, especially on upper floors of building.
III	Shaking felt with no damage. Felt indoors by several people, motion usually rapid vibration. May not be recognized as an earthquake, as motion is similar to vibration of large trucks passing.
IV	Shaking felt indoors by many and outdoors by a few. Vibration is similar to passing of heavy or heavily loaded trucks. Creaking of walls, especially in the upper range of this scale.
V	Shaking felt by everyone indoors and outdoors by most people. Building tremble, with dishes and glassware breaking. Windows may crack. Hanging objects and doors will swing. Trees and bushes shake slightly.
VI	Strong shaking felt by everyone indoors and outdoors. Damage slight in poorly constructed buildings. Building plaster will fall in small amount, with some cracked plaster and fine cracks in chimneys.
VII	Very strong shaking with moderate damage. Damage negligible in building of good design and construction, slight to moderate damage in well-built buildings, considerable damage in poorly built or badly designed structures.
VIII	Severe shaking with moderate to heavy damage. Considerable damage in normal well-built buildings, slight damage in structures designed to withstand earthquakes. Damage great in poorly built structures. Heavy furniture moved and/or overturned.
IX	Violent shaking with heavy damage. Cracked ground conspicuous. Considerable damage to structures designed to withstand earthquakes, including being thrown off plumb. Damage great to substation (masonry) buildings with some collapse, cracked frames, serious damage to reservoirs/dams, underground pipes sometimes broken.
X	Extreme shaking, very heavy damage. Considerable damage to all structures. Some well-built wooden structures destroyed. Serious damage to dams, dykes and embankments.
XI	Extreme shaking, near total damage. Broad fissure, earth slumps and land slides. Damage severe to wood frame structures. Few if any structures remain standing. Great damage to dams, dykes, and embankments. Bridges destroyed, rail lines bent and displaced.
XII	Extreme shaking, total damage. Practically all structures greatly damaged or destroyed. Distorted lines of sight and level. Objects thrown upward into air.

The extent and type of damage depends on the magnitude of the earthquake, the distance from the earthquake epicenter or origin point, the frequency of the ground motion, the kind of faulting, and the soil and rock type of the area (NRCan 2016a). The magnitude of an earthquake is a measure of the amount of energy released by that earthquake. It is described by using the Richter scale, a logarithmic scale where each level is 10 times greater than the previous level (NRCan 2016a) (Table 11.2).

Table 11.2 Richter Scale (modified from NRCan 2016a, and EMO 2012)

< 2.0	Micro – Usually only recorded by seismographs. Most people are unable to feel them.
2.0–2.9	Minor – Few people feel them and no building damage.
3.0–3.9	Minor – Some people feel them with some object inside structure can be seen shaking. Rarely causes damage.
4.0–4.9	Light – Most people feel it. Noticeable shaking of indoor items such as hanging objects.
5.0–5.9	Moderate – Everyone feels it. Poorly constructed building may be severely damaged. Slight damage to well-designed structures.
6.0–6.9	Strong – Widespread shaking far from epicenter (~160 km). Chimney collapse, buildings moved from their foundations.
7.0–7.9	Major – Severe damage over great distances. Buildings collapse, bridges twist.
8.0–8.9	Great – Severe damage in areas several hundreds of kilometres across. Objects thrown into the air.
9.0 and greater	Great – Severe damage and devastation in areas several thousand of kilometers across.

Provincial Risk Statement

Earthquake risk is not uniform across the country nor within the province. Most earthquakes in Canada are associated with major faults in British Colombia and along the St. Lawrence River Valley. The third major earthquake zone is in the Arctic islands (Figure 11.1) (NRCan 2016a and Gendzwill 1999). The relative hazard risk in most of Saskatchewan is low. Only in the extreme south-central portion of the province is the risk level considered to be moderate (Figure 11.2). This region is where the only earthquake measured to be 5.5 magnitude was observed and recorded.

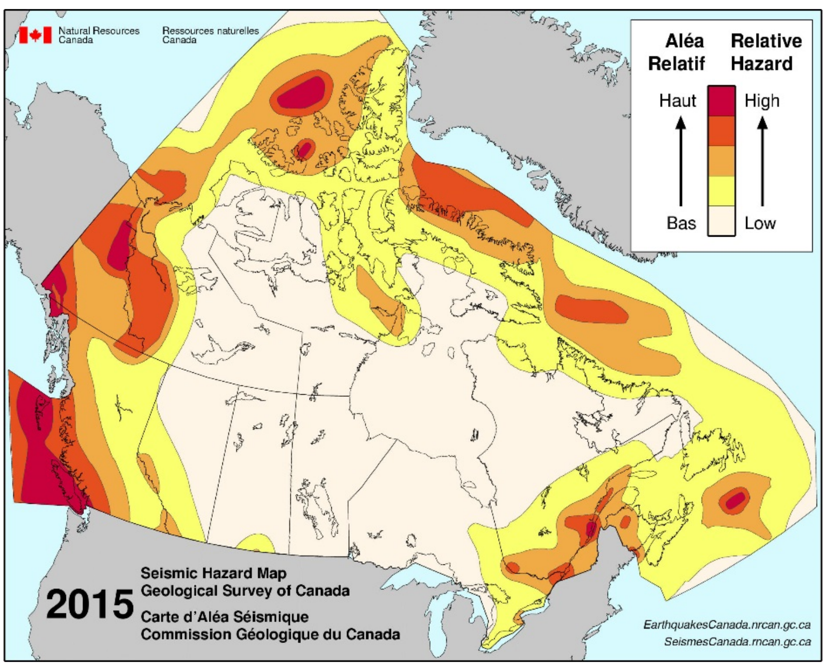


Figure 11.1 Seismic hazard map of Canada (NRCan 2017b)

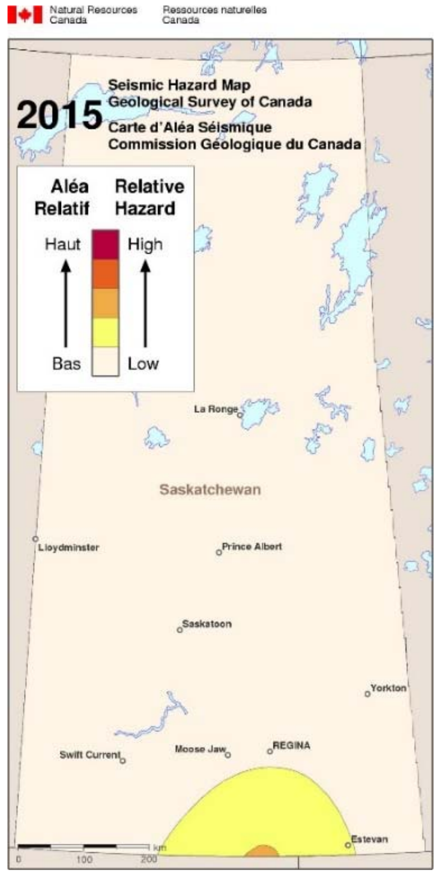


Figure 11.2 Seismic hazard map of Saskatchewan (NRCan 2017b)

While many parts of Canada have earthquakes, Saskatchewan has had very few earthquakes with magnitude 3.0 or greater between 1627 and 2015 (Figure 11.3, Table 11.3). In Saskatchewan, earthquakes are the result of being located close to known or suspected faults. The most likely natural mechanism for seismic activity in the province is known as strike-slip faulting. Cavity development in the Prairie Evaporite Formation (Figure 11.4) by either natural or industrial activity may also lead to seismic activity (Horner and Hasegawa 1978, Gendzwill ND). The Prairie Evaporite Formation is the source of potash with 10 operating potash mines in Saskatchewan (Government of Saskatchewan 2017).

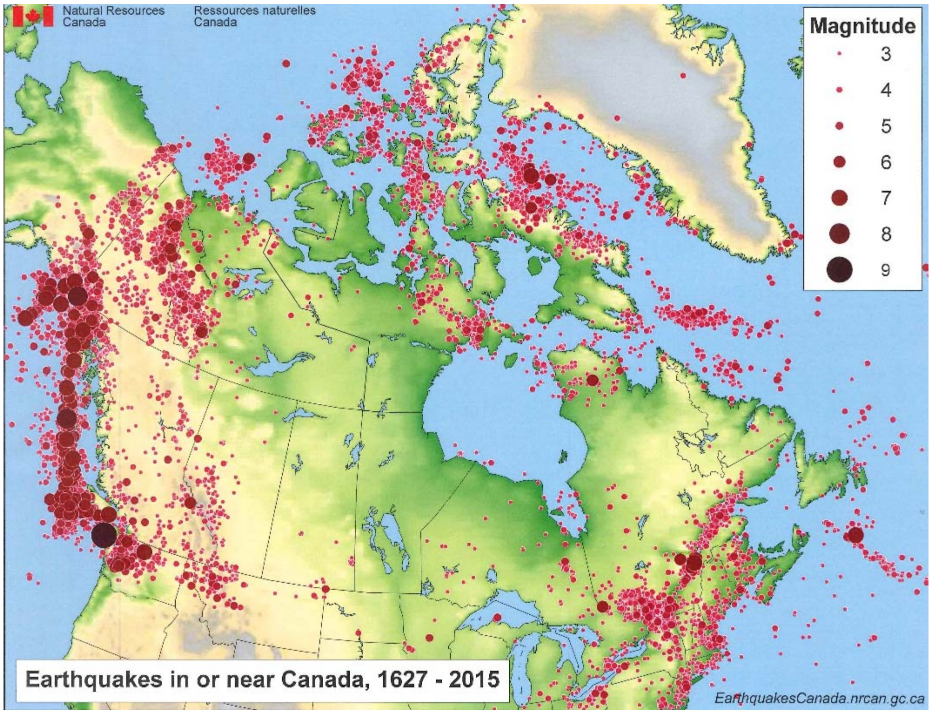


Figure 11.3 Earthquake in or near Canada (1627–2015) with magnitudes of 3 or greater (NRCan 2016b)

Table 11.3 Total number of earthquakes in Saskatchewan (1909–2016) (Data source: NRCan 2017a, Gendzwill ND)

Magnitude	Number of occurrences over 108 years	Percent chance of occurrence
5 or greater	1	2
4 to <5	0	0
3 to <4	23	49
2 to <3	23	49
1 to <2	0	0

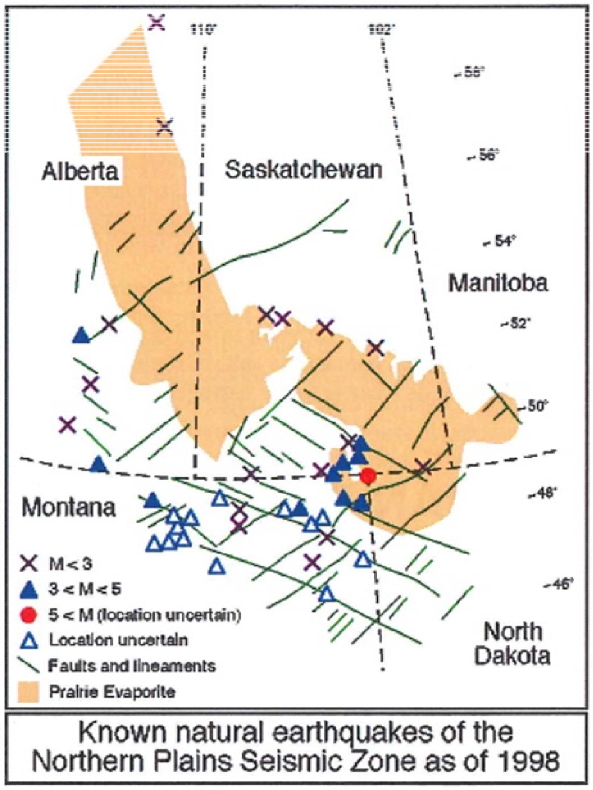


Figure 11.4 Natural earthquakes from 1909 to 1998 (Gendzwill ND)

Saskatchewan's largest quake occurred in 1909 with a magnitude of 5.5 and was felt over an area of about 1.3×10^6 km^2 covering south-central Canada and north-central United States. Due in part to low population and few structures, the only confirmed damage was some broken windows and articles fallen from shelves (Horner and Hasewawa 1978, Gendzwill ND).

Other earthquakes, that may or may not be associated with mining activities, have resulted in people being temporarily confined to a refuge station in underground mines. Such an event occurred at the Potash Corp mine near Rocanville in September 2016, when a magnitude 3.8 earthquake happened. The power supply stopped functioning, resulting in backup power being utilized. This backup power supply was unable to bring the workers to the surface. Forty people safely stayed in the underground fully stocked refuge stations until the power was restored, after which the people returned to the surface (National Post 2016). Examining the potential for significant earthquakes as the result of mining or fluid injection associated with oil recovery is beyond the scope of this report.

Climate Change Implications

In Saskatchewan, earthquakes are not influenced by changing climate.

Worst-Case Scenario

Saskatchewan is not at high risk for a naturally occurring earthquake, let alone a severe earthquake, but if a major earthquake were to occur, the most plausible worst-case scenario as it affects Saskatchewan would be an earthquake in the south-central part of the province where the relative risk is greatest (Figures 11.2 and 11.4). [Note that the impact levels shown in italics relate to the provincial risk matrix. Refer to the methodology section in Chapter 4 for more information regarding this matrix.] In such a scenario, an earthquake would lead to the failure of Morrison Dam on the East Poplar River near Coronach. If the dam were at its full supply level, the resulting floodwaters would move downstream through the Fort Peck Indian Reservation in Montana to the Missouri River (Figure 11.5). The impacts on the Saskatchewan side of the international boundary would be *insignificant to moderate*. Human health and safety could be compromised for the few Saskatchewan households and inhabited properties downstream of the dam in Saskatchewan, resulting in an *insignificant* impact. The social impact to the province of Saskatchewan would also be *insignificant*. The economic impact would be *moderate* due to the loss of the Poplar River Generating Station which provides 13 percent of the province's generating capacity (based on its net capacity compared to the province's total net capacity of all electrical generating systems) (SaskPower 2018). Depending on the timing of the failure, loss of that much baseload capacity could be significant. The public administration impact for the province of Saskatchewan would be *moderate* because the destruction of the dam would require both provincial and municipal specialized response to mitigate the impacts of the dam failure. Another consideration is that, because the East Poplar River is an international waterway, provincial, federal and US governments would need to work together to minimize potential political issues that could arise. The environmental impact on the Saskatchewan side of the border would be *insignificant*.

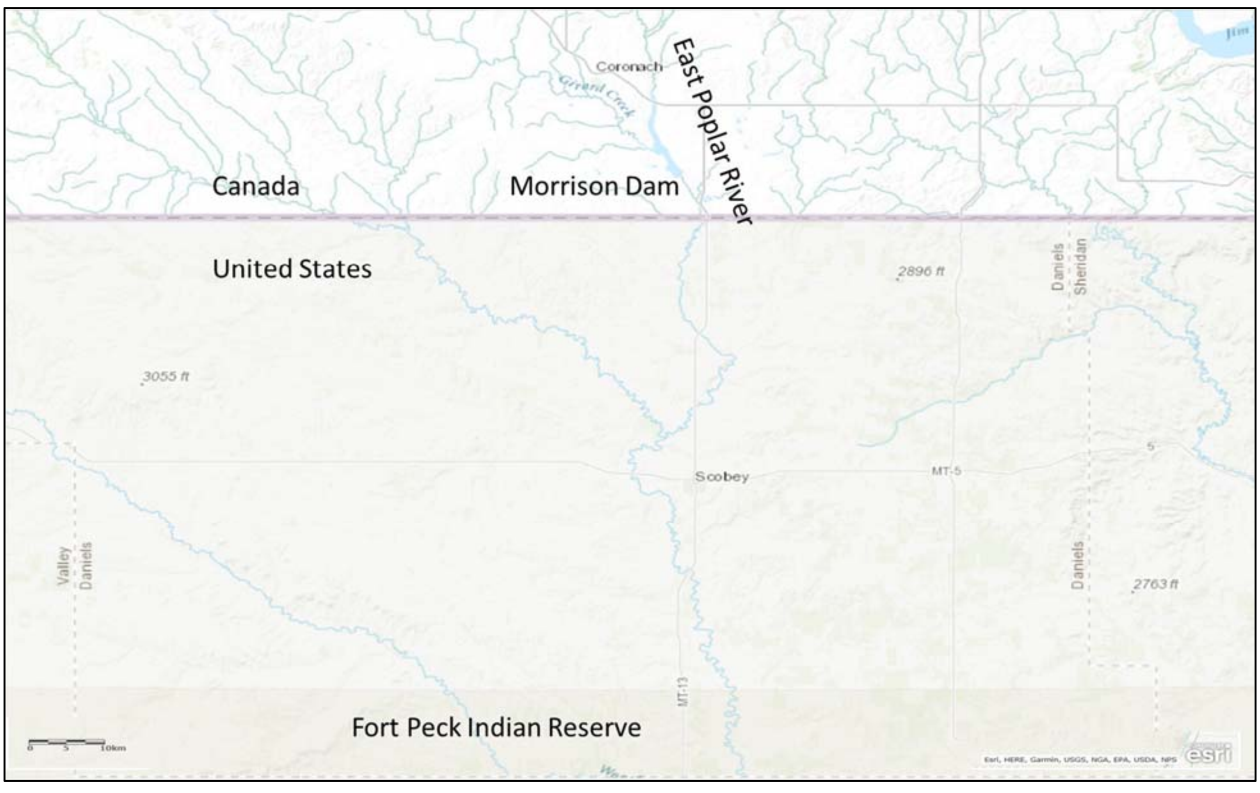


Figure 11.5 Morrison Dam and East Poplar River (Modified from International Joint Commission Maps ND)

The provincial consultations in the spring of 2017 indicated that earthquakes were not regarded as a severe hazard or major threat in Saskatchewan; there was very little mention of them (Corkal 2018). Only the Swift Current consultation brought up the issue of Yellowstone National Park and the likelihood of the Yellowstone Caldera erupting (Corkal 2018). In the last 2.1 million years, three exceedingly large volcanic eruptions have occurred. The probability of a large caldera-forming eruption within the next few thousand years is exceedingly low (Lowenstern et al. 2005).

Existing Controls

None of the existing dams in Saskatchewan were designed for earthquake loading, as they were built at a time when seismic risk was not considered in the design process (CDA 2007). In general, Saskatchewan dams are located in areas of low seismic activity. While Saskatchewan does not have dam safety legislation, some dam owners have considered seismic risk in recent dam safety evaluations. Alberta, which does have dam safety legislation, has evaluated seismic risk at all of its major dams (Alberta Infrastructure 2007).

Underground mines have refuge stations for workers who are unable to make it to the surface. These stations are equipped with power, air, and water (National Post 2016). These refuge stations are utilized by underground personnel in the case of various mining emergency situations such as fires or cave-ins.

Provincial Earthquake Risk Analysis

The risk matrix heat map (Figure 11.6) summarizes the normal conditions and worst-case scenario conditions. The red circle with the ‘E’ in the center is the aggregate risk level of the worst-case scenario event.

Earthquakes in Saskatchewan are not overly common, compared to the rest of the country. Between 1908 and 2017, Saskatchewan had an estimated 47 earthquakes with a magnitude of 2.3 or greater. The majority of earthquakes in the province are classified as minor or light (Table 11.2), with 49 percent having magnitudes less than 3, and 49 percent having magnitudes of 3 to less than 4. While these light to micro earthquakes are likely, their level of impacts would be considered insignificant.

The plausible worst-case scenario earthquake was designated at a magnitude of 5.5 or moderate (Table 11.2). It has a 2 percent chance of occurring (or *unlikely*) and its aggregated risk level in Saskatchewan would be low (Figure 11.6). In addition, based on percent chance of occurrence and the fact that earthquakes in Saskatchewan are not influenced by climate change, the probability of occurrence will decrease to *rare*.

Conclusions

Natural earthquakes in Saskatchewan are likely but have insignificant impacts. Large earthquakes are unlikely but could pose moderate to major impacts, especially if international governmental jurisdictions are involved.

This section does not examine the potential of influence of various industries on earthquakes.

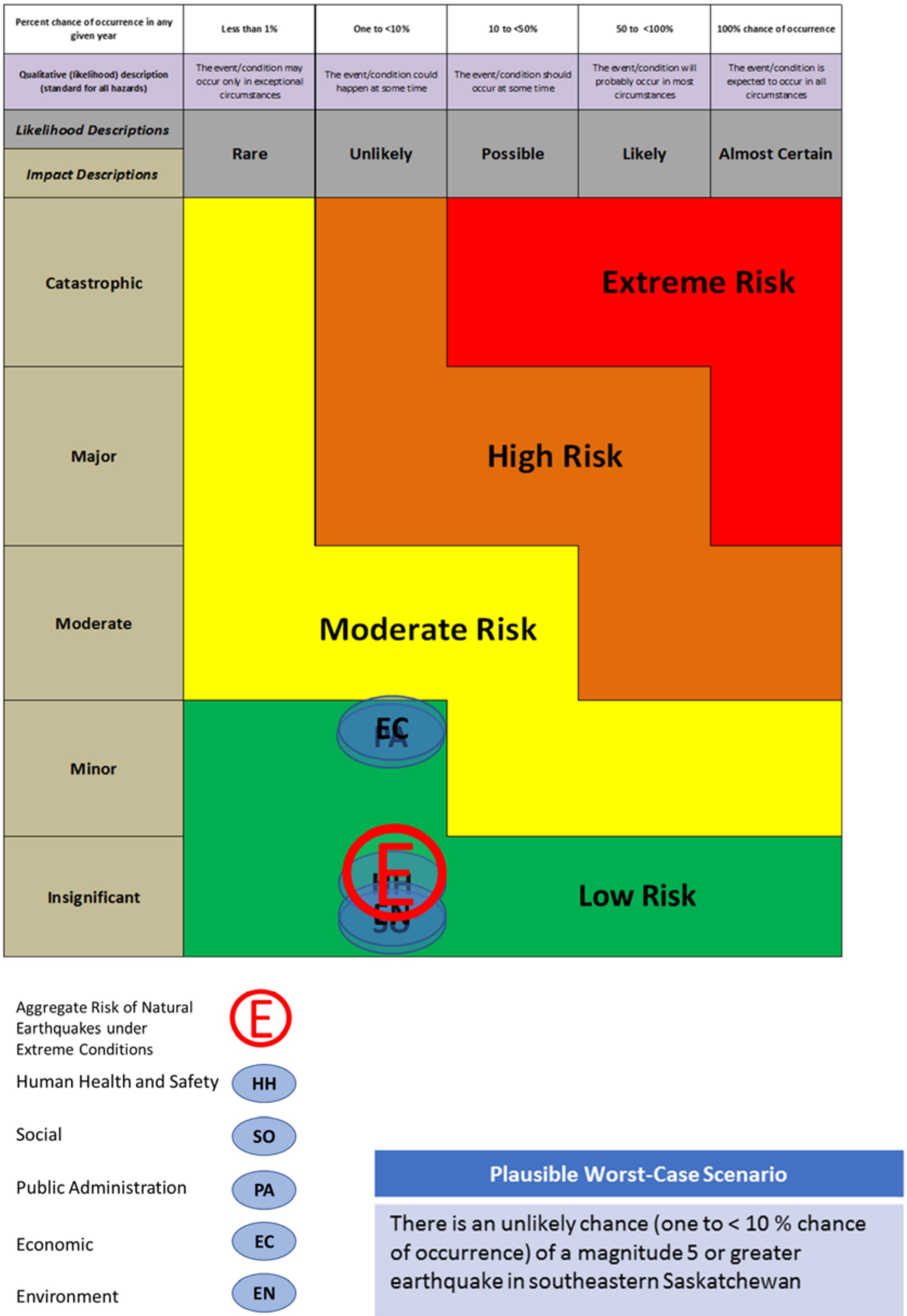


Figure 11.6 The risk of natural earthquakes in Saskatchewan based on impact categories and percent chance of occurrence. The red circle with the E in the centre indicates the aggregate risk of earthquakes across the provincially based impact categories for the plausible worst-case scenario.


Tornado in progress (Photo Source: D. Sherratt)

12. ALL HAZARDS SUMMARY

"Natural hazards need to be viewed in combination and not as isolated events in order to understand cumulative effects and dependencies" (Anonymous Stakeholder in Corkal 2018).

"[Natural hazards] are imminent and preparedness is crucial" (Anonymous Stakeholder in Corkal 2018).

The natural hazards examined were flooding (mountain runoff, plains runoff, lake, overland and groundwater), drought (agricultural, hydrologic, meteorological and socio-economic), forest fires (human caused close to communities), grass fires (greater than 1,000 hectares), summer convective storms (tornadoes, high winds, heavy rain, hail), winter storms (freezing rain, high winds, snow, blizzard conditions) and earthquakes. Each of these natural hazards was assessed individually examining two scenarios. The first was utilizing a plausible worst-case scenario that incorporated a historic event but was adapted to present-day situations. The second added a layer of climate change to the plausible worst-case scenario focused around the 2050s.

Each of the natural hazards impacts different regions of the province. Natural hazards such as drought, overland flooding, forest fires and winter storms can impact extensive geographic regions. Others, like plains runoff flooding, lake flooding, convective summer storms, mountain runoff flooding and grass fires, are relatively localized. Groundwater flooding and earthquakes are highly localized. In addition, each of these natural hazards occurs over varying time frames. For example, drought can last for a number of years while severe convective summer storms take place in a matter of hours or less. Linkages also occur among many of the natural hazards, and if one is occurring or has occurred, another natural hazard may happen as the result of the first one. For example, all forms of flooding can be heavily influenced by both winter and summer storms and could be considered a secondary impact to these storm events. Similarly, drought conditions can lead to an increase in the occurrence and severity of grass fires.

Most of these worst-case natural hazards have occurred at some point in the last 100 years. Many, therefore, can be deemed to have an "unlikely" likelihood of occurrence. A good estimate of present-day consequences of the plausible worst-case scenario for each hazard is applied on the basis of these historic events. The level of impacts resulting from these various hazards ranges from insignificant to catastrophic depending on the impact category of the natural hazard. An aggregate risk level for each natural hazard is estimated for each of the natural hazards based on these impacts and the likelihood of occurrence (Table 12.1 and Figure 12.1).

Table 12.1 Comparison of plausible worst-case natural hazard scenarios

Natural Hazard	**Case Study Location**	**Likelihood of Occurrence**	**Impact Categories**					**Aggregate Risk**
			Human Health & Safety	*Social*	*Public Administration*	*Economic*	*Environment*	
Mountain Runoff Flooding	Prince Albert	Rare	Moderate	Minor	Moderate to Major	Minor	Minor	Low to Moderate
Plains Runoff Flooding	Regina	Unlikely	Moderate	Minor to Moderate	Major	Major	Moderate	Moderate
Lake Flooding	Fishing Lakes Last Mountain Lake	Unlikely	Moderate	Minor	Minor	Minor	Moderate to Major	Moderate
Overland Flooding	Agricultural region of Saskatchewan	Unlikely	Minor	Minor to Moderate	Minor	Major	Moderate	Moderate
Groundwater Flooding	Highly localized	Unlikely	Insignificant to Minor	Insignificant to Minor	Insignificant to Minor	Insignificant to Minor	Insignificant to Minor	Low
Drought – All Types	Agricultural region of Saskatchewan	Unlikely	Major to Catastrophic	Major to Catastrophic	Catastrophic	Catastrophic	Moderate to Major	High
Forest Fire	Human-caused forest fires close to communities; forested zone of province	Unlikely	Major	Moderate to Major	Major	Moderate	Minor to Moderate	Moderate to High
Grass Fire	Grass fire > 1,000 ha; agricultural region of Saskatchewan	Unlikely	Major	Moderate to Major	Minor	Minor to Moderate	Minor	Moderate
Convective Summer Storms	Regina and area	Unlikely	Catastrophic	Major to Catastrophic	Major	Major to Catastrophic	Major to Catastrophic	High
Winter Storms	Southern Saskatchewan	Unlikely	Major	Minor to Moderate	Moderate to Major	Major	Moderate	Moderate to High
Earthquake	Highly localized along the Saskatchewan and Montana border	Unlikely	Insignificant	Insignificant	Moderate	Moderate	Insignificant	Low

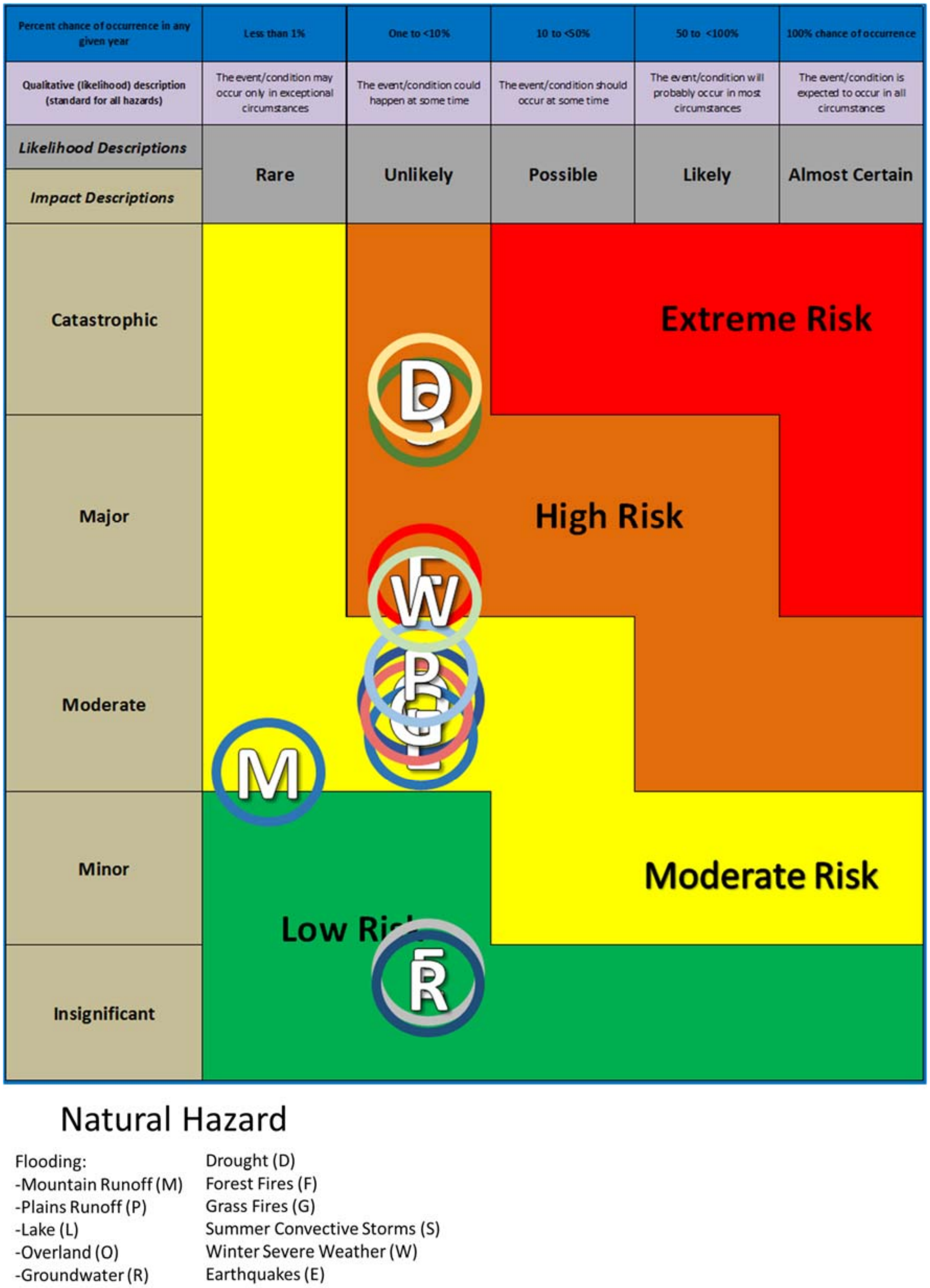


Figure 12.1 Aggregate risk matrix of the plausible worst-case scenarios of all the assessed natural hazards

As noted in the methodology chapter, a final step is to compare the aggregate risk levels of the assessed natural hazards. Table 12.1 and Figure 12.2 assist with the comparison of the spatial extent of the hazard, the likelihood of occurrence and impact categories, as well as each natural hazard's aggregate risk. The side bar entitled "aggregate risk of plausible worst-case scenarios" provides an itemized list of severity of the aggregate list level of each of the examined natural hazards.

Natural hazards that were deemed to have a **high aggregated risk level** were drought and convective summer storms. There are a number of reasons for these two natural events having high risks. *Droughts* tend to affect large areas of Saskatchewan and last longer than other hazards. Human activities require adequate and reliable water supplies. Droughts of the plausible worst-case scenario scale would have a major to catastrophic negative influence on the province's agricultural sector and economy, as well as the availability of high-quality potable water for both urban and rural residents and for other water uses. These factors led to assessing the social and public administration impacts as major to catastrophic.

Convective summer storms generally only last a few hours or less and can have catastrophic impacts on human safety, including the potential for multiple deaths and injuries. Impacts on infrastructure categories, especially in an urban hub like Regina, can be major to catastrophic. Ultimately, the level of impact depends on secondary influences that an EF5 tornado would have on the region affected, for example, if it results in major damages to industrial or transportation sectors.

AGGREGATE RISK OF PLAUSIBLE WORST-CASE SCENARIOS

High Risk
- Drought
- Convective Summer Storms

Moderate to High Risk
- Forest Fires
- Winter Storms

Moderate Risk
- Overland Flooding
- Plains Runoff Flooding
- Lake Flooding
- Grass Fire

Low to Moderate Risk
- Mountain Runoff Flooding

Low Risk
- Groundwater Flooding
- Earthquake

Forest fires and *winter storms* have an **aggregate risk level of moderate to high**. *Forest fires* can cover large forested regions of the province and can result in multiple fatalities and widespread evacuations. Infrastructure would likely be lost, and provincial and municipal government bodies would encounter a reduction in the ability to deliver core functions, particularly in the region affected by the fire. *Winter storms* tend to affect large geographical regions of the province. Winter storms that include freezing rain, high winds and blizzard conditions can last for multiple days. These storms would have moderate to major impact levels because of the potential for loss of life arising from vehicular traffic fatalities due to road conditions, infrastructure damage due to the freezing rain and blizzard conditions, and disruption in services due to power outages.

Three of the five flooding scenarios have an **aggregate risk level of moderate**. *Overland flooding* can impact large portions of the agricultural regions of the province and result in minor to major impacts. Overland flooding can lead to significant income losses for agricultural producers as well as infrastructure damage. Other than overland flooding, most floods affect relatively small regions of the province, thus making the impacts more localized. *Plains runoff flooding* tends to be associated with spring runoff and, in recent years, convective summer storms. As with the convective summer storms, the level of impacts can increase, with potential damage to infrastructure like dykes (secondary negative impacts) resulting in more extensive damage. *Lake flooding* affects small regions when compared to the entire province and has minor impacts on the provincial economy, public administration and social well-being. The impacts on human health are classified as moderate due to the possibility of spring time "ice shove" that could result in loss of life.

Grass fires have a **moderate aggregate risk level**. They tend to be relatively localized but can have moderate to major impacts. For example, they can result in multiple fatalities and cause large evacuations. They can also have significant impact on local infrastructure and can result in severe damage to the local agricultural sector. *Grass fires* also occur more often in drought situations and therefore can be a secondary impact in the *drought* scenario.

Mountain runoff flooding has very localized impacts and is considered to have an **aggregate risk level of low to moderate.** There are only a few communities at risk of mountain runoff flooding, with Prince Albert being the most significant. A mountain runoff flooding event in Prince Albert would result in extensive evacuations and large portions of the city damaged or destroyed. Prince Albert plays a significant role in the public administration for the northern half of Saskatchewan and therefore could put management and administrative responsibility for the north at peril.

Groundwater flooding and *earthquake* **aggregate risks are low.** This is because both are highly localized in nature, with insignificant impacts. The only reason earthquakes rate higher than may be expected is because of the economic impact of the failure of Morrison Dam, as both loss of a structure and loss of some of Saskatchewan's power supply. In addition, the dam is located on an international waterway. Therefore, if that dam is compromised, it would result in a provincial, federal and international response to the situation.

When the climate change component is added to the plausible worst-case scenario, the likelihood categories of each of the natural hazards may change. Good estimates of the consequences of the plausible worst-case scenario for each hazard were provided because they are based on historic events. The future impacts are estimates, based on the current state of knowledge in relation to the projected climate change scenarios and associated potential impacts.

As noted in chapter 5, the projected increases in temperature and precipitation set up scenarios in which the number, intensity and duration of both drought and flood events all increase. With warmer temperatures, the atmosphere will be able to hold more moisture. This implies there will be increases in intensity and frequency of extreme precipitation events, with the result of dry times becoming drier and wet times wetter (Wheaton et al. 2013).

The climate change layer results in *drought* increasing its likelihood of occurrence from unlikely to possible (Table 12.2 and Figure 12.2). This results in drought's aggregate risk factor increasing from high risk to **high-to-extreme risk.**

Convective summer storms' likelihood of occurrence may increase from unlikely to possible under future climate change due to the increased water-holding capacity of the atmosphere. However, as stated in Chapter 9, the initiation mechanisms for convective storms needs to be considered, and the effect of climate change on that mechanism is unknown at this time. This results in a range of likelihood levels and the **aggregate risk level of *convective summer storms* ranging from high to extreme**. Due to convective storms' shorter time period of influence and impact area, they are rated lower than drought in the aggregate risk matrix.

Overland flooding's aggregate risk is projected to increase to moderate to high under projected climate change scenarios for the 2050s. The increased water-holding capacity of the atmosphere could increase the amount of precipitation, leading to more rain events and resultant overland flooding. In addition, the economic consequences can change with an order of magnitude, thus resulting in the potential for overland flooding having an aggregate risk level of moderate to high under future climate conditions.

Mainly due to the increasing *drought* frequency projected with future climate change, the likelihood of *grass fires* increases from unlikely to possible. This results in an aggregate risk increase to moderate to high risk.

The rest of the natural hazards should maintain the same aggregate risk levels under a changed climate as was determined with the plausible worst-case scenario.

Earthquakes in Saskatchewan are not influenced by climate change. This results in their likelihood of occurrence dropping to rare, with their overall aggregated risk level remaining low.

AGGREGATE RISK UNDER FUTURE CLIMATIC CONDITIONS (~2050s)

High to Extreme Risk
- Drought
- Convective Summer Storms

Moderate to High Risk
- Forest Fires
- Winter Storms
- Overland Flooding
- Grass Fires

Moderate Risk
- Plains Runoff Flooding
- Lake Flooding

Low to Moderate Risk
- Mountain Runoff Flooding

Low Risk
- Groundwater Flood
- Earthquake

Table 12.2 Natural hazard comparison of plausible worst-case scenario with projected climate of the 2050s

Natural Hazard	Case Study Location	Likelihood of Occurrence	Impact Categories					Aggregate Risk
			Human Health & Safety	*Social*	*Public Administration*	*Economic*	*Environment*	
Mountain Runoff Flooding	Prince Albert	Rare to Unlikely	Moderate	Minor	Moderate to Major	Minor	Minor	Low to Moderate
Plains Runoff Flooding	Regina	Unlikely to Possible	Moderate	Minor to Moderate	Major	Major	Moderate	Moderate
Lake Flooding	Fishing Lakes Last Mountain Lake	Unlikely	Moderate	Minor	Minor	Minor	Moderate to Major	Moderate – less shoreline ice damage
Overland Flooding	Agricultural region of Saskatchewan	Unlikely to Possible	Minor	Minor to Moderate	Minor	Major	Moderate	Moderate to High
Groundwater Flooding	Highly localized	Unlikely	Insignificant to Minor	Insignificant to Minor	Insignificant to Minor	Insignificant to Minor	Insignificant to Minor	Low
Drought – all types	Agricultural region of Saskatchewan	Unlikely to Possible	Major to Catastrophic	Major to Catastrophic	Catastrophic	Catastrophic	Moderate to Major	High to Extreme
Forest Fire	Human-caused forest fires close to communities; forested zone of province	Unlikely to Possible	Major	Moderate to Major	Major	Moderate	Minor to Moderate	Moderate to High
Grass Fire	Grass fires > 1,000 ha; agricultural region of Saskatchewan	Unlikely to Possible	Major	Moderate to Major	Minor	Minor to Moderate	Minor	Moderate to High (depending on biomass availability)
Convective Summer Storms	Regina and area	Unlikely to Possible	Catastrophic	Major to Catastrophic	Major	Major to Catastrophic	Major to Catastrophic	High to extreme
Winter Storms	Southern Saskatchewan	Unlikely	Major	Minor to Moderate	Moderate to Major	Major	Moderate	Moderate to High (with greater risk of freezing rain)
Earthquake	Highly localized along the Saskatchewan and Montana border	Rare	Insignificant	Insignificant	Moderate	Moderate	Insignificant	Low

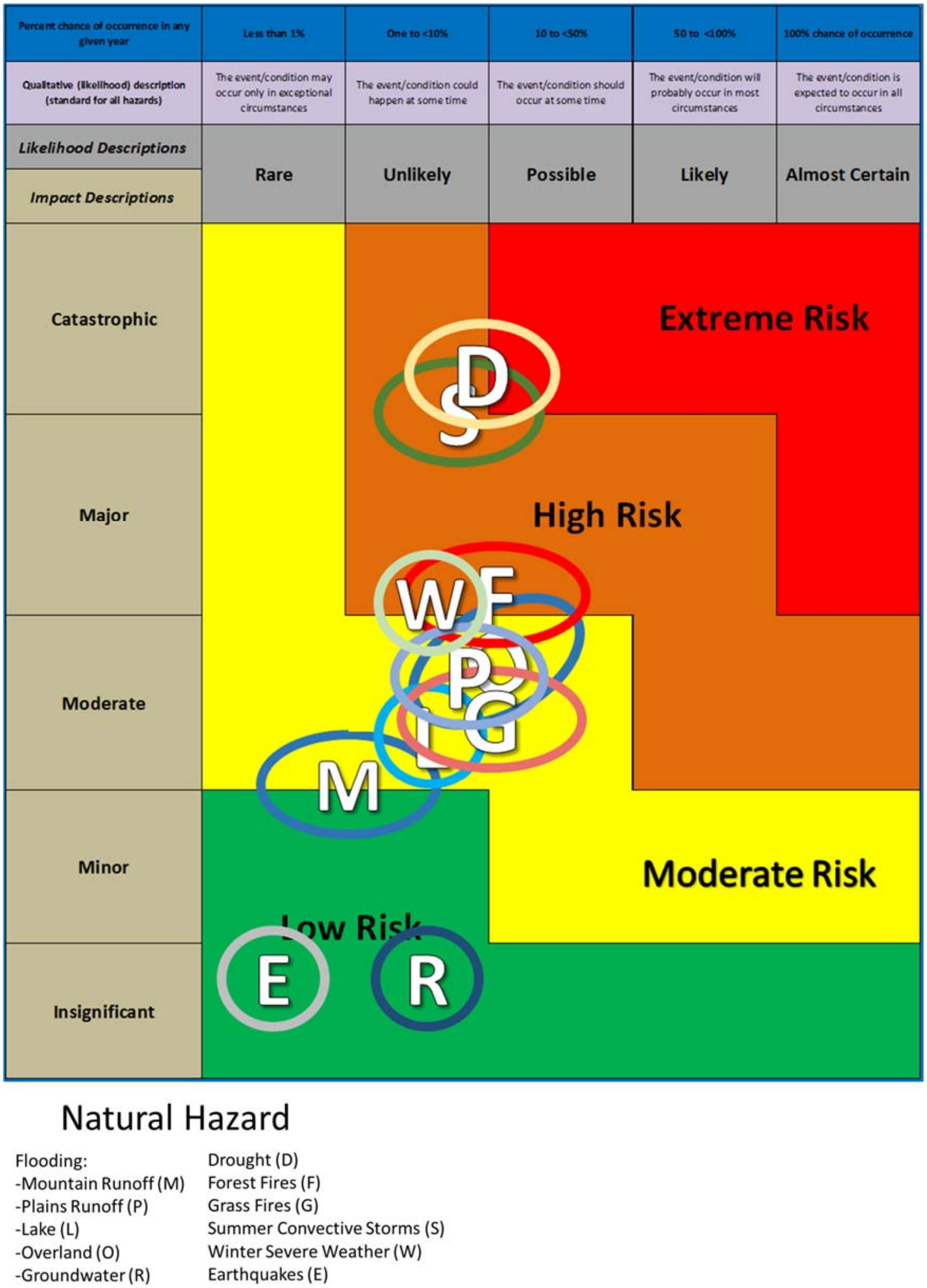


Figure 12.2 Aggregate risk matrix of the plausible worst-case scenario with projected climate of the 2050s of all of the assessed natural hazards

13. CASE STUDIES: AN ANALYSIS OF THE EFFECTS OF HISTORIC FLOODING ON SASKATCHEWAN'S COMMUNITIES

I. Stewart, M. Geremia and D. Corkal

Description

Many areas throughout the province of Saskatchewan experienced flooding and/or excessive wet conditions during the 2010 to 2016 period. This led to many insurance claims and disaster recovery activities to address flooding damages to public and private built infrastructure, including buildings, roads, bridges, railways, dams, utilities, commercial developments, private residences and cottages.

Three case studies are summarized to provide an overview of the types of damages that historic flooding has caused throughout Saskatchewan's built environment (public and private infrastructure). The examples are at three rural/urban development scales. ***Moose Jaw River Watershed*** focuses on flood impacts to an urban center, ***Southey Basin*** on a town, and ***Quill Lakes*** on a rural municipality.

The case studies demonstrate the wide diversity and extent of challenges that flooding poses on Saskatchewan communities, and the types of mitigations that are currently being practised locally and across the province. They depict examples of economic, social and environmental impacts caused by flooding. Future climate change impacts are not expressly discussed; however, climate models suggest future climate will have greater variability in intensity and frequency of storms and weather events.

Many Saskatchewan communities have experienced multiple flooding events at greater intensities during recent times (when compared historically), particularly throughout the 2010–2016 period. If this recent period is viewed as an analogue for future climate change, the case studies demonstrate some of the challenges that Saskatchewan may face should floods become more frequent and intense in the future; they also demonstrate the types of preparedness planning efforts and mitigations that may be beneficial to reduce flood risk exposure and strengthen resilience.

Moose Jaw River Watershed

Introduction

This case study focuses on the City of Moose Jaw and the Wakamow Valley Authority within the Moose Jaw River Watershed.

Location Overview

The Moose Jaw River Watershed, as shown in Figure 13.1, is 9,360 km^2 in size. This area includes 22 rural municipalities, 2 towns, 10 villages and the City of Moose Jaw. The upper headwaters of the Moose Jaw River are located approximately 30 km west of Weyburn in very flat terrain. The river flows northwest, paralleling the edge of the Missouri Coteau, with many small tributaries entering the river from the more rugged, higher terrain to the southwest. Near the town of Rouleau, the Moose Jaw River is joined by Avonlea Creek, a significant contributor of runoff because of the higher topography and more extensive drainage pattern within this basin. In the City of Moose Jaw, the Moose Jaw River is joined by Thunder Creek. Thunder Creek, with its headwaters southwest of Central Butte, flows southeast through Paysen and Kettlehut Lakes, and into Pelican Lake. Because of the relatively high elevation at the outlet of Pelican Lake, water usually does not spill out to flow towards Moose Jaw. Therefore, most of the water flowing from the Thunder Creek system into the Moose Jaw River is from Sandy Creek, whose headwaters are in the Missouri Coteau southwest of Mortlach. From the city of Moose Jaw, the river flows northeast, joining the Qu'Appelle River approximately five kilometres downstream of Buffalo Pound Lake. The Moose Jaw River is the largest tributary to the Qu'Appelle River (Water Security Agency 2006).

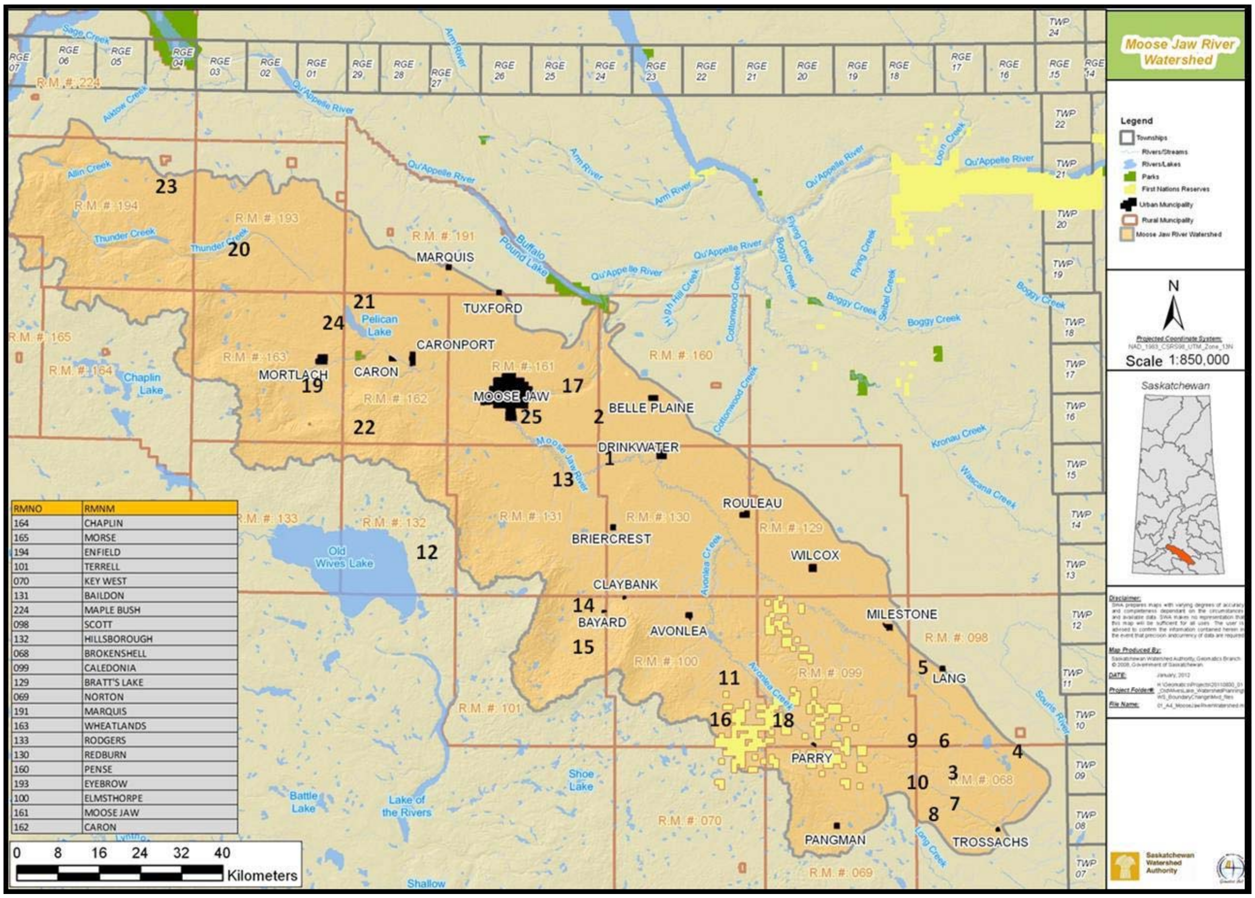


Figure 13.1 Moose Jaw River Watershed

In the winter of 1974, near-record snowfall resulted in widespread spring flooding across the province; farms and ranch land were flooded, while the cities of Moose Jaw and Regina and the town of Lumsden received major flood damage. The Moose Jaw River overflowed its banks in Moose Jaw, as did Wascana Creek in Regina. Lumsden was saved by emergency diking. Flood damages for the entire province were approximately $6,611,800 (approximately $31 million in 2017 dollars) (Public Safety Canada 2013). The spring peak of the Moose Jaw River was the highest in a 65-year recorded history to 1974. That peak was only exceeded in 2011 when the river experienced both a spring flood in April and a summer flood in June.

The focus of this study is the City of Moose Jaw and immediate vicinity, including the riparian area administered by the Wakamow Valley Authority.

The annual spring melt general has two parts. First, local snow melts and causes runoff throughout the city. Second, melt water from the fields surrounding Moose Jaw flows into Spring Creek, Thunder Creek and the Moose Jaw River, causing water levels to rise through the city.

Rural Municipalities, Towns, Villages and Authorities

The study area includes the following municipalities:

City of Moose Jaw	– population 33,890
RM of Moose Jaw (No 338)	– population 1,147
Wakamow Valley	– 500 acres (200 ha) of parkland and conservation area.

The city of Moose Jaw sits at the confluence of Thunder Creek and the Moose Jaw River, specifically at the location of Plaxton Lake. Spring Creek joins the Moose Jaw River within the city limits downstream of Plaxton Lake.

The city suffered damages during the 1974 flood event that saw the Moose Jaw River, Thunder Creek and Spring Creek overflow their banks, placing a metre of water in the downtown area of the city and causing the flooding of 60 city blocks (including 480 homes). This resulted in the evacuation of 1400 people (April 18 and 19) but no recorded injuries or deaths.

Moose Jaw put into place a land acquisition program for many homes built along the community's namesake river, and residents had the choice to sell their property back to the city authorities and move out of the flood risk area. The land was then given to the Wakamow Valley Authority, and the former community was returned to its natural park state. There has been no further construction in these areas since 1974. After the former Canada–Saskatchewan Flood Damage Reduction Program provided city officials with the 1:500 flood lines and zoning was put in place, no more vulnerable building could be undertaken.

Later in 1974, in mitigation for future events, the City took part in an extensive diking and diversion project along Thunder Creek and Spring Creek. These works divert potential flood water north and away from the city centre. Further, the city dyked around its water and sewage treatment plants in order to protect this critical infrastructure against a future 1:500 year flood event.

Although actions taken since the 1974 flood have significantly reduced the potential for damages from flooding, there remains a residual risk associated with urban infrastructure, recreational areas and private property. These are discussed in the following sections.

Built Infrastructure

Roads

One of the most severe examples of embankment erosion affected the off-ramp at Wellesley Street/Main Street South (shown in Figures 13.2 and 13.3). Erosion caused the road and side slope to fail and fall into the Moose Jaw River.

Figure 13.2 Slope is extremely unstable, 12 m drop into the river

Figure 13.3 Road and side slope failure

Bridges

The study area has a wide variety of bridges. Most the bridges were designed many years ago, with the design criteria being based upon conditions at the time. During the 2015 spring runoff, several bridges along the Moose Jaw River were damaged. Those most severely affected were the road bridge along the main highway into the city (the Manitoba Expressway) and the 7th Avenue Bridge where ice flows had caused damage to concrete and wooden pillars. These examples are shown in Figures 13.4 to 13.6.

Figure 13.4 Ice flow damage to the concrete pillar on Manitoba Expressway

Figure 13.5 7th Avenue bridge with broken pillars and cross bracing washed out

Figure 13.6 Broken piles and cross bracing; the ones that are still in situ are severely damaged and need to be replaced

Both bridges were damaged by ice flows which resulted in the expressway being reduced to a single lane, and the 7th Avenue bridge had to be completely closed to all except pedestrian traffic. The estimated repair costs to these bridges are close to $800,000 or up to $5,000,000 for replacement. The Manitoba Expressway bridge was repaired in 2017. The 7th Avenue bridge has not been repaired and remains closed.

CPR Dam

The original Canadian Pacific Railway Dam was built in 1884 as a control for the level of water in Plaxton Lake in order to provide water for steam locomotives. It was modified a number of times since then. The dam was damaged in the spring of 2010 and then again in 2011 by ice flows and debris. This caused the lake and river to be almost dry at various times. Temporary repairs costing $50,000 were performed until sufficient funding was attained to provide a permanent replacement. The new, fully adjustable replacement structure was completed in 2015 and consists of the dam and a fish ladder, at a cost of $5 million (Figure 13.7 and 13.8).

Figure 13.7 Photo of the original dam taken in 2011 at the height of the spring runoff (source: www.discovermoosejaw.com)

Figure 13.8 Photo of the new dam taken in September 2015 (source: www.discovermoosejaw.com)

Parks and Recreation

Wakamow Valley is an urban natural park and conservation area with over 20 km of trails and almost 500 acres (200 ha) of parkland. The valley features four playgrounds including a wheelchair-accessible play area, four public pavilions available to rent for private events, an ecological zone with four distinct ecosystems, a 60-site campground and a Burger Cabin.

The Wakamow Valley was affected by flooding in both 2011 and 2013. Prior to the 2013 event the Authority had taken over responsibility for the campground in a formal transfer from the City of Moose Jaw. The Authority was aware of the historical flooding problems and elected to put in preventive measures (e.g., sandbagging; Hesco barriers; raising plug-in points at the campground etc.) in order to reduce the damage, particularly to the buildings and electrical supplies within the River Park Campground. The Authority chose to take on these measures, as the campground is its main source of revenue. Despite these efforts, the campground continues to suffer damage annually.

Typical damage consists of heavy silting and debris from fallen trees that has been deposited around the parks and campground areas.

The most severe damage is the erosion to the river banks which is becoming worse year after year due to their high moisture content and higher river water levels. The Authority has had to address the erosion, particularly close to the new Assiniboine Footbridge, as there was a danger of the erosion undermining the bridge abutments.

Private Property

In April of 2011, the City of Moose Jaw issued an evacuation order for the occupied residences in the low-lying area of the Wakamow Valley. This was due to a buildup of ice jams along the Moose Jaw River. The buildup resulted in damage such as flooded basements and backed up sewage systems.

The area suffered the same type of damage again in 2015, with the estimate for repair set at $100,000 (Figure 13.9).

Figure 13.9 Flooded house in the Wakamow Valley

Being Prepared for Disaster

The City of Moose Jaw's Emergency Management Organization (EMO) makes contingency plans for the city during a large-scale emergency and is responsible for anticipating emergency events and to plan an effective response. In partnership with local volunteers, including Emergency Social Services, Moose Jaw Search and Rescue, Red Cross, Salvation Army and Moose Jaw Amateur Radio Club, the EMO offers a range of advice and information which is displayed on its web pages (City of Moose Jaw ND), that also includes:

- Wildfire Management – Current wildfire activity, interactive wildfire map, fire bans
- Provincial Disaster Assistance Program – Claim procedure and process
- Shelter-in-Place – Emergency action in the event of a chemical spill or unplanned release
- Know the Risks – Planning for severe storms, thunder and lightning, tornadoes

During the spring, city crews monitor close to 30 locations throughout the city that are identified within the extent of the historical flood map (shown in Figure 13.10), with results dictating mitigating actions that include:

- Clearing curbside drains (catch basins),
- Temporary pumping, and
- Temporary dyking/sandbagging.

Residents are asked to help by making sure their neighbourhood catch basin is clear and draining properly.

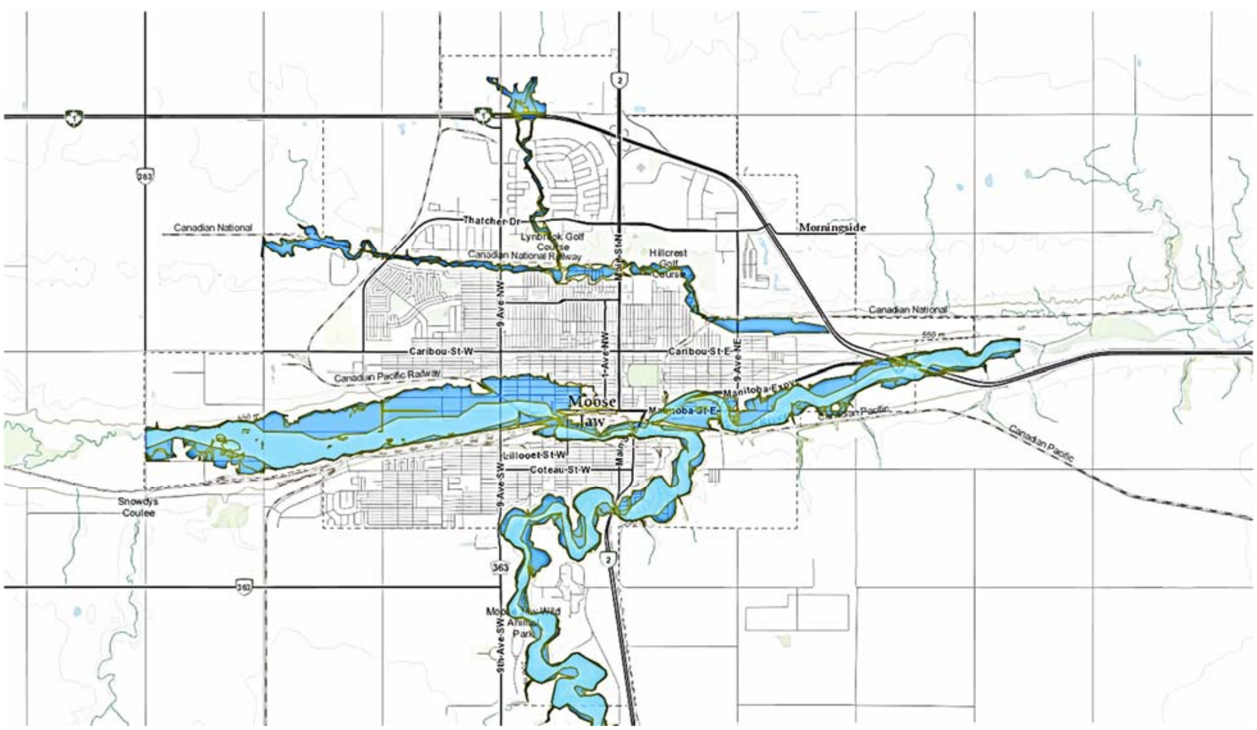


Figure 13.10 Historical flood map

Conclusions

The City of Moose Jaw and the Wakamow Valley Authority have applied experience gained, particularly over the last 40 years, by implementing a number of mitigating measures in order to reduce the flood risks and risks associated with other natural hazards. These actions have led to significant reductions in flood damages since 1974. The residents are encouraged by the authorities to be an active part of the mitigating strategy by remaining vigilant and reporting any unexpected occurrences.

Southey Basin

Introduction

The Saskatchewan Flood and Natural Hazard Risk Assessment Project includes an overview of three case studies of flooding, to identify typical impacts to public and private infrastructure, economic costs, and environmental damages. Three locations were selected to cover a city, a town and a rural municipality. This case study focuses on the Southey Basin, as a typical town and associated watershed impacted by flooding.

Location Overview

The land area centred on the town of Southey, including the surrounding farming land, is referred to as the Southey Basin area for this case study. The Southey Basin is located within the moist mixed grassland ecoregion of southern Saskatchewan's Prairie Ecozone (AAFC ND). The area topography is characterized by glacially formed prairie potholes, and the land use is mainly cropland and pasture. The internal drainage network of the basin has been altered locally over time by land use practice changes, including roadway development, drainage and agriculture intensification.

The Qu'Appelle River is located just 11 kilometers to the south of the town of Southey; however, the Southey Basin does not have a positive drainage outlet to the river. Nor does it have a positive drainage outlet to Loon Creek, a major tributary to the Qu'Appelle River located just 10 km to the northeast of the town. Therefore, the Southey Basin comprises a relatively large area of internal drainage located on the uplands north of the Qu'Appelle River Valley and west of Loon Creek. The basin does not contribute to the river and stream outflow network.

Although the typical climate is considered to be water deficient in this region, the Southey Basin area experienced a number of wetter than normal years leading up to the record flooding in the spring of 2015. The region experienced local flooding damages in several of the years leading up to 2015. The accumulated impact of the preceding wet period and the 2015 spring runoff appears to have caused a widespread fill-and-spill type of runoff occurrence in this prairie pothole region (Fang et al. 2007). There are a number of terminal sloughs in the Southey Basin where the accumulating flood flows resulted in unprecedented basin flooding. One of the most notable terminal sloughs is located 1.6 km south of the town of Southey on Highway No. 6 (Figure 13.11).

Figure 13.11 Large terminal sloughs south of the town of Southey; Highway #6 in the background (Photo source: Town of Southey April 2015)

This case study includes the village of Earl Grey toward the western limit of the Southey Basin. It was reported by the local flood observers in 2015 that the fill-and-spill flood event has a general west to east direction of flow from the areas near Earl Grey toward the areas near Southey and the large terminal sloughs in that area.

Rural Municipalities, Towns and Villages

The Southey Basin includes portions of two RMs: the RM of Cupar and the RM of Longlaketon. There are several communities in the two RMs; however, only two communities are considered to be within the basin area: the village of Earl Grey and the town of Southey. Other communities within the two RMs are not included in the basin, as they are separated topographically (e.g., the village of Markinch, town of Cupar, town of Craven, and village of Silton). These other communities and their surrounding areas may have experienced similar flooding issues as seen in the Southey Basin but are not included within this case study. As noted earlier, topographic boundaries are created by the Qu'Appelle River Valley to the south of the basin and the Loon Creek to the east.

RM of Cupar (No 218) – administration office in the town of Cupar
town of Southey
combined RM population – 1,307

RM of Longlaketon (No 219) – administration office in the village of Earl Grey
village of Earl Grey
combined RM population – 1,262

Note – Population numbers provided by Statistics Canada, 2016

Impacts to Public Infrastructure

Roads and Transportation

Highway No. 6 runs through the centre of the Southey Basin and intersects a number of the terminal sloughs. The highway grade was partially submerged at two locations south of Southey (Figure 13.12).

Figure 13.12 Highway No. 6 south of the Town of Southey with construction of shoulder berms (Photo Source: Walker Projects Inc. Spring 2015)

In addition to the provincial highways, the rural road network also suffered damages. Common damages resulting from the flooding were surface washouts, grade material washouts and base material failures. The rural roadways also had areas of more severe damages resulting in submerged roads at flooded terminal sloughs (Figure 13.13). For example, the RM of Cupar posted an updated RM "Flooded Road" map on its web site on April 13, 2015, which shows 43 locations where its road network is flooded (RM of Cupar 2015). In the RM of Longlaketon, there were numerous damage locations on the rural road network. The flood damage assessment report prepared by Walker Projects Inc. for Saskatchewan Provincial Disaster Assistance Program (PDAP) included 80 incident/damage locations related to the 2015 flood event in the RM of Longlaketon (Walker Project Inc. 2015).

Figure 13.13 Submerged areas on rural municipal road south of the Town of Southey (Photo Source: Walker Projects Inc. Spring 2015)

Community Services

Several services in the town of Southey were affected:

- Flood flows from areas west of Southey accumulated at the Lion's Park and Campground located in a low-lying area at the west side of town. The park and campground were under flood water for a long period of time. The town experienced loss of use of the recreation area, loss of revenue from the campground, and damages to the physical infrastructure.
- Excessive flooding threatened local residences, streets and sewer services near Lion's Park. Water berms were needed at this location and the Town set up temporary berms and an emergency relief pumping operation here to control the flooding level (Figures 13.14 and 13.15).
- The excessive rainfall in the Southey Basin caused the town's recently constructed effluent evaporation pond to exceed its design capacity. To mitigate this, the Town constructed a temporary berm on land adjacent to the evaporation pond and performed an emergency release to the temporary site.
- The Town of Southey's future community development plans are impacted, as planning approvals require that flood-proofing measures are taken into account.

Figure 13.14 Town of Southey, Lions Park and Campground, Water Berms and Pump (Photo Source: Walker Projects Inc. Spring 2015)

Figure 13.15 Town of Southey, Lions Park and Campground, Emergency Pumping (Photo Source: Walker Projects Inc. Spring 2015)

Impacts to Private Property

The farming community in the Southey Basin experienced various flooding damages to private property:

- Loss of use of productive cropland and pastures
- Flooded cattle-handling facilities including corrals, shelters and barns
- Flooded farm yard sites including residences, machine shops and staging areas
- Flooded and contaminated well sites
- Flooded and damaged private access roads
- Shelterbelt destruction from excessive submergence in flood water
- Soil erosion and gully erosion damages on farmland

For example, Figure 13.16 shows the extent of flooding at farm yard buildings situated along a flooded terminal slough south of Southey.

Figure 13.16 Flooded farm buildings at terminal slough in Southey Basin (Photo Source: Walker Projects Inc. Spring 2015)

Response and Mitigation Actions

Provincial Disaster Assistance Program (PDAP)

The Provincial Disaster Assistance Program (PDAP) is the primary recovery program provided by senior governments for disaster recovery. PDAP is designed to help residents, small businesses, agricultural operations, communal organizations, non-profit organizations, parks and communities recover from the effects of natural disasters, including flooding, tornadoes, plow winds and other severe weather (Government of Saskatchewan ND). PDAP provides assistance for restoration of uninsurable damages to essential infrastructure. This includes restoring flood-damaged roads to pre-flood conditions where practical. Similar to the wet years preceding the 2015 flooding, the RMs had disaster claims with PDAP again in 2015 due to the extensive flooding damages.

A major roadway restoration undertaking by the RM of Cupar and the PDAP following the spring flooding in 2015 involved relief pumping of the terminal sloughs south of the town of Southey (Figure 13.17). This relief pumping is reported to have operated for 92 days, with twin discharge lines running from the terminal sloughs to an outlet into Loon Creek about 12 km to the east. It was reported that a volume of 1.3 million cubic metres was pumped at a cost of about $2.0 million (information reported to Walker Projects Incorporated by a local stakeholder).

Figure 13.17 Relief pump lines taking flood water from Southey Basin to Loon Creek (about 12 km) (Photo Source: Walker Projects Inc. Summer 2015)

The relief pumping efforts benefited the rural transportation network by restoring safe travel on the primary rural roads. Other at-risk infrastructure that benefited from the relief pumping efforts included provincial Highway No. 6, farm residences, and farm land and yard sites.

Emergency Flood Damage Reduction Program

Emergency Flood Damage Reduction Program (EFDRP) is a major mitigation program provided by the Province of Saskatchewan. The program provides support to eligible applicants for their cost of approved emergency temporary and/or emergency permanent flood protection works that are built to provide protection from imminent flooding in the program year. EFDRP is open to applications from First Nations, communities, rural municipalities, businesses, non-profit organizations, and owners of rural yard sites, country residences and cottages for support for their costs of approved emergency temporary and/or emergency permanent flood protection works

(Water Security Agency 2015). Permanent flood protection works include projects like berms and culverts.

The Water Security Agency Annual Report, dated March 31, 2017, stated that the Province was providing $67 million in EFDRP funding for temporary and permanent works along with engineering and technical support for flood prevention (Water Security Agency 2017).

Some common mitigation work under the EFDRP included temporary emergency dykes to protect rural properties. An example is illustrated in Figure 13.18 where the farmyard site at the bottom-centre of the image started with temporary emergency dykes on three sides to protect the residence and other buildings. When it became obvious that the flood water would persist for a longer term, the property owner initiated conversion of the temporary dykes to permanent protective works with the support of the EFDRP program.

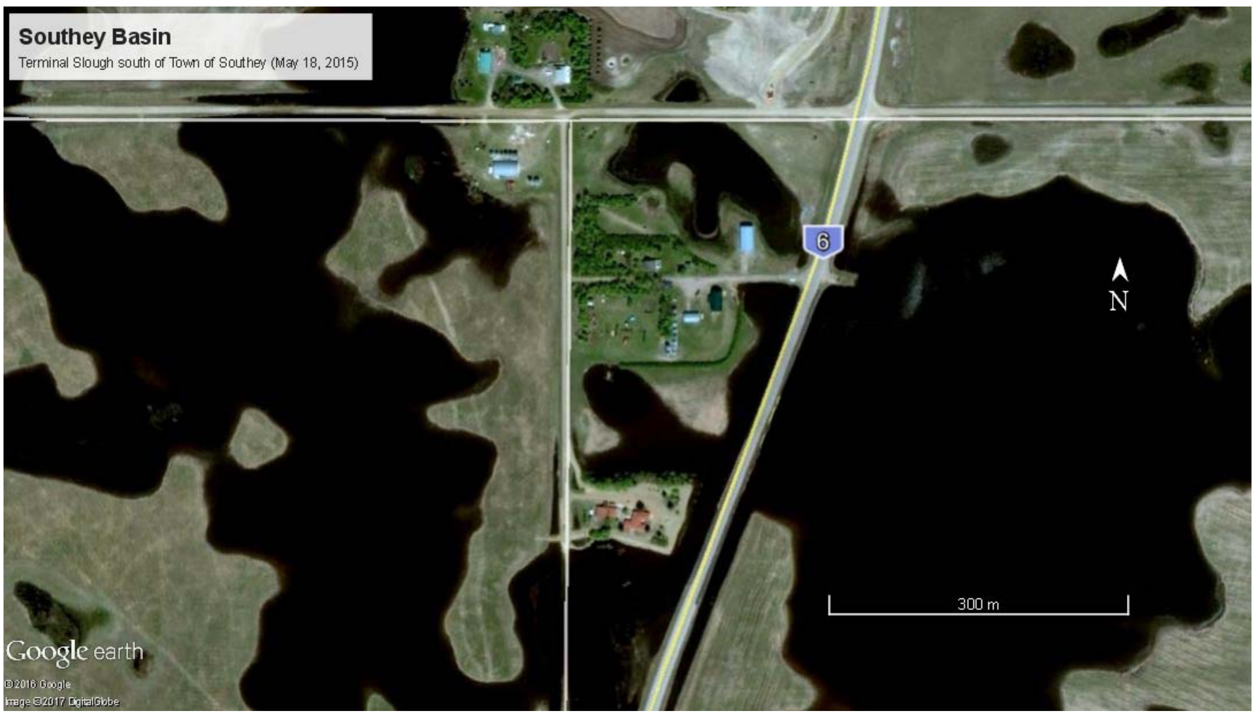


Figure 13.18 Southey Basin; yard site at bottom-centre of image is dyked on 3 sides (Photo Source: Google Earth Image)

Other Emergency Response and Mitigation Actions

The Provincial Ministry of Highways responded to the partially submerged highway sections by dispatching crews and equipment to construct temporary berms on the shoulders of the highway to limit the effects of flooding. Longer term restoration work for affected areas of Highway No. 6 included relief pumping of the terminal slough and/or raising the highway grade.

The Provincial Emergency Measures Organization (EMO) has equipment inventory and staff to assist disaster areas on an emergency basis. For example, in Southey, the EMO responded to emergency needs by providing the water berms that were deployed at Lions Park and providing a sandbagging machine.

Conclusions

The Southey Basin flooding disaster affected many stakeholders in the region and the impacts were projected to persist for multiple years due to the terminal basin nature of the regional topography. As well, the risk of a repeat flood event is elevated, as there are no positive outlets for release of accumulating flood water and moderate storm events could potentially create additional flooding problems in the basin.

The Water Security Agency contracted Walker Projects Inc. in 2015 to make a conceptual level estimate of works needed for a regional drainage scheme to alleviate flooding impacts within the Southey Basin area. A permanent installation using a combination of drain channels and a pipeline with pump installations was conceptually estimated to have a construction cost of about $15 million to $20 million. The scheme would also incur annual operating and maintenance costs.

Quill Lakes

Introduction

The Saskatchewan Flood and Natural Hazard Risk Assessment Project includes an overview of three case studies of flooding, to identify typical impacts to public and private infrastructure, economic costs, and environmental damages. Three locations were selected to cover a city, a town and a rural municipality. This case study focuses on the Quill Lakes as a rural municipality and associated watershed impacted by flooding.

Location Overview

The **Quill Lakes** is a wetland complex bounded by the communities of Wynyard, Foam Lake, Wadena, Watson and Dafoe, located approximately 150 km north of Regina (Figure 13.19). The area was formerly composed of three distinct lake wetlands: **Big Quill Lake**, **Middle Quill Lake** and **Little Quill Lake.** The lakes are considered as non-contributing drainage and form a semi-closed basin. The lake complex is Canada's largest saline lake and was designated a “Wetland of International Importance” under the Ramsar Convention. Its salinity, measured as total dissolved solids (TDS), can range from 7,500 to 70,000 mg/L, significantly higher than that of freshwater lakes (e.g., Last Mountain Lake north of Regina measures 1,500 mg/L TDS.)

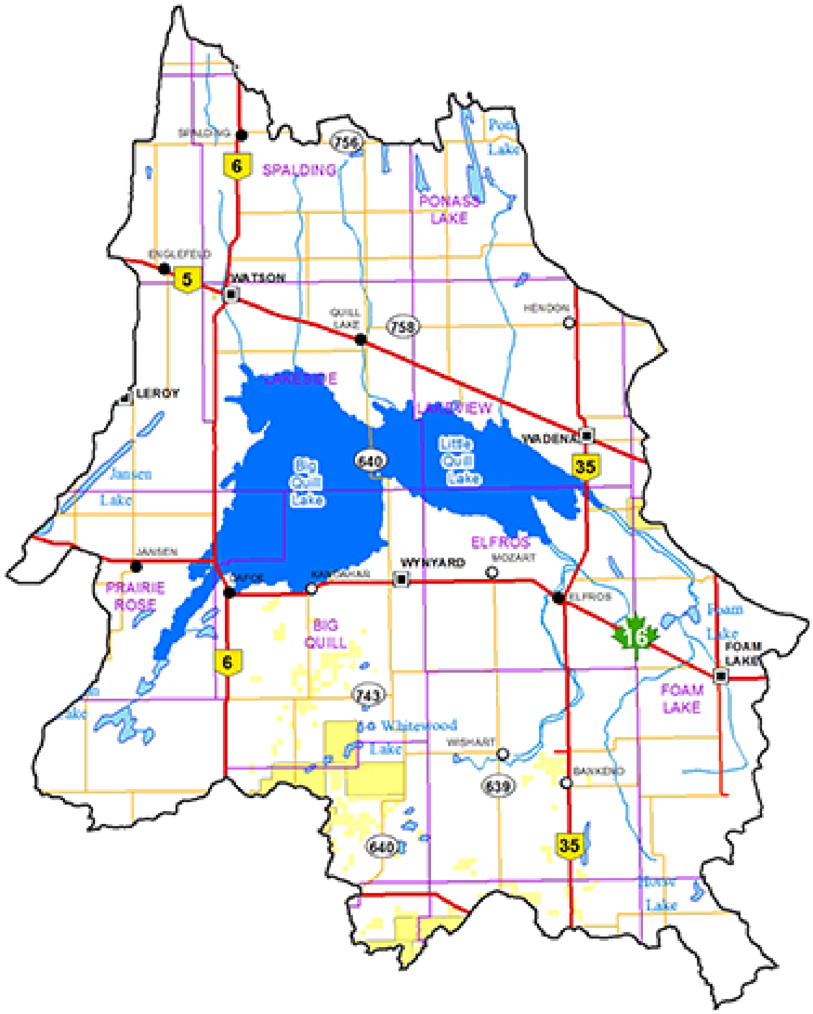


Figure 13.19 Little and Big Quill Lakes (Water Security Agency 2017)

The Quill Lakes were the first Canadian site in the North American Waterfowl Management Plan, were designated as a site in the International Biological Programme and Saskatchewan Heritage Marsh Program in May 1994, and were designated a Western Hemisphere Shorebird Reserve Network site of International Significance. The site is an important staging and breeding area for spring and fall migration of shorebirds. The site qualifies as an Important Bird Area for its globally and nationally significant migratory and breeding populations of more than a dozen species of birds. Some species migrate as far south as South America.

Salinity varies within the lakes and with their water levels, but effectively limits the flora diversity of the region. The watershed is primarily provincial Crown land administered by the Fish and Wildlife branch of Saskatchewan Ministry of Environment. The surrounding area, consisting of undulating glacial till, is mostly used for agricultural purposes.

In 2004, the lakes were estimated to cover an area of about 635 square kilometres (245 sq. mi). Big Quill Lake is pear-shaped and approximately 27 km long; it measures 18 km at its widest point. Middle Quill Lake, also known as Mud Lake, the smallest of the three, is about 6 km long and 3 km wide. Little Quill Lake is approximately 24 km long and 11 km wide.

Due to the water depth having increased by 6.5 m since 2004, the latest estimate completed in 2016 considers that the lakes have increased in surface area to nearly 750 km^2, with all three bodies of water now merging to create one lake. The Water Security Agency estimates that approximately 58,000 acres (23,500 ha) of public land and 27,000 acres (11,000 ha) of private land have been flooded, with an additional 56,000 acres (22,700 ha) at risk if the wet cycle that has fed the Quill Lakes continues.

Table 13.1 Key elevations for the Quill Lakes (Golder Associates 2015)

LAKE	DESCRIPTION	ELEVATION (m)	SOURCE
Little Quill	Highway 35 road shoulder near Little Quill Lake	522.0	Golder Final Report Table 1 (January 2015)
Little Quill	Little Quill Lake spill elevation to Big Quill Lake and full supply level	518.16	Golder Final Report Table 1 (January 2015)
Big Quill	Existing Big Quill Lake spill elevation	521.47	Golder Final Report Table 1 (January 2015)
Big Quill	Highway 6 minimum road surface at centerline (shoulder)	520.98 (520.74)	Golder Final Report Table 1 (January 2015)
Big Quill	CP rail bed	520.8 (estimated)	Golder Final Report Table 1 (January 2015)
Little Quill and Big Quill	Minimum elevation of Grid Road 640	519.62	LiDAR
Little Quill and Big Quill	Approximate elevation when cropland starts to flood	519.0	Golder Letter on Surface Area (April 13, 2015)

The water level in the Quill Lakes reached 520.7 m earlier in 2017 and towards the end of the year was 520.52 m. The current level slightly exceeds the highest peak achieved about 100 years ago.

Figures 13.20 to 13.25 are Google Earth images demonstrating a time-lapse progression of the Quill Lakes from 1984 to 2016. The period from 2010 to 2016 was a prolonged wet period.

As closed-basin lakes experience changes in prolonged (e.g., multi-year) naturally occurring wet or dry periods, their lake elevations will change over time. The lakes will fluctuate to higher or lower elevations and their shorelines will extend over larger or smaller areas of land. In cases of inundation by highly saline water, soil quality may also be affected. Another key factor in changing water levels is wind fetch and wave formation, which may threaten areas beyond the actual lake shoreline. Figure 13.26 illustrates the naturally occurring long-term decline of several closed-basin prairie lakes and their rebound in recent wet years (van der Kamp et al. 2008, and van der Kamp p.comm. 2017).

Figure 13.20 Quill Lakes 1984 (Image Source: Google Earth)

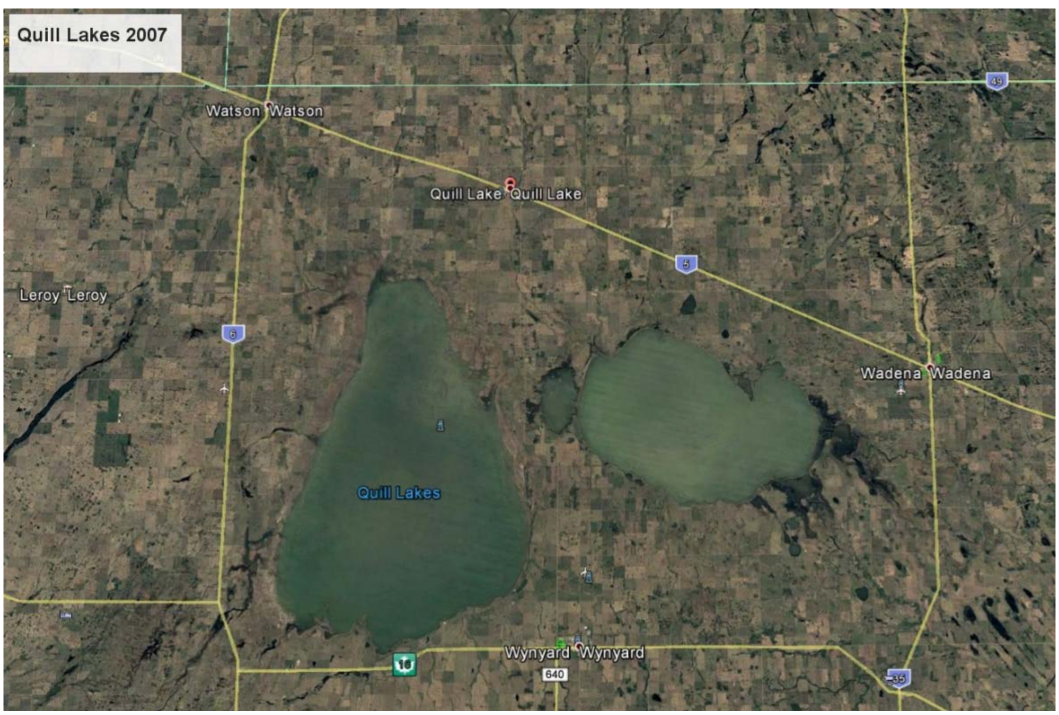


Figure 13.21 Quill Lakes 2007 (Image Source: Google Earth)

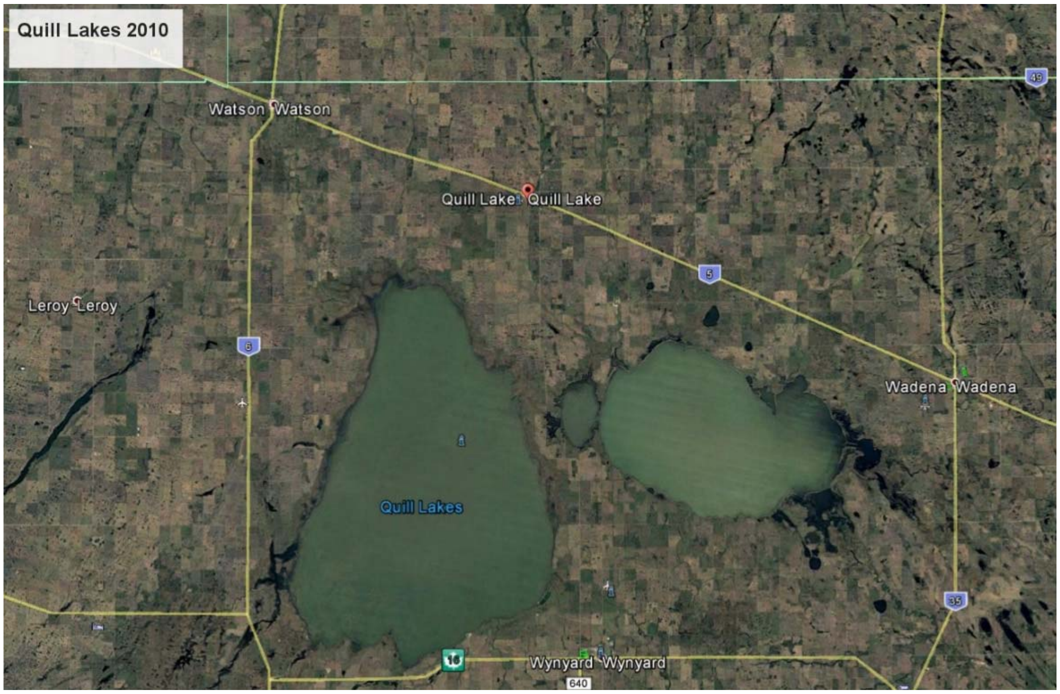


Figure 13.22 Quill Lakes 2010 (Image Source: Google Earth)

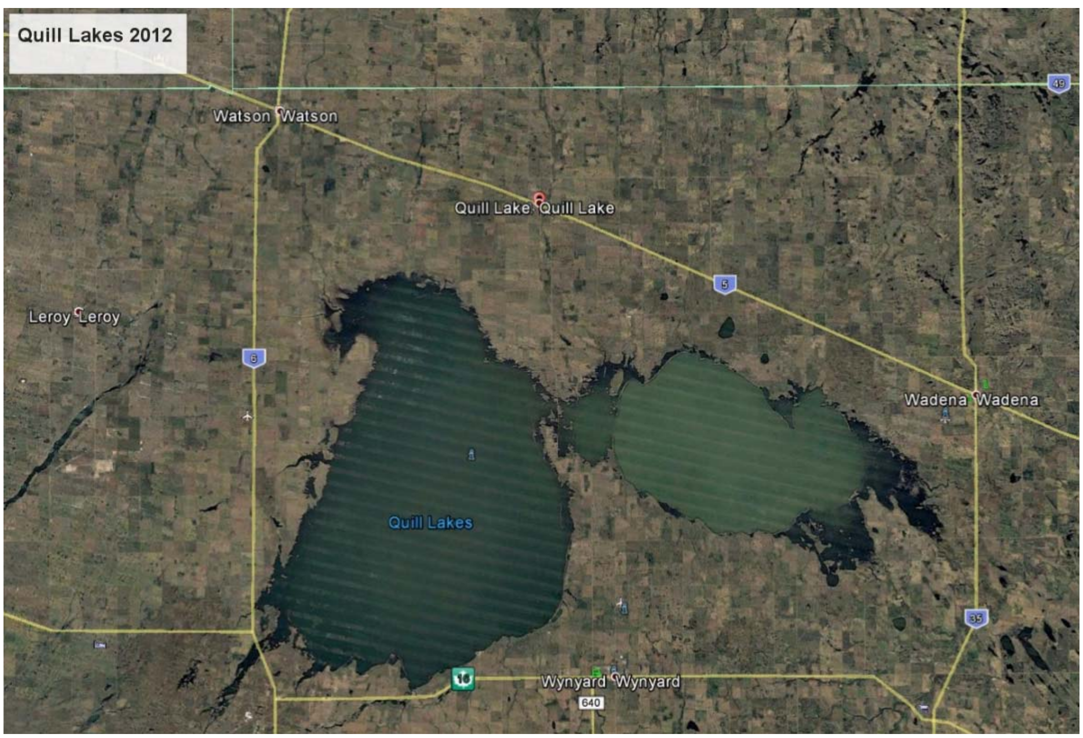


Figure 13.23 Quill Lakes 2012 (Image Source: Google Earth)

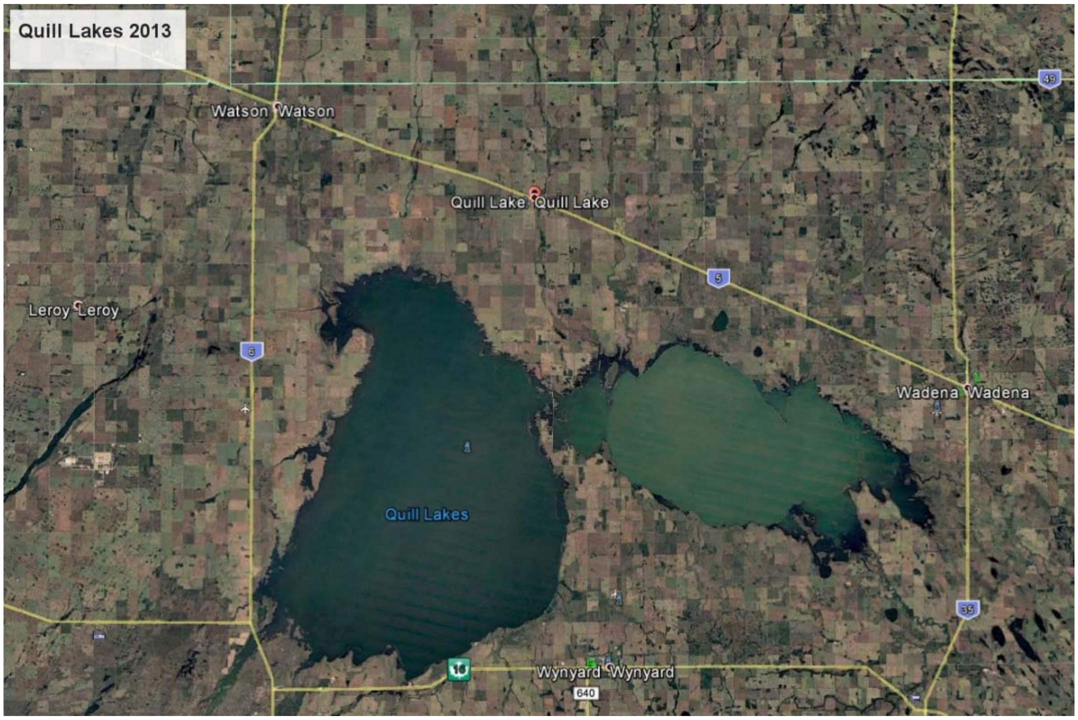


Figure 13.24 Quill Lakes 2013 (Image Source: Google Earth)

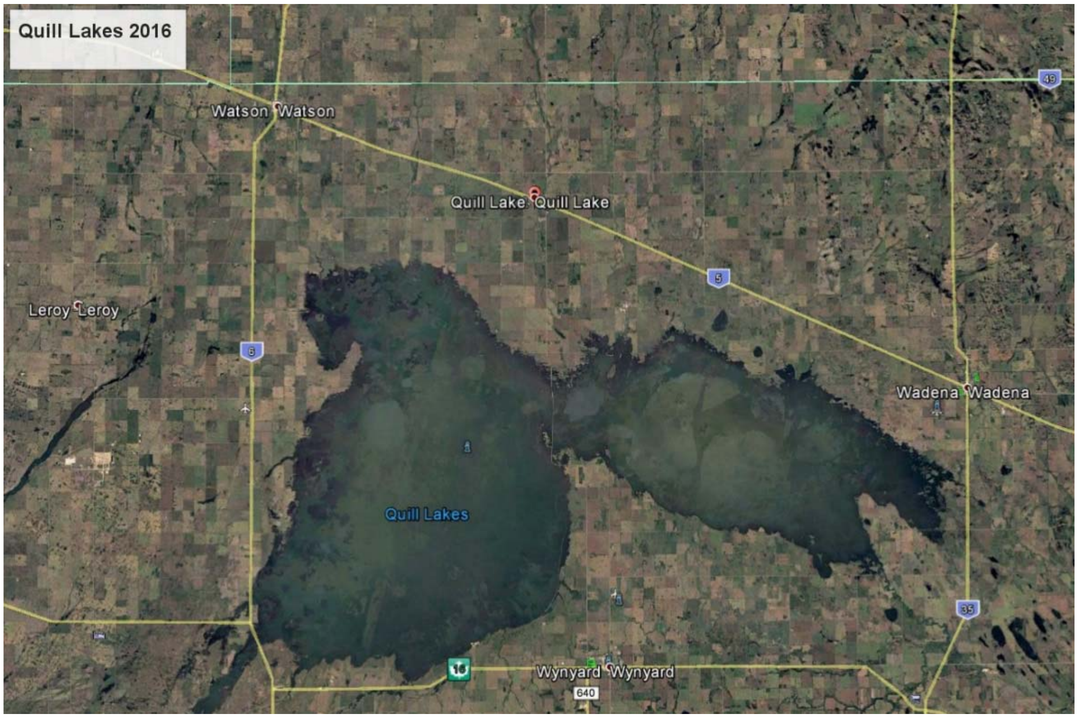


Figure 13.25 Quill Lakes 2016 (Image Source: Google Earth)

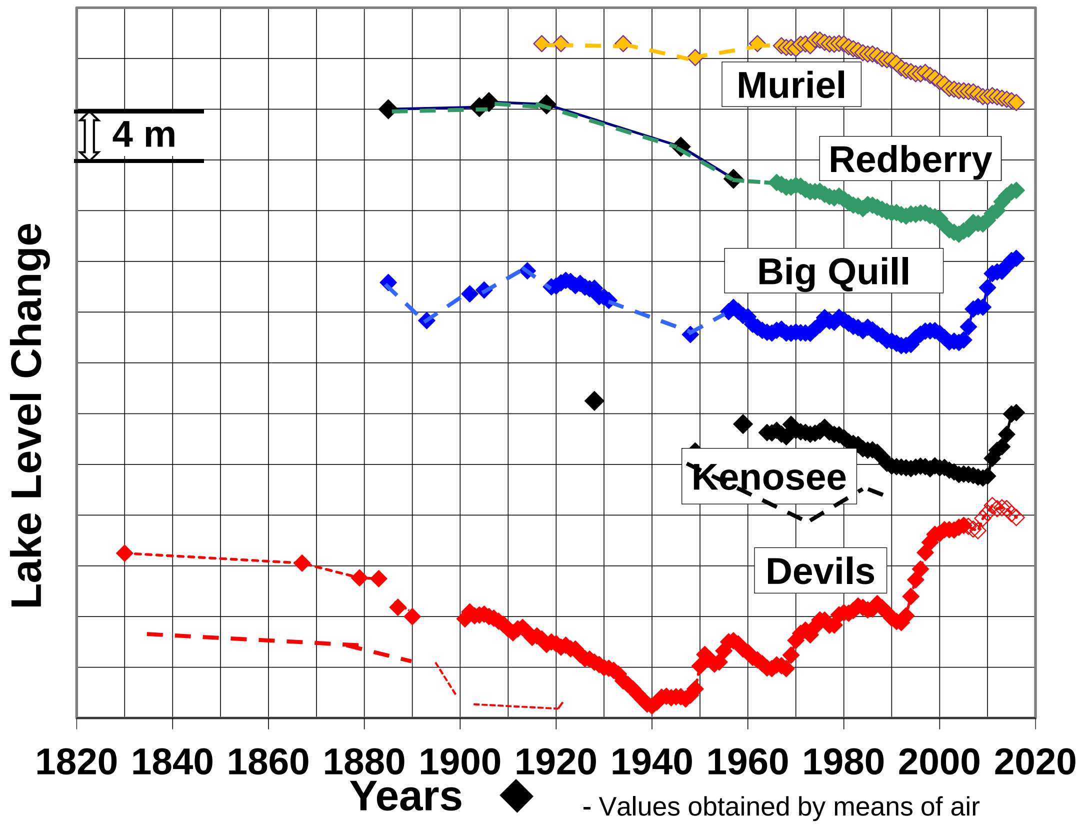


Figure 13.26 Long-term water level changes in closed-basin prairie lakes. (van der Kamp, personal communication 2017)

Rural Municipalities, Towns and Villages

The village of Dafoe and the organized hamlet of Kandahar in the RM of Big Quill are most under threat, should the Quill Lakes shoreline continue to expand. The area includes several rural municipalities, towns and villages:

RM of Lakeside (No 338) – administration office in the village of Quill Lake
combined RM population – 796

RM of Lakeview (No 337) – administration office in the town of Wadena
combined RM population – 1,642

RM of Big Quill (No 308) – administration office in the town of Wynyard
combined RM population – 2,354

RM of Elfros (No 307) – administration office in the village of Elfros
combined RM population – 528

In July 2016, the village of Elfros suffered damage as a result of localized flash flooding, with substantial damage to nearly half of the 57 private properties. Approximately 140 mm of rainfall hit the village in under two hours, causing streets to flood and the village's sewer system to back up. Highway 16 was temporarily closed, and a CP train was stopped due to fears of a line wash-out. Elfros declared a state of emergency and emergency response equipment was deployed to the area. The Provincial Disaster Assistance Program (PDAP) set up a recovery centre to guide and advise residents through the claims process.

Impacts to Public Infrastructure

Roads

The Quill Lakes are bordered by provincial highways No. 5 - North, No. 6 - West, No.16 - South and No. 35 - East. These roads are asphalt covered and maintained by the provincial Ministry of Highways. The main municipal highway, No. 640, runs north–south between the Big Quill and Middle Quill lakes. This is designated as a primary-weight, all-season gravelled road. The remaining roads are a variety of gravelled grid roads and un-gravelled land access roads.

Since 2010, many roads within the RMs have experienced some level of damage; some have sustained enough damage to warrant temporary closure and weight restrictions. The damaged portions included roads, culverts and bridges.

The damage was assessed and described using the following criteria:

- Major Minor Top Wash Out or Minor Top Failure
- Major Top Wash Out or Major Top Failure
- Bulk Material Wash Out
- Road Wash Out or Road Base Failure
- Road Partially Submerged or Undermined
- Road Underwater

In 2011 the RMs of Lakeside and Lakeview, with a combined total of 206 locations damaged, required support from the Provincial Disaster Assistance Program (PDAP). The cost of repairs was estimated to be close to $1 million. Since this time, the area has experienced further annual rainfall events and excessive water received into the lakes' basin. This has culminated in the eventual closure of the municipal highway 640, which is considered the biggest loss of built infrastructure. There have been several attempts to rebuild the road over the last five years. These attempts included the RM of Lakeside placing approximately $4 million of road materials in 2014 to build up the road (Figure 13.27) and provide protection from severe wind and wave erosion, but unfortunately all efforts have failed (Western Producer July 2015). This has resulted in a detour of approximately 80 km for residents between the town of Wynyard and the village of Quill Lake.

Figure 13.27 Highway 640 – picture taken in 2014. The road has been closed since September 2015.

The Ministry of Highways has recently raised a 1-km section of Highway 6 and armoured the road shoulders to protect the road from wind and wave erosion (Figure 13.28). The road requires regular inspection and maintenance.

Figure 13.28 Highway 6 near Dafoe; 1-km section of road was raised, and shoulders were armoured to protect against wind and wave erosion.

Bridges

The bridges were designed many years ago, with the design criteria based upon conditions at the time. As the water levels and flows have increased, it has been found that most of the bridges are now under capacity for the volume of water passing through the RM during recent flooding events, particularly in the last five years. Some of the bridges have suffered some structural damages to either the bridge itself or the surrounding area.

In general, damages to the bridge structures consist of material loss along abutments, wing walls and damage to decks and side rails.

Culverts

The situation is the same as with the bridges. Many of the RM's culverts are undersized for the hydraulic capacity currently needed. The consequence of this is that the RMs are seeing an increase in the number of culverts washed out and damaged.

Rail Line

The Canadian Pacific Railway rail bed between Wynyard and Lanigan is threatened (Figure 13.29), although the rail line is providing protection around the affected area in order that the rail link is maintained. The rail bed height is within 0.8 m of the water level.

Figure 13.29 CP rail line west of Dafoe; picture taken August 2014 (Photo source: Wadena News Sept 2015)

Private Property

A family farm along Highway 6 near Dafoe is surrounded by lake water (Figure 13.30). The owner has constructed a berm to protect the property and farmyard; however, thousands of acres of pasture and land have been lost. In 2004 the lake was 3 km away from the farm (Western Producer 2015).

Figure 13.30 A farm surrounded by the Quill Lake protected by an owner-constructed berm (Photo source: Western Producer July 2015)

Environmental Considerations and Social Acceptance

The Quill Lakes Flood Mitigation Study Concept Design Report identified a variety of options to address concerns with the current high water levels in the Quill Lakes (as of 2017). Some mitigation options pose environmental concerns that would need to be considered. Social acceptance and responses to different mitigation options will also vary, and are therefore important factors to consider in any potential mitigation actions.

Conclusions

A study recently commissioned by the Water Security Agency into flood mitigation strategies provided a range of options. These options ranged in cost anywhere between $5 million and $1.2 billion and included the following activities:

- Holding the water in the Quill Lakes
- Inflow diversion
- Upland storage
- Remove the water from the Quill Lakes
- Inflow reduction.

Rising water levels on the Quill Lakes could also potentially lead to significant environmental concerns within the study area. If the Big Quill Lake spill point is overtopped, the saline water from the Quill Lakes will be discharged into Last Mountain Lake, possibly causing water quality issues. Further, increased flows through Kutawagan Creek and Saline Creek could potentially cause erosion or other environmental concerns.

Allowing the Quill Lakes to rise naturally and potentially overflow to Last Mountain Lake will likely result in significant further damage to the surrounding land and important infrastructure in the study area. The set of time-lapse aerial images shown in Figures 13.20–13.25 show how much the flooded area has increased for the Quill Lakes basin. As the water levels continue to rise, damages to surrounding properties will increase and critical infrastructure may be overtopped. These damages could potentially be mitigated by constructing dykes around properties and possibly further raising critical transportation routes, including Hwy 16, Hwy 6 and the CP rail line (KGS Group Consulting Engineers 2016).

14. SUMMARY OF EXISTING CONTROLS

There are many measures that can be and have been taken to reduce the risks associated with the analyzed natural hazard events. As mentioned previously, risk reduction measures include reducing the natural hazard, reducing the exposure and reducing the vulnerability. These can also be categorized as reactive or proactive risk reduction strategies. As well, some reactive risk reduction strategies transform into being proactive. Each chapter on the selected natural hazards examined in detail the current existing controls in place to reduce the vulnerability to that natural hazard event; this chapter provides an overview of these existing controls.

Existing controls for reducing the risks of natural hazards incorporate multiple levels of government and individual response. The various forms of flooding have multiple existing controls in place (Chapter 6), including utilization of large infrastructure such as dams and diversion canals. Other controls include floodplain mapping and incorporating appropriate zoning. It is important to have preparedness action at the community and individual levels, such as having evacuation plans and protection of critical infrastructure. Every community in the province is required to have an emergency plan and while some do, others do not. The Water Security Agency (WSA) is responsible for water management in the province. Its responsibilities include managing the province's water supply, protecting water quality, ensuring safe drinking water and treatment of wastewater, owning and managing 69 dams and related water supply channels, reducing flood and drought damage, protecting aquatic habitat and providing information about water. Foremost among WSA's responsibilities is flood forecasting to avoid loss of life and reduce flood damage.

Like flooding, existing controls for drought (Chapter 7) require incorporating federal, provincial, municipal and individual responses. Many of these responses, such as crop insurance, are longer term, but others, such as accessing groundwater reservoirs for cooling water in industry, are reactive in nature. The stakeholder consultations illustrated the point that proactive planning and revisiting drought preparedness planning is key to appropriate risk management. Grassfires are associated with dry conditions, and municipalities are responsible for fire management of fires within the affected rural municipality (RM) (Chapter 8). Depending on various factors associated with the grassfires, cooperation may be required between the surrounding municipalities and the province to suppress the fire. It was noted in the consultations that good communication among all levels of government and the various emergency response teams is a key requirement, and is an ongoing work in progress (Appendix A).

The existing controls for forest fires have two primary components (Chapter 8): educational measures, such as through FireSmart, and fire suppression practices. The Province is responsible for fire management on Crown land, including fire detection, preparedness and suppression. These three components require cooperation and communication among companies, individuals, and the local, provincial and federal governments.

Severe weather events (Chapters 9 and 10) have existing controls that are both proactive and reactive in nature. It is the federal government's mandate to provide all available information regarding inclement dangerous weather events. The Province and some municipalities provide additional assistance through social media such as SaskAlert. After an event has occurred, insurance systems are in place to assist individuals and companies to mitigate the damages that resulted from the severe weather event.

Major earthquakes are such a rare event in the province that it is seldom that mitigative measures are incorporated into infrastructure plans. For example, none of the existing dams in Saskatchewan were designed for earthquake loading (Chapter 11). Underground mines have refuge stations that have been utilized because of an earthquake, but they were incorporated into the mine design for multiple reasons.

The consultations (Appendix A) brought forward specific ideas to augment the existing controls. These included public education, better communication among all levels of government and emergency response teams, and incorporating the information obtained from this project into long-term planning.

15. BRIEF OVERVIEW OF EXISTING EMERGENCY RESPONSE CAPACITY

This chapter provides a brief overview of the emergency response capacity that currently exists in the province of Saskatchewan as it pertains to natural hazard events. Saskatchewan's land base is large and relatively sparsely populated (Chapter 2), thus having a well functioning, efficient, swift, suitable reactive emergency response strategy to natural hazard(s) is imperative. Saskatchewan has multiple levels of emergency response agencies and organizations ranging from government (federal, provincial and municipal), to various types of non-government organizations to volunteers. The general approach to emergency response in Saskatchewan and elsewhere is that first responders are local and as the severity of the emergency becomes more apparent, senior levels of government become more engaged in the response.

Initial response to a natural hazard event usually occurs during or right after that event. First responders include medical professionals and hospitals, fire departments, the police and municipalities. Municipalities are obligated to establish emergency plans as designated by The Emergency Planning Act, 1989 (Government of Saskatchewan 2018d). While some Saskatchewan communities have good plans, others do not (Halliday Chapter 6). The Government of Saskatchewan does have the authority to declare a state of emergency through an Order-in-Council and direct municipal resources or direct one municipality to assist another during an emergency (Government of Saskatchewan 2018d). When an emergency escalates beyond the capacity of a local jurisdiction or multiple jurisdictions, the Provincial Emergency Operations Centre may be activated. The centre has access to emergency services officers and rapid response teams as well as equipment and supplies that the individual jurisdictions may not have access to (Government of Saskatchewan 2018d). One area of concern that was brought forward during the consultation process of this project was the capacity of the emergency response planning to deal with evacuations. The stakeholders recommended that this situation needs to be considered and improved upon due to limited capacities of remote communities, particularly in the northern portions of the province (Corkal Appendix A).

The federal Emergency Management Act recognizes the roles that all stakeholders must play in Canada's emergency management system. It sets out the federal leadership role and responsibilities of the Minister of Public Safety and Emergency Preparedness, including coordinating emergency management activities among government institutions and in cooperation with the provinces and other entities. Responsibilities of other federal ministers are also set out in the *Act*. Public Safety Canada led the development of the National Emergency Response System (NERS) with provincial and territorial officials, which was approved by federal/provincial/territorial Ministers in January 2011. The NERS enables coordinated efforts in responding to emergencies (Government of Canada 2018).

The Government Operations Centre (GOC) is the principal means by which the Minister of Public Safety and Emergency Preparedness' leadership role in establishing an integrated approach to emergency response is exercised. Housed at Public Safety Canada, the GOC, on behalf of the Government of Canada, supports response coordination of events affecting the national interest. It brings all partners into a common environment to harmonize and synchronize collective actions of those partners. The GOC operates 24/7 to provide watch, warning, analysis, planning, logistics support and coordination across the federal government and with its partners, including provincial and territorial governments, non-governmental organizations, the private sector, and international partners (Public Safety Canada 2016).

Other key emergency response organizations include non-governmental organizations such as the Canadian Red Cross and the Salvation Army. The Canadian Red Cross (CRC) provides various types of assistance to communities that are dealing with an emergency. The CRC works in partnership with first responders, emergency managers and public official to support their response activities and also with other voluntary sector organizations (Canadian Red Cross 2018). The assistance can be family reunification, emergency lodging, food and clothing, reception and information, and personal services (Canadian Red Cross 2018). For example, in 2015, the Canadian Red Cross provided assistance to nearly 8,000 people who were evacuated from Saskatchewan's north. On behalf of the Government of Saskatchewan, the Red Cross made sure basic needs were provided to the evacuees in shelters to keep the people as comfortable as possible (Canadian Red Cross 2015). The Canadian Red Cross also assessed communities that were affected by flooding in 2014. The Red Cross provided trained disaster response volunteers, and clean-up materials, and also replaced essential personal items that were destroyed by the floodwaters (Canadian Red Cross 2014). The Province of Saskatchewan contracts the Canadian Red Cross to provide disaster relief services in Saskatchewan (Government of Saskatchewan 2015).

Organizations such as the Salvation Army have also responded to provide assistance when natural disasters occur. The Salvation Army's Emergency Disaster Services are able to provide a variety of services for both the disaster survivors and the emergency responders. They work with the emergency preparedness authorities to respond appropriately to the situation (The Salvation Army 2018). The Salvation Army has assisted with Saskatchewan flood victims such as when southeastern Saskatchewan was heavily affected by flooding in 2014 (The Salvation Army 2014).

A third association that has been used during a natural hazard event but to a very limited extent is the Search and Rescue Saskatchewan Association. The association is not trained to respond to natural hazard situations and although they have been used in extreme cases, they are not insured for this type of situation and response. It is made up of 15 search and rescue regional jurisdictions throughout the province. This association is made up of about 350 volunteers that work under the direction of the local police service or RCMP, the community's Emergency Measures Organization or other agency of jurisdiction (Search and Rescue Saskatchewan Association of Saskatchewan 2015). While Search and Rescue volunteers are available 24/7, the people are volunteers which may result in limited personnel capacity depending on the availability of the volunteers.

When a fire on Crown land occurs, the detection, preparedness and suppression is the responsibility of Saskatchewan Ministry of Environment Wildfire Management Branch (WMB). Detection is based on public reporting, detection aircraft and ground patrols and a system of cameras that have been installed in fire tower locations. Preparedness includes having firefighting crews available for the April to October forest wildfire season. The firefighting crews are distributed among the province's Forest Protection Areas. WMB maintains a fleet of aircraft for aerial firefighting made up of airtankers with support from guide aircraft. Saskatchewan is also part of the Canadian Interagency Mutual Aid Resources Sharing Agreement that moves fire equipment and personnel between provinces as needed (Johnston Chapter 8).

In 2015, the Province of Saskatchewan established a civil service response team (CSRT) made up of staff from numerous ministries that assists the government's Emergency Management and Fire Safety branch to respond to emergency situations. This team assists municipalities with a multitude of services including installing sandbags, assist with but is not directly associated with fire fighting such as equipment deployment and assisting with evacuations. The members of this team complete a three-week training session at the Emergency Management and Fire Safety base in Prince Albert (Legislative Assembly of Saskatchewan, Government of Saskatchewan 2015). In 2016, the province indicated that the civil service response team would be reviewed and potentially expanded (Legislative Assembly of Saskatchewan, Government of Saskatchewan 2016). In spring of 2018, the CSRT is made up of eight rapid responders, 65 CSRT team members. The Provincial Emergency Operations Center and the Rapid Response Team are housed with Emergency Management and Fire Safety. The CSRT are volunteers and the Rapid Response Team are paid employees.

Rural Municipalities (RM) are responsible for fire management of fires wholly or partially within their RM. There are approximately 400 active fire departments made up of career, volunteer and paid on-call personnel. Wildfire Management brand does not respond to fires in any RM land and does not attend grass fires. Emergency Management and Fire Safety will send a Rapid Response Team if assistance is requested. Saskatchewan RMs vary widely in their capacity to supress fires and often work together to fight severe fires (Johnston Chapter 8). The rapid spread of grass fires is a situation where mutual aid agreements are suitable. Communities and RMs are concerned about the potential of rapid spread of grass fires and the lack of aerial support to suppress grass fires (Corkal Appendix A). This is in part due to WMB crews, including aerial support, are only generally available from April to October but the grass fire season can occur outside that period, especially if there is little or no snow cover during the November to March period.

Various rural municipalities are concerned about accessibility of various provincial and federal programs that are available and can assist them with extreme events. In 2017, the Saskatchewan Association of Rural Municipalities Annual Convention brought forward questions regarding the provinces rescue services. One of the resolutions was for the provincial government to develop and regulate a province-wide system of fire and rescue services that were affordable, sustainable and available to all Saskatchewan citizens. The provincial government indicated various supports it can provide to the municipalities and that it will continue to work with communities to address their needs in terms of what type of emergency is occurring, how often it is occurring and where it's occurring so that the issue can be assessed (Saskatchewan Association of Rural Municipalities; Honourable Donna Harpauer, Minister of Government Relations; May 2, 2017)

Police forces in Saskatchewan are made composed of both the Royal Canadian Mounted Police (RCMP) and municipal police forces (Statistics Canada 2016). Saskatchewan's Police Commission Policy Manual indicates that '*the police service will maintain order in situations of disaster protecting citizens and property*' (Saskatchewan Police Commission 2017). The municipal police services are required to have effective and mutually beneficial liaison with other agencies including other police services (e.g., RCMP), fire departments, emergency medical services among others (Saskatchewan Police Commission 2017). The 113 RCMP detachments in Saskatchewan enforce all federal, provincial and municipal laws (RCMP 2018).

Saskatchewan has a number of hospitals and integrated health facilities scattered throughout the province with the majority located south of the 54th parallel (Government of Saskatchewan 2018a). The capacity of each of these facilities varies widely, with hospitals in Saskatoon and Regina having the largest emergency response capacity.

The first-on-scene for medical emergencies include first responders, and ambulance (both ground and air), paramedic and emergency medical technicians (EMT) services. First responders are usually local volunteers while the ambulance, paramedics and EMTs are able to provide trained medical services.

Natural hazards result in more than just physical injury but also result in mental health injuries as well. Saskatchewan has a variety of resources available in emergency situations including HealthLine, mobile crisis helpline, crisis suicide help line and farm stress line. These services provide assistance to those affected by the natural hazard event with appropriate organizations or programs (Government of Saskatchewan 2014, Mobile Crisis Services 2018). The Salvation Army and The Canadian Red Cross also have roles in assisting people, both first responders and those impacted, with their stress levels during an emergency event (Canadian Red Cross 2018, The Salvation Army 2018).

The Canadian Armed Forces (CAF) have the capability of responding to forest fires, flood and other natural disasters. The CAF will only assist with these disasters when they are asked by the Province. The CAF then follows an established plan of action to support the communities in crisis. The most recent occurrence of CAF assisting the Province of Saskatchewan was when the Province asked for help with the wildfire situation in northern Saskatchewan in 2015. This assistance had both pros and cons (Corkal 2018). There was a suggestion that the deployment of the federal Canadian Armed Forces should be implemented more frequently, as scale and need requires; however, such deployments require training and guidance from experienced firefighters, and those with specific local knowledge of the region (Corkal 2018). The CAF has also assisted the provinces of Manitoba and Alberta with flooding situations (National Defence and the Canadian Armed Forces 2018).

*“**During a natural disaster communication is probably the most challenging part**.”*

“Good communication plans need to be developed and clearly communicated to all residents”
(Anonymous Stakeholders from Corkal 2018)

Communication among all emergency response agencies is key for mitigating emergency situations related to natural hazards. Two communication strategies implemented in recent years include one that is focused on the agencies responding to the event. The Provincial Public Safety Telecommunications Network is managed through a partnership between Ministry of Government Relations, SaskPower and the RCMP. This Network provides public safety users such as police services, emergency preparedness and volunteer search and rescue groups, fire departments, and emergency medical services with inter-operable radio communications that allows them to communicate with each other during emergency situations (Government of Saskatchewan 2018c). The second is one where the communication strategy targets the general public. The province has implemented a program known as SaskAlert that provides critical information on emergencies in real time. These alerts can be issued by Environment Canada (weather warning and watches), various provincial ministries and local governing jurisdictions (Government of Saskatchewan 2018b).

One very effective strategy in engaging the public and media in an emergency situation is to designate a single individual, either an elected official, a public servant or some other person, as the consistent spokesperson related to the event. A recent example is the 2013 Calgary flood where the mayor of Calgary assumed that role. A single source, knowledgeable in the emergency response, will reduce the likelihood of mixed messages and inappropriate public response.

Another component of communication strategies is that it is essential that communication lines between the various emergency response jurisdictions remain open with the affected citizens and the public during and after the event. This communication needs to occur in a safe and timely means to help advance public safety protection and hazard mitigation strategies. If provincial or federal assistance are utilized, citizens of the affected region were emphatic that local knowledge, expertise, input and participation are essential factors in any disaster risk reduction preparedness planning and response activities (Corkal 2018). Local understanding and awareness is essential, and may require different communications strategies and frequent initiatives and attempts by officials – common, clear information must be disseminated to those affected to maintain credibility and public safety (Corkal Appendix A).

An important component of this communication strategy are the mutual aid agreements that many RMs and communities of Saskatchewan have. These agreements become increasingly important when a hazardous event is beyond the capacity of the local jurisdiction. The agreements also allow affected jurisdictions to have access to assistance from others trained in specific emergency response strategies (Wheaton et al. Chapter 7 and Corkal Appendix A).

"The people of this province have the right attitude and demeanor to endure these hardships [natural hazards in Saskatchewan] and improve upon them. They need good vision and science to help them make the best decisions"

"Climate change…will change the playing field for all of these natural hazards"

"During a natural disaster communication is probably the most challenging part"
"this study is on the right track, getting the people's view"

"[I] would like to see results incorporated into long-term government planning."
(Anonymous Stakeholders from Corkal 2018).

16. CONCLUSIONS AND RECOMMENDATIONS

Natural hazards and associated extreme events are key determinants of the character of many natural and human-influenced systems (Diaz and Murnane 2008). Saskatchewan has been affected by various natural hazards including flood, droughts, and wildfires as well as others. The effects of these events have influenced various facets of Saskatchewan's society, economy and landscape. The purpose of this project was to develop a comprehensive provincially focused flood and natural hazard risk assessment.

As the Province of Saskatchewan moves to a more proactive risk management strategy for dealing with natural hazards, an important step is to determine the province's vulnerability to various natural hazards. By learning from the past and considering future vulnerability to climate change, the province can determine feasible mitigative responses or initiatives to reduce future risk. This was achieved by building a risk matrix suitable for Saskatchewan needs and was accomplished by incorporating information from national and international literature as well as utilizing expert knowledge from regional, provincial and national sources. Saskatchewan's risk matrix method was applied to each of the selected natural hazards with the goal being to determine the risk level of each natural hazard.

The natural hazards examined were flooding (mountain runoff that supply water for some of Saskatchewan's rivers, plains runoff, lake, overland and groundwater), drought (that encompassed agricultural, hydrologic, meteorological and socio-economic), forest fires (human caused close to communities), grass fires (greater than 1,000 hectares), summer convective storms (tornadoes, high winds, heavy rain, hail, lightning), winter storms (freezing rain, high winds, snow, blizzard conditions) and earthquakes. These natural hazards have already been experienced and have the potential of occurring under future climate conditions.

The risks of each of these natural hazards were assessed individually by examining two scenarios. The first was utilizing a plausible worst-case scenario that incorporated historic events, that typically resulted in having occurred at some point in the last 100 years, but was adapted to present-day situations. The second added a layer (scenario) of climate change to the plausible worst-case scenario focused around modeled climate for the 2050s. An aggregate risk matrix combining all of the hazards was created to assist with the comparison of the spatial extent of each hazard, the likelihood of occurrence and the impact categories of each of the selected natural hazards.

The natural hazards deemed to be at high risk under the plausible worst-case scenarios were drought and convective summer storms. There are several reasons for these two

AGGREGATE RISK OF PLAUSIBLE WORST-CASE SCENARIOS

High Risk
- Drought
- Convective Summer Storms

Moderate to High Risk
- Forest Fires
- Winter Storms

Moderate Risk
- Overland Flooding
- Plains Runoff Flooding
- Lake Flooding
- Grass Fire

Low to Moderate Risk
- Mountain Runoff Flooding

Low Risk
- Groundwater Flooding
- Earthquake

natural events having high risks. Droughts tend to affect large areas of Saskatchewan and their occurrence often lasts longer than other hazards. Human activities require adequate and reliable water supplies. Droughts of the plausible worst-case scenario scale would have a major to catastrophic negative influence on the province's agricultural sector and various economic activities that are water and agricultural reliant. The major to catastrophic negative influence would continue as the availability of high quality potable water for both urban and rural residents would be impaired, as well as for other water uses (including industry). These factors led to assessing the social and public administration impacts as major to catastrophic.

Convective summer storms (tornadoes, high winds, heavy rain, hail, lightning) generally only last a few hours or less and can have catastrophic impacts on human safety including the potential for multiple deaths and injuries. Impacts on infrastructure categories, especially in an urban hub like Regina, can be major to catastrophic. Hail damage impacts include items such as building to vehicle damage, including broken windows, high horizontal winds damage levels can range from light (shingle damage) to buildings being structurally compromised. Heavy rains can lead to flooding and tornadoes can lead to total structural damage. All of the components of convective storms can lead to injury and loss of life. In addition, the level of impact depends on secondary influences that an EF5 tornado would have on the affected region. For example, if it results in major damages to industrial or transportation sectors.

Forest fires and winter storms have an aggregate risk level of moderate to high. Forest fires can cover large forest regions of the province and can result in multiple fatalities and wide-spread evacuations. Severe impacts to forestry and tourism may also occur. Infrastructure would likely be lost and provincial and municipal government bodies would encounter a reduction in the ability to deliver core functions, particularly in the region affected by the fire. Winter storms tend to affect large geographical regions of the province. Such storms may include freezing rain, high winds and blizzard conditions and can persist for multiple days. These storms would have moderate to major impact levels because of the potential of loss of life arising from vehicular traffic fatalities due to road conditions, infrastructure damage due to the freezing rain and blizzard conditions, and disruption in services due to power outages.

Three of the five flooding scenarios have an aggregate risk level of moderate. Overland flooding can impact large portions of the agricultural regions of the province and result in minor to major impacts. Overland flooding can lead to significant income losses for agricultural production as well as infrastructure damage. Other than overland flooding, most floods tend to be local in nature, and affect relatively small regions of the province. Plains runoff flooding tends to be associated with spring runoff and in recent years, convective summer storms. As with the convective summer storms, the level of impacts can increase with potential damage to infrastructure like dykes (secondary negative impacts) resulting in more extensive damage. Lake flooding affects small regions when compared to the entire province with minor impacts on the provincial economy, public administration and social well being. The impacts on human health are classified as moderate due to the possibility of spring time "ice shove" that could result in loss of life.

When the 2050s modeled climate change component was added to the plausible worst-case scenario, the likelihood categories of each of the natural hazards changes. Generally speaking, future climate scenarios indicate greater climate variability and increasing risks and impacts due to the changes of the intensity, frequency, and duration of extreme events and related natural disasters. Good estimates of the consequences of the plausible worst-case scenario for each hazard were provided because they are based on historic events. Future impacts are estimates, based on current state of knowledge in relation to the projected climate change scenarios and associated potential impacts.

AGGREGATE RISK UNDER FUTURE CLIMATIC CONDITIONS (~2050s)

High to Extreme Risk
- Drought
- Convective Summer Storms

Moderate to High Risk
- Forest Fires
- Winter Storms
- Overland Flooding
- Grass Fires

Moderate Risk
- Plains Runoff Flooding
- Lake Flooding

Low to Moderate Risk
- Mountain Runoff Flooding

Low Risk
- Groundwater Flood
- Earthquake

As noted in Chapter 5, the projected increases in temperature and precipitation set up scenarios for increasing the number, intensity and duration of both drought and flood events. With the warmer temperatures, the atmosphere will be able to hold more moisture. This implies there will be increases in intensity and frequency of extreme precipitation events with the result of dry times becoming drier and wet times wetter (Wheaton et al. 2013).

The climate change layer results in drought increasing its likelihood of occurrence from unlikely to possible (Table 12.2 and Figure 12.2). Hence, drought's aggregate risk factor increases from high risk to high to extreme risk in the future scenario.

Convective summer storms' likelihood of occurrence may increase from unlikely to possible under future climate change due to the increased water holding capacity of the atmosphere. However, as stated in Chapter 9, the initiation mechanisms for convective storms need to be considered and the effect of climate change on those mechanisms is unknown at this time. This results in a range of likelihood levels and the aggregate risk level of convective summer storms ranging from high to extreme. Due to convective storms' shorter time period of influence and impact area, they are rated lower than drought in the aggregate risk matrix and it is unknown whether the overall risk will be greater.

Overland flooding aggregate risk is projected to increase to moderate to high under projected climate change scenarios for the 2050s. The increased water holding capacity of the atmosphere could increase the amount of precipitation leading to more rain events and resultant overland flooding. In addition, the economic consequences can change by an order of magnitude thus resulting in the potential of overland flooding having an aggregate risk level of moderate to high under future climate conditions.

Mainly due to the increasing drought frequency projected with future climate change, the likelihood of grass fires increases from unlikely to possible. This results in an aggregate risk increase to moderate to high risk.

In addition to the risk assessments, a brief examination was carried out of proactive (emergency response capacity) and reactive (existing controls) mitigation strategies that include risk reduction strategies was carried out. These measures assist with reducing the exposure to the natural hazard and reducing the vulnerability. There are many measures that can be taken to reduce the risk associated with natural hazards in Saskatchewan. In a general sense, risk reduction measures can include reducing the exposure, and reducing the vulnerability (for example, by increasing capacity to cope with a natural hazard). Once measures are taken, the remaining risk to people, assets, the economy and the environment is termed the residual risk. Residual risk will likely always exist, but risk can be significantly reduced.

Saskatchewan has multiple levels of emergency response agencies and organizations ranging from government (federal, provincial and municipal), to various types of non-government organizations to volunteers. The general approach to emergency response is that first responders are local people and groups, who may or may not be trained professionals in emergency management. As the severity of the emergency becomes more apparent, more senior levels of provincial and federal government become more engaged in the response.

Initial response to a natural hazard event usually occurs during or right after that event. First responders include medical professionals and hospitals, fire departments, the police forces and municipalities. The Government of Saskatchewan has the authority to declare a state of emergency through an Order-in-Council and to direct municipal resources or to direct one municipality to assist another during an emergency (Government of Saskatchewan 2018d). When an emergency escalates beyond the capacity of a local jurisdiction or multiple jurisdictions, the Provincial Emergency Operations Centre may be activated. The Centre has access to emergency services offices and rapid response teams as well as equipment and supplies that the individual jurisdictions may not have access to (Government of Saskatchewan 2018d).

The federal government has the Emergency Management Act, which assists with coordinating emergency management activities at the federal level and in cooperation with the provinces and other entities. As well, the federal Government Operations Centre provides watch, warning, analysis, planning, logistics, support and coordination across the federal government and its partners. In addition, the Canadian Armed Forces will assist with various types of emergency situations if requested by the province.

In the consultation workshops, stakeholders identified some areas of concern with Saskatchewan's existing emergency response:

- Municipalities are obligated to establish emergency plans as designated by The Emergency Planning Act, 1989 (Government of Saskatchewan 2018d). While some Saskatchewan communities have good plans, others do not (see also Halliday Chapter 6).
- The capacity of emergency response planning to deal with evacuations is not always adequate. The stakeholders recommended that this situation needs to be considered in greater detail and improved upon due to limited capacities of remote communities, particularly in the northern portions of the province (see also Corkal Appendix A).
- Communication among all the agencies involved in planning as well as actual emergency response is a challenge and often seen as inadequate. The consultation process emphasized that local understanding, awareness and engagement are essential, and may require

different communications strategies. Frequent or initiatives and attempts by officials are needed to ensure that common, clear information is disseminated to those affected by the natural disaster to maintain credibility and public safety (see also Corkal Appendix A).

The success or effectiveness of any natural disaster preparedness program relies on awareness, effective planning, and communications. On-going awareness is required during natural disasters, and even when there is no exposure to a specific natural hazard. The most effective approach in addressing natural hazard risks relies on prepared people, communities, and all orders of government.

Existing controls and longer-term mitigation strategies can reduce the level of emergency response required. Longer-term strategies are often costly investments but can reduce the vulnerability to various natural hazards and in the long-run, also prove to be economically advantageous.

Mitigation measures can be proactive or reactive, depending on the event. For example, examples of proactive controls would be ongoing and established government safety nets like crop insurance and FireSmart. Other examples would be spring flood forecasting (provincial) and severe weather forecasting (federal). A good example of both a proactive and reactive mitigation would be from Saskatchewan Ministry of Highways and Transportation. They provide a reactionary service after an extreme weather event (i.e., snow clearing) while also providing information to users of the current state of the road systems to caution users of road conditions and safety issues (e.g., snow, road construction, closures due to flooding etc).

This natural hazard risk assessment brought many recommendations regarding each of the individually assessed hazards. Some general risk assessment recommendations are:

- The economic consequences of the natural hazards are challenging to determine because they change by an order of magnitude, depending on the location in the province, the type of hazard, and what was impacted by the event, e.g, a case study economic analysis of the impacts of the 2015 wildfires. Economic analyses would provide additional information to support decision making and should include both direct losses to infrastructure and lost opportunities like tourism.
- Information regarding other impacts of hazards such as biological, physical and health consequences is also sparse in several cases and requires augmentation.
- More specific regional vulnerability assessments are needed to improve the confidence levels of the methods developed in this document.
- Only an initial comparison of select natural hazards were in the scope of this project. A more comprehensive comparison additional natural hazards, possibly including secondary hazards that are not necessarily natural hazards, would be useful.
- Risk assessments should be reviewed and updated on a regular basis. As more information becomes known, particularly on the climate change aspects, the provincial scale risk assessment should be reviewed and updated.
- Climate change scenarios identify that greater impacts are expected. As local or regional areas may be required to recover from exposure to natural hazards (e.g. flooding), it is prudent to consider how recovery plans may best position the affected areas locally and regionally – build better and strengthen resilience, where this may be possible.

This assessment is the initial step in identifying how to increase resiliency in Saskatchewan. The province is exposed to a wide range of vulnerabilities to flooding, droughts and forest fires. It is also clear that existing disaster response mitigations and approaches are established. The notion of strengthening provincial resilience is a desirable goal, which can be far more than aspirational. The stakeholder workshops identified potential opportunities to further enhance resilience, including examples such as (see also Corkal Appendix A and Corkal 2018):

- Prevention of new development within flood plains is an action that could become universal for all urban and rural areas. Enhanced surveys and development of new, updated flood risk maps to inform public and private flood risk could be a mid to longer-term program.
- A WaterSmart Program could be developed for all of the province, with the engagement of local stakeholders.
- Much is also known of drought risks across the southern agricultural areas of the province (less so in the forested northern areas). The concept of formalizing and annually updating a drought contingency plan for the province would be advantageous.
- A DroughtSmart or Water-Scarcity-Smart program could be fashioned to assist readiness to respond to drought when it does occur.
- The existing FireSmart approaches are proven multi-stakeholder strategies and plans. These can always be improved upon in the northern forested areas, and further developed to apply to the grassland wildfire context.
- Larger-scale programs and/or investments in mitigations (e.g. flood infrastructure, alternate water sources and diversions for water scarcity, enhanced strategic fire protection equipment, technology and responses) are also viable options that may vary depending on monetary budgets and long-term planning.

This risk assessment shows that Saskatchewan is vulnerable to natural hazards, and particularly so to droughts and water scarcity, severe summer and winter storms, floods and excessive wet conditions, and wildfires (forests and grassland fires). While we know much about our exposure risks, we understand that there is clearly room to reduce our vulnerability and strengthen coping capacity and resilience to natural disasters. Some future actions are relatively simple: putting into place more and better preparedness planning for droughts, floods, and fires. Some future actions are more complex, such as larger-scale investments to safeguard people, communities and industry.

The stakeholder workshops identified a strong desire by local people, communities and industry experts to build their knowledge and coping capacity. Such stakeholders retain a wealth of knowledge, skills and experience of local, regional and special interest vulnerability. They not only desire to be engaged in designing strategic natural disaster approaches – they expect it.

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Darrell Corkal, P. Eng. conducted this work with Walker Projects Inc., an engineering consultant providing services to clients across Saskatchewan and western Canada. Darrell is the president of h2adapt inc. specializing in water resources, water quality and treatment, climate change adaptation, and stakeholder facilitation targeted to aid water resource management and decision-making. He previously worked for Agriculture and Agri-Food Canada's Prairie Farm Rehabilitation Administration helping farmers, communities and watershed organizations obtain secure sustainable, and good quality water supplies. Darrell has extensive experience working on water infrastructure (dams, pipelines, reservoirs, irrigation works), water resource studies, water quality/treatment research, and climate change adaptation projects for agriculture, rural communities and First Nations. As a researcher-collaborator on international multi-disciplinary academic teams, Darrell worked on projects aimed at strengthening institutional and stakeholder capacity to address climate-induced water stress in Canada, Chile, Argentina, Brazil and Colombia.

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As a consultant, he has investigated flooding issues in Latin America and China. He served on the International Joint Commission’s Task Force on Red River flooding. As well, he is one of the principal authors of the United Nations Guidelines for Reducing Flood Losses and an author of the World Meteorological Organization’s Guide to Hydrological Practices.

Mark Johnston
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Jeff Lettvenuk
Jeff is the GIS Lead, Environment Division, with Saskatchewan Research Council (SRC) and is a GIS and application development specialist with thirty years of professional design and programming experience in the natural resource sector. Along with technical leadership, his primary responsibilities at SRC include UAV image acquisition, GIS and data management services for research initiatives that include forestry, landscape ecology, water sciences and mining.

Ian Stewart
Ian Stewart, PMI-RMP has been with Walker Projects Inc. for the last four (4) years, as a Project Manager in the Civil Engineering division. He has experience on water and wastewater projects as well as building and site re-development projects. Ian has completed in excess of sixty (60) site inspections and associated damage assessment reports for municipal flood designations in Saskatchewan, under the Provincial Disaster Assistance Program. Prior to arriving in Canada, he was a Senior Project Manager with BAE Systems in Saudi Arabia, where his main work packages included systems support to Typhoon (Eurofighter) Tranche 1 delivery and the design and construction of an Aviation Academy. He also has experience in other industry sectors, such as; Communications (Nortel Networks, EMEA Region), Heavy Engineering (NEI Clarke Chapman UK Ltd) and the Military, whilst resident in the UK and Germany.

Elaine Wheaton
Elaine Wheaton is a Climate Scientist, an Adjunct Professor at the University of Saskatchewan and Emeritus Researcher, Saskatchewan Research Council. She has considerable research experience in the areas of climate change, impacts, adaptations, hazards, risks and vulnerability assessment. Specific sectors of expertise include agriculture, water, health, and risk assessment. She has international research experience in several countries, including those in South and Central America, Asia, and Europe. Her awards include the 2007 Nobel Peace Prize certificate for substantial contributions to the work of the Intergovernmental Panel on Climate Change, Wolbeer

Award for contributions to water resources research, Emeritus Researcher and Distinguished Scientist appointments at the Saskatchewan Research Council, and the YWCA Science and Technology award. She is widely published in refereed science journals, books and technical reports. She is the author of the award-winning book, "But it's a Dry Cold! Weathering the Canadian Prairies."

Virginia Wittrock
Virginia is a Research Scientist / Climate Research Specialist at the Saskatchewan Research Council. Her research interests have been in the areas of climate change, impacts, adaptation, hazards and vulnerability. She is on the Saskatchewan Board of Directors for the Canadian Water Resources Association.

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CHAPTER APPENDICES

Appendix Chapter 4.1 Full risk matrix

Impact Categories (Emergency Management Ontario 2012, Public Safety Canada 2012, White 2016, Australian Government Attorney-General's Department 2015, consulations with various provincial government ministries 2017)					Likelihood Categories					
Human Health and Safety	Social	Public Administration	Economic	Environment	Percent chance of occurrence in any given year	Less than 1%	One to <10%	10 to <50%	50 to <100%	100% chance of occurrence
					Qualitative (likelihood) description (standard for all hazards)	The event/condition may occur only in exceptional circumstances	The event/condition could happen at some time	The event/condition should occur at some time	The event/condition will probably occur in most circumstances	The event/condition is expected to occur in all circumstances
Deaths, Injuries, Illness, Psychosocial, Stress	*Communities, Culture, Relationships*	*Provincial Scale*	*Direct and Indirect Economic Implications (including infrastructure)*	*Air Land water Biodiversity*	*Likelihood Descriptions* / *Impact Descriptions*	Rare	Unlikely	Possible	Likely	Almost Certain
• Multiple public fatalities (>50) and / or critical injuries with long-term or permanent incapacition (>50) • Extreme and ongoing exceedance of recognized health-related standards (e.g., CCME Selenium Guidelines or Canadian Ambient Air Quality Standards) • Community evacuations of >50,000 people	• Permanent reduction in quality of life of impacted and nearby communities • Permanent degradation of surrounding values and natural resources • Permanent relocation / abandonment of communities • Widespread severe psychosocial impacts e.g widespread panic and hoarding, mass riots, and long-term psychosocial impacts • Disputes related to development or decisions erupt into large and violent campaigns of civil disobedience • Widespread permanent loss to culturally significant objects	• Multi-municipal, provincial, national and international, specialized response . • Provincial government is unable to deliver their core functions; inability to govern. • Violation of international and national treaties or agreements • Sustain, permanent loss of stakeholder and public trust in the provincial government	• Failure of a significant industry or sector in the jurisdiction as a direct result of the natural hazard event . • Economic decline and / or loss of asset value greater than 5% of the provincial GDP (~$4B) • Closure of an entire resource sector. • Permanent loss of investment in the province. • Existing markets for Saskatchewan's natural resources is closed. • Inability for efficient and leading companies to break-even. • Destruction of both critical infrastructure and high value property	• Significant regional or watershed damage incapable of remediation • Ecosystem function permanently disrupted or species extirpation	Catastrophic	Moderate Risk	High Risk	Extreme Risk	Extreme Risk	Extreme Risk
• Multiple public fatalities (>5) and / or critical injuries with long-term or permananent incapacitiation (>5) and / or serious injures (>50) • Ongoing exceedance of recognized health-related standards (e.g., CCME Selenium Guidelines or Canadian Ambient Air Quality Standards) • Community evacuations of >5000 people	• Quality of life for communities and surrounding area impacted for more than 10 years – major community social problems • Values are degraded but partially recoverable over the long-term • Extended evacuation of communities • Irreparable damage to high value structures or items of cultural and historical significance • Disputes related to development or decisions result in blockades and campaigns of civil disobedience and are extremely disruptive to the general public ; Significant regionally widespread psychosocial impacts	• Provincial Governing bodies encounter severe reduction in the delivery of core functions . • Multi-municipal, provincial and national specialized response . • Achievement of key provincial government objectives is threatened and some not met. • Major loss of stakeholder and public trust over years, although recoverable with time. • Municipal governments unable to deliver core services	• Significant structural adjustment required by identified industry or business to respond to and recover from the natural hazard event . • Major damage and impact on critical infrastructure • Economic decline and / or loss of asset value greater than 0.5% of the provincial GDP (~$400M) • Major portions of a resource sector impacted or suffer serious decline. • Substantial loss of investment in the province, reversible over time. • Existing market access for Saskatchewan natural resources is threatened / new market access not achieved. • Inability for various business sectors to break-even.	• Significant regional damage not entirely capable of remediation • Ecosystem disruption or reduced species abundance • Severe effects on environmental values	Major	Moderate Risk	High Risk	High Risk	High Risk	Extreme Risk
• Single fatality and / or critical injuries with long-term or permananent incapacitiation (>1) and / or serious injures (>5) • Infrequent, periodic exceedances of recognized health-related standards (e.g., CCME Selenium Guidelines or Canadian Ambient Air Quality Standards) • Community evacuations of 500 people	• Quality of life of affected region and surrounding area moderately impacted for up to 10 years • Short-term evacuation of community • Values are degraded but fully recoverable within 10 years • Disputes related to development or decisions result in isolated blockades or other acts of civil disobedience ; Significant localized psychosocial impacts including panic, self-evacuation, hoarding • Some damage or localized widespread damage of culturally significant objects	• Provincial Governing bodies encounter significant reduction in the delivery of core functions . • Achievement of key government objectives impacted (significant time delay or cost increase) • Moderate loss of stakeholder or public trust, short-term duration (less than 6 months) • Municipal governing bodies encounter severe reduction in the delivery of core functions . • Multi-municipal and provincial specialized response .	• Key industry or business sector is significantly impacted by the natural hazard, resulting in medium term (i.e., more than one year) profit reductions directly attributable to the event . • Noticeable drop of investment levels in the province. • Economic decline and / or loss of asset value greater than 0.05% of the provincial GDP (~$40M) • Disruption of 2-3 critical community infrastructure services	• Regional damage capable of remediation over time • Damages last >two years • Values affected tend to be moderate	Moderate	Moderate Risk	Moderate Risk	Moderate Risk	High Risk	High Risk
• One serious injury requiring medical care and medical technology • Approaching limits of recognized health-related standards (e.g., CCME Selenium Guidelines or Canadian Ambient Air Quality Standards)	• Minor effects on quality of life • Short term adverse impacts on values of the affected region lasting less than 5 years; recoverable with minor effort • Disputes related to development or decisions result in isolated acts of civil disobedience with minor disruptions to the public ; Some localized psychosocial impacts including disruption to routine and some anxiety • Some damage to localized culturally significant objects	• Provincial government encounters limited reduction in delivery of core functions . • Achievement of key government objective may be impacted . • Multi-municipal specialized response . • Municipal government encounter a reduction in the delivery of core functions .	• Significant impact on localized industry or business sector resulting in short-term (i.e., less than one year) profit reduction directly attributable to the event • Economic decline and / or loss of asset value greater than 0.005% of the provincial GDP (~$4M) • Disrupt 1 critical infrastructure service for short time	• Localized damage capable of remediation • Damages are short term <one year • Values affected tend to be minor	Minor	Low Risk	Low Risk	Moderate Risk	Moderate Risk	Moderate Risk
• First aid injury with no professional care required (MofE, MofGR) • No impact on public health and safety	• No obvious impact on quality of life • Minor delay in major cultural event	• Provincial government's delivery of core functions is unaffected and normal • Municipal or multi-municipal general response (mutual aid agreements) • Municipal government encounters limited reduction in delivery of core functions .	• Insignificant economic impact • Economic decline and / or loss of asset value greater than 0.0005% of the provincial GDP (~$400,000)	• Localized, reversible and temporary damage • Minor impact on local environmental values	Insignificant	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk

Appendix Chapter 9.1 Tornado wind damage scale

Comparison of F and EF wind damage ratings (Environment and Climate Change Canada 2013)

F (Fujita) / EF (Enhanced Fujita) Rating	F (Fujita) – Scale Wind Speed Rounded to 10 km/h	EF (Enhanced Fujita) Scale Wind Speed Rounded to 5 km/h	Typical Damage (modified from Wheaton 1998 and Environment Canada 2006)
0	60-110	90-130	Light damage, tree branches broken, siding removed
1	120-170	135-175	Roof surface damaged, windows blown out, small buildings destroyed, moving cares pushed off road
2	180-240	180-220	Roofs removed from homes, mobile homes destroyed, large treed uprooted
3	250-320	225-265	Upper stories of brick houses destroyed, outer walls of most homes removed
4	330-410	270-310	Two storey brick houses destroyed, cars and vans carried long distances
5	420-510	315 or more	Virtually everything destroyed.

Appendix Chapter 9.2 Five Saskatchewan severe thunderstorms in the 1990s (McInnis 2001)

	Storms					
Storm Information		Regina Storm, 08 August 1979	Oxbow Storm, 29 July 1995	Pilot Butte Storm, 26 August 1995	Spring Valley Storm, 29 August 1995	Osler Storm, 04, July 1996
	Hail swath ➢ Length (L) ➢ Width (W) ➢ Direction (D) ➢ Hail stone size (HS)	L: 347 km W: mostly 25 km D: NW (300°)	L: 137km W: 10-16 km D: W (250°); more likely SW Small hail at Oxbow	L: 508 km W: 16-32 km D: W (270°) Golfball and larger, drifts 50 cm deep in Pilot Butte	L: 370 km W: 16-19 km D: W (280°) Pea to golfball >golfball at Coderre	L: 295 km W: 10-25 km D: W (280°) Loonie size in places Golfball at N. Battleford Softball size at Osler
	Wind events: Tornadoes: ➢ F-Scale ➢ Direction ➢ Dimensions Other Wind ➢ Microburst or Plough winds	Tornadoes: Fl Regina (18:00) F2 Regina (18:00) D: 280° L: 15 km Wind gusts: up to 120 km/h	'Plough winds': 100-150 km/h microburst hits Oxbow Another storm hits Northgate with a 'plough wind'	Tornado: F0 N side of Regina? 'Plough wind': > 120 km/h at Pilot Butte Wind gusts: 80-100 km/h in Regina ~100 km/h at Gull Lake	Tornadoes: F1 Courval/Coderre area (17:20) Fl-F2 30 km S of Moose Jaw (18:10) F2-F3 Spring Valley (18:40) Winds gusts: >100 km/h	2 tornadoes: Funnel clouds sighted at Ruddell (17:00); Maymont (18:00) F2-F3 tornadoes (250-330 km/h) Wind gusts /microburst: 120-150 km/h touchdown E of Saskatoon
	Rainfall intensity: ➢ Light ➢ Moderate ➢ Heavy	Moderate to heavy	Heavy rainfall at Oxbow	Flooding: N side of Regina Bible College at Caronport flooded with 20-25 cm rain in 1 hr	Heavy	43mm in Saskatoon 76mm north of Saskatoon North Battleford flooded
	Damages: ➢ Events ➢ Monetary Losses	Regina two areas hit hard: Normanview (NW) & Glencaim (E); roof torn of	SOE. aid from PDAP; MDS Oxbow water supply tower left leaning	Pilot Butte: SOE declared within l hr of event. All trees & buildings	Courval 7 grains bins destroyed 3-500 gal. fuel tanks moved	SOE; MDS; PDAP standby only Wind damages

		Exhibition Park Building Minor injuries 5900 claims for about $4 million (1979) $10 million (total) aprox. $24 million (2000)	Local Inn lost roof Transformer moved 3 minor injuries $5-10 million	suffered damages 9 injuries PDAP for assistance $16-30 million	S of Moose Jaw 1 farm destroyed Spring Valley 4 farms demolished No injuries $11-12 million	through Maymont, Saskatoon and Osler Widespread power outage (12 towers costing $1 million) No injuries Saskatoon hit slightly Drive Inn demolished Initial est. > $8 million

Appendix Chapter 9.3 Threshold criteria for public weather alerts

Threshold criteria for selected public weather alerts in Saskatchewan (Environment and Climate Change Canada 2017)

Threshold criteria is a set of defined weather or environmental parameter, and their associated values related to a known weather hazard that are used as a level marker for determining the beginning of and ending of a severe weather event (ECCC 2017).

Frost

Alert type	Location	Threshold criteria
Advisory	Agricultural zone of Saskatchewan	Issued during the growing season when widespread frost formation is expected over and extensive area. Surface temperatures are expected to fall near freezing in the overnight period.

Heat

Alert type	Location	Threshold criteria
Warning	Saskatchewan - south (excluding Meadow Lake, The Battleford, Prince Albert and Hudson Bay)	Issued when two or more consecutive days of daytime maximum temperatures are expected to reach 32C or warmer and nighttime minimum temperatures are expected to fall to 16C or warmer Or Issued when two or more consecutive days of humidex values are expected to reach 38 or higher
Warning	Saskatchewan – north and central (including Meadow Lake, The Battlefords, Prince Albert and Hudson Bay)	Issued when two or more consecutive days of daytime maximum temperatures are expected to reach 29C or warmer and nighttime minimum temperatures are expected to fall to 14C or warmer Or Issued when two or more consecutive days of humidex values are expected to reach 34 or higher

Short Duration Rainfall (Heavy Downpour)

Alert type	Location	Threshold criteria
Warning	Saskatchewan	When 50 mm or more of rain is expected within one hour

Long Duration Rainfall

Alert type	Location	Threshold criteria
Warning	Saskatchewan	When 50 mm or more of rain is expected with 24 hours Or When 75 mm or more of rain is expected within 48 hours

Severe Thunderstorm

Alert type	Location	Threshold criteria
Watch	Saskatchewan	When conditions are favourable for the development of severe thunderstorms with one or more of the following conditions: • Wind gusts of 90 km/hr or greater • Hail of two centimeters or larger in diameter; or • Heavy rainfall, as per rainfall criteria
Warning	Saskatchewan	When there is evidence based on radar, satellite picture or from a reliable spotter that any one or more of the following three weather conditions is imminent or occurring: • Wind gusts of 90 km/hr or greater • Hail of two centimeters or larger in diameter; or • Heavy rainfall, as per rainfall criteria

Tornado

Alert type	Location	Threshold criteria
Watch	Saskatchewan	When conditions are favourable for the development of severe thunderstorms with one or more tornadoes
Warning	Saskatchewan	When a tornado has been reported or when there is evidence based on radar or from a reliable spotter that a tornado is imminent

Wind

Alert type	Location	Threshold criteria
Warning	Saskatchewan	70 km/hr or more sustained wind and/or gusts to 90 km/hr or more

Appendix Chapter 10.1 Threshold criteria for severe winter weather public alerts

Threshold criteria is a set of defined weather or environmental parameter, and their associated values related to a known weather hazard that are used as a level marker for determining the beginning of and ending of a severe weather event (ECCC 2017).

Blizzard

Alert type	Location	Threshold criteria
Warning	Saskatchewan	When winds of 40 km/hr or greater are expected to cause widespread reductions in visibility to 400 metres or less, due to blowing snow or blowing snow in combination with falling snow, for at least four hours

Blowing Snow

Alert type	Location	Threshold criteria
Advisory	Saskatchewan	When blowing snows, caused by winds of at least 30 km/hr, is expected to reduce visibility to 800 metres or less for at least three hours

Extreme cold

Alert type	Location	Threshold criteria
Warning	Southern Saskatchewan	Issued when the temperature or wind chill is expected to reach minus 40C for at least two hours
Warning	Northern Saskatchewan	Issued when the temperature or wind chill is expected to reach minus 45C for at least two hours

Fog

Alert type	Location	Threshold criteria
Advisory	Saskatchewan	When low visibility in fog are expected for at least six hours

Freezing Drizzle

Alert type	Location	Threshold criteria
advisory	Saskatchewan	When a period of freezing drizzle is expected for at least eight hours

Freezing Rain

Alert type	Location	Threshold criteria
Warning	Saskatchewan	When freezing rain is expected to pose a hazard to transportation or property OR when freezing rain is expected to last at least two hours

Frost

Alert type	Location	Threshold criteria
Advisory	Agricultural zone of Saskatchewan	Issued during the growing season when widespread frost formation is expected over and extensive area. Surface temperatures are expected to fall near freezing in the overnight period.

Snowfall

Alert type	Location	Threshold criteria
Warning	Saskatchewan	When 10 cm or more of snow falls within 12 hours or less

Wind

Alert type	Location	Threshold criteria
Warning	Saskatchewan	70 km/hr or more sustained wind and/or gusts to 90 km/hr or more

Winter Storm (these warning may occur in autumn and spring)

Alert type	Location	Threshold criteria
Watch	Saskatchewan	When conditions are favourable for the development of severe and potentially dangers winter weather including: • A blizzard • A major snowfall (25 cm or more within a 24-hour period) and • A significant snowfall (snowfall warning criteria amounts) combined with other winter weather hazard types such as freezing rain, strong winds, blowing snow and/or extreme wind chill
Warning	Saskatchewan	When severe and potentially dangerous winter weather conditions are expected, including: • A major snowfall (25 cm or more within a 24-hour period) and • A significant snowfall (snowfall warning criteria amounts) combined with other cold weather conditions such as freezing rain, strong winds, blowing snow, extreme cold and/or extreme wind chill Blizzard conditions may be part of an intense winter storm in which case a blizzard warning is issued instead of a winter storm warning

Appendix Chapter 10.2 Blizzard extremes for selected locations in Saskatchewan (EC 2012).

Location	Extreme Duration Date	Extreme Duration (hrs.)	Extreme Temp Date	Extreme Min. Temp. (C)	Extreme Windchill Date	Extreme Windchill (W/m2)	Extreme Wind Speed Date	Extreme Wind Speed (km/h)	Extreme Event Precipitation Date	Extreme Event Precipitation (mm)	Extreme Windchill Equivalent Temperature Date	Extreme Windchill Equivalent Temperature
Broadview	1/11/1975	19	1/11/1975	-32.7	2/5/1988	2631	12/24/1992	74	12/8/1973	6.6	1/11/1975	-54.181
Estevan	2/6/1978	40	1/29/1985	-33	1/10/1975	2594	12/8/1973	87	2/23/1994	19	1/29/1985	-53.1187
Kindersley	12/27/1990	28	12/27/1990	-30.8	12/27/1990	2525	12/24/1992	93	12/27/1990	12.8	12/27/1990	-52.0108
Moose Jaw	2/6/1978	63	1/11/1975	-31.7	1/11/1975	2597	1/19/1963	100	3/30/1967	20	1/11/1975	-53.9303
North Battleford	12/12/1955	36	1/29/1966	-31.1	1/29/1966	2457	2/21/1956	87	12/12/1955	24.4	1/29/1966	-50.6698
Prince Albert	3/3/1956	16	1/2/1959	-29.3	1/2/1959	2414	3/13/1955	71	2/27/1965	17.7	1/2/1959	-48.2123
Regina	2/5/1978	72	1/29/1985	-33.5	1/11/1975	2555.056	1/9/1966	97	2/8/1985	12.8	1/11/1975	-54.1005
Saskatoon	12/12/1955	26	1/29/1990	-24.5	1/29/1990	2229	12/12/1955	89	2/3/1962	32.5	1/29/1990	-41.3115
Swift Current	2/6/1978	69	1/22/1963	-37.2	1/22/1963	2826.719	12/11/1963	99.6324	3/17/1967	31.3	1/22/1963	-60.3861
Yorkton	11/26/1955	25	1/11/1975	-32.2	1/11/1975	2596	2/20/1965	80	2/3/1962	21.6	1/11/1975	-53.8468

APPENDIX A STAKEHOLDER INSIGHTS

D.R. Corkal

Executive Summary

"The people of this province have the right attitude and demeanor to endure these hardships [natural hazards in Saskatchewan] and improve upon them. They need good vision and science to help them make the best decisions"

"Climate change…will change the playing field for all of these natural hazards"

"During a natural disaster communication is probably the most challenging part"

"this study is on the right track, getting the people's view"

"[I] would like to see results incorporated into long-term government planning."

(Anonymous Stakeholders)

Six workshops were held across Saskatchewan, with around 200 invited stakeholders representing diverse interests, institutions and agencies (local, provincial, federal), including:

- Communities and Rural Municipalities, including their associations (Saskatchewan Urban Municipalities Association, Saskatchewan Association of Rural Municipalities)
- First Nations communities, and respective associations (e.g. Tribal Councils)
- Government agencies (local, provincial, federal)
- Academia, Subject Matter Experts and Specialists (in disaster risk reduction; emergency management professionals - preparedness planners and responders; mitigation and climate change adaptation professionals, etc.)
- Industry (forestry, mining, agriculture, energy, road and rail transportation, etc.)
- Non-government organizations (e.g. emergency management organizations, insurance providers, watershed groups, environmental groups, agriculture and engineering associations, industry groups such as irrigation associations, etc.)

The stakeholders identified unique impacts, mitigations and priorities for each regional area, and identified many points common to all regions. The stakeholders identified:

- natural hazard risks and local/regional vulnerabilities
- current mitigations practiced, and
- their considerations of the implications of future natural hazard risks and mitigations under a climate change scenario

The stakeholders appreciated the workshops and information sharing. They indicated a desire to keep the following types of activities on-going:

- share information, current science and knowledge
- improve natural disaster preparedness planning and response plans
- continue to engage local stakeholder discussions with future planning and actions

The following sections provide a high-level overview of the major natural hazard impacts and mitigation priorities, as identified by the stakeholders. Detailed lists of the natural hazards were identified at each regional workshop and are compiled in the body of the main report entitled "Saskatchewan Flood and Natural Hazard Risk Assessment Stakeholder Insights Report" (Corkal, 2018). Subsequently, the stakeholders evaluated the detailed lists by voting on those they recognized as being the most critical. The stakeholder-priorized impacts and mitigations were then grouped and organized around common themes, as listed below in Tables 1 to 3.

Droughts and Water Scarcity

Stakeholders recognise droughts and water scarcity are common natural hazard risks in Saskatchewan, and are essentially part of Saskatchewan's natural climate variability. People recognize that the recent period (2010-2016) has been extremely wet across much of Saskatchewan. [The year 2015 did experience agricultural drought in select geographic areas, but generally speaking, sloughs and groundwater supplies remained well above average.] Even with such exposure to extremely wet conditions over a six-year period, all stakeholders understand drought is a natural characteristic of the prairies and expect that future droughts will recur. Prolonged droughts have serious impacts to agriculture, communities and many sectors. Rural communities are particularly hard hit due to their strong reliance on agriculture and related sectors. Severe droughts affect both provincial and federal economic activities. Stakeholders desire to be "better prepared" for drought and realize that strengthening local resilience is possible. Saskatchewan requires a comprehensive multi-sector drought contingency plan to address water scarcity, and risks from medium- to long-term drought exposure (e.g. multi-year droughts, increasing water scarcity and water supply shortages). The concept that climate change may exacerbate future drought risk is also recognized by stakeholders as an important factor in preparedness planning for drought and water scarcity.

All stated that more severe water scarcity or prolonged multi-year drought, requires a much more co-ordinated institutional response from provincial and federal governments to address severe economic, social and environmental impacts (e.g. loss of soil organic matter, negative ecosystem impacts, etc.). The key feature for drought or severe water scarcity as a natural hazard, relates to its slow on-set. Drought impacts may intensify over time and generally have wider-spread geographic exposure than natural disasters such as flooding, which tends to be more localized. Much can be learned from past droughts, yet people acknowledge that droughts tend to be forgotten when times are better. People relate to, and are concerned about, the potential for future droughts similar to those in the past (e.g. 2001-02, 1930s). A "DroughtSmart" program would be beneficial, along with long-term planning. Drought and water scarcity preparedness planning needs to be continually improved and at-the-ready, even during non-drought years. While not often seen as an "emergency" due to its slow onset, drought preparedness planning can adopt many if not all of the emergency preparedness planning concepts recognized to be standard operating procedures for flood risk and/or fire risk natural hazard reductions. Planning for drought needs to be a regular (annual) occurrence, even during wet periods or non-water scarce periods. As with FireSmart planning, drought preparedness planning continually needs to be updated, with stakeholders and institutions to be "at the ready" to implement actions that address water scarcity risks as they may occur.

Table 1: Drought Impacts and Mitigations (priorized by stakeholders)

Drought Impacts	Drought Mitigations
i. Community and Municipal Water Impacts o Potable water availability and quality o Alternate water supplies o Community evacuation **ii. Social and Institutional Impacts** o Inter-jurisdictional challenges o Priority of water use (hierarchy of needs – who gets water during water shortages?) o Lack of public acceptance of impacts o Lack of local awareness or watershed groups o Increased water use/competition between people, industries, agriculture during rationing periods o Social impacts on people, impaired coping o Unequal coping capacity in different areas **iii. Ecosystem and Resource Impacts** o Water supply shortages o Water competition (local needs, communities, agricultural sector especially with irrigation, mining sector, energy sector, recreation/tourism impacts, etc.) o Increased wildfire risk (grasslands and forests, especially before spring "green-up" and in fall); less water available for fire suppression o Agricultural sector (farmland) is the most severely affected sector (crop failures, livestock affected, direct on farm impacts to production; spin-off rural community impacts, potential rural / provincial economic downturn) o Energy sector impacted (hydro, energy consumption) o Ecological impacts (poor water quality, plant and animal disease, increased algae, impaired grasslands, wetlands and ecosystems, including wildlife health) **iv. Infrastructure and Information** o Water resource data and information flow [to share data with various stakeholders, institutions and agencies] o Illegal drainage problems o Road maintenance is easier to complete during drought periods	**i. Water Management** o Water storage, reservoirs, stockpiling o Allocations; Rationing; Water Pricing o Watershed assessments o Effective drainage; correct drainage issues o Sharing of equipment / pumps, pipelines o Alternate water supplies o Resilient water infrastructure o Co-ordinated institutional plans (local, provincial, federal) o Strengthened engagement of stakeholders and watershed groups o Improved local, sector water management strategies (conservation, protection) **ii. Long-term planning** o Incorporate drought risk in long-term plans; scenario planning o Emergency preparedness plans in place and understood o Learn from past experiences (since settlement) o Use lessons from past to guide preparedness plans Plan for a "non-rainy" day o Incorporate preparedness planning ("WaterSmart" programs with "FireSmart programs") o Incorporate climate change into natural hazard risk assessment and preparedness **iii. Resource Protection and Conservation** o Improved water resource planning o Source water protection o Knowledge of water resources for drought mitigation and fire suppression o Open fire restrictions (drought and fire correlate) o Preservation of wetlands and ecosystems **iv. Knowledge, Public Education, Communications** o Education and awareness o Value of water conservation and restrictions stakeholder knowledge and understanding, including knowledge of past lessons

	o Communications plans on water management (esp. during water scarcity and drought) o Improved water knowledge base (shared between experts and the public)

Floods and Excessive Water

Most stakeholders have had some experience with floods or excessive moisture. Much of Saskatchewan has experienced extremely wet conditions during the period from 2010 to 2016. Stakeholders believe that floods and their variability have intensified in recent times. They recognize that floods affect all types of infrastructure, communities, and economic activities. And they recognize other effects on "soft infrastructure" (e.g. loss data, administrative and financial records, etc.). Mitigations generally involve water management, flood protection, safeguarding of infrastructure, back-up systems, and effective zoning, planning and development (to remove activities and infrastructure in flood-prone areas, and prevent building or commercial developments in high-risk flood-prone locations). A "**WaterSmart**" program would be beneficial. Flooding and excess water emergency preparedness planning must be adopted at a local scale, with consideration for regional implications (e.g. water management and runoff implications). Integrated agency responses are essential. There is a concern that flood intensities are changing over time (i.e. becoming more severe). Some of the drivers for flood protection will be administrative and regulatory, and will also include engineering design and insurance considerations. In Saskatchewan, most flood risk maps for urban areas date to the 1980s. Residual risk of flooding can be decreased considerably by zoning urban and rural areas with updated flood risk assessments to restrict development in flood plains.

Table 2: Flood Impacts and Mitigations (priorized by stakeholders)

Flood Impacts	Flood Mitigations
i. Infrastructure Impacts o Railways, Highways, Rural roads o Access to communities and critical infrastructure is cut-off or impaired o Urban storm water drainage o Utilities (Sask Power, energy outages and infrastructure access limitations) o Dams, incl. dam safety o Landfills, waste sites o Loss of water and wastewater facilities o Buildings, structures, property, agricultural land (commercial, private and recreational property damages) **ii. Human and Economic Impacts** o Not a full understanding of risk o Social impacts, individuals, communities o Stress and anxiety to affected citizens, people, emergency responders, institutions o Displacement of people, industry, and community impacts	**i. Planning and Monitoring** o Hydrology, forecasting, emergency planning, flood water control, flow and conveyance management (infrastructure) o Improved hydrology, understood at a local level o Improved topography (e.g. LiDAR surveys) o Property buy-out to remove development that exists in flood-prone locations o Flood-risk mapping - for urban and rural areas (most existing urban flood risk maps in Saskatchewan date back to the 1980s) o Water quality protection plans **ii. Infrastructure Design** o Water control, flow and management (infrastructure and ecosystems inc. wetlands) o Infrastructure planning, reduced urban runoff, managed runoff with existing sub-

o Displacement of First Nations communities, rural remote communities, people in critical facilities such as hospitals, care homes, seniors' residences, etc. o Livestock and agricultural land impacts may be unique o Access in/out of flooded areas cut-off o Economic activities stopped or reduced, tourism and production impaired o Human toll and stress (from impaired property, economic stress and loss during flood and post-recovery, which can be a prolonged period) **iii. Environmental Impacts** o Contaminated water risking water safety; increased salinity; degradation of surface water supplies, and contaminated ground water supplies; impairment of lakes, rivers and recreational water sources (e.g. nutrients, other runoff contaminants) o Erosion, slumping, infiltration o Shoreline alteration o River or stream changes o Animal carcass disposal o Runoff of animal and human waste (e.g. dispersion of flooded lagoons) **iv. Institutional Impacts** o Emergency Planning o Hydrology (knowledge) o Institutional responses o Need for coordination of institutions **v. Policy Impacts** o Non-compliance of by-laws, zoning o Non-enforcement by insurance agencies o Agricultural drainage issues	divisions, and new residential and commercial development, etc.) o More, better engineering to protect from flood risk o Consider water storage with drainage design (i.e. design for excess water and for water scarcity) o Identify critical infrastructure o Improve infrastructure where beneficial (road grades and access road, flood protection, drainage, soil erosion protection **iii. Zoning, Policy, Infrastructure** o Zoning improvement; enforcement of legislation; by-laws and building codes, land use plans, community development and sub-divisions, private and commercial development, source water protection plans (the Saskatchewan regulatory flood is the 1:500 year event) o Flood risk management: plan wisely, do not construct on flood-prone locations o Develop/incorporate new standards (e.g. flood frequency returns) **iv. Proactive Planning and Preparedness** o Regional and local planning; partnership planning, agency integration, effective leadership, for communities, parks, etc. (strengthened and more coordinated institutional responses)

	- Local, provincial, federal mitigation planning - Emergency preparedness plans in place and understood - Proactive measures, financial incentive for flood protection and awareness - Incorporate climate change into natural hazard risk assessment and preparedness planning - Flood hazard response planning and communications; emergency preparedness planning and implementation /public education - Effective communications (emergency preparedness and response) - Emergency power, alternate water supplies - Evacuation planning, local input - Incorporate climate change into natural hazard risk assessment and preparedness planning **v. Knowledge and local capacity** - Hydrology and knowledge (inc. local) of water flow on land systems, ecosystems, collect better water data - Downstream impacts and effects knowledge (inc. local) - Develop a common understanding of risk - Learning from impacts and experiences - Educate local leaders, councils, and public - Support and train local groups and volunteer responders; incorporate local knowledge and strengthen local flood response capacity to respond to floods; cross-training with disaster response - Watershed education **vi. Ecosystem Benefits** - Wetland preservation to improve water management, buffer extreme wet conditions - Green infrastructure to assist with water management and runoff protection

Wildfires – Forest Fires and Grassland Fires

Stakeholders identified both forest wildfires and grassland wildfires as natural hazard risks in Saskatchewan. Wildfires impact people, communities, economic activities, and all types of infrastructure. The rapid growth of a large fire requires astute emergency management responses to protect human life. Evacuations may be required. The impacts of wildfires are more pronounced with dry or drought conditions. Mitigations require effective emergency response preparedness planning and incident response at a local and regional scale. Road, rail, air access is critical, as fires often affect remote or rural areas. Communications and local response actions are also critical. Saskatchewan's **FireSmart** programming is recognized as a very effective preparedness planning measure, and emergency management approach. Access to water for fire suppression, back-up energy supplies, backup communications systems, zoning, development, and integrated agency responses are all critical features in mitigating impacts from wildfires. Stakeholders and residents in remote communities desire firefighting training so they could participate in protecting their communities and be early responders so as not to be in a position of inactivity while waiting for emergency responders (e.g. EMS) to address fire risks.

Table 3: Wildfire Impacts and Mitigations (priorized by stakeholders)

Wildfire Impacts	Wildfire Mitigations
i. Social Impacts o Law and order, looting, crime, security o Isolation of rural people, or those in remote locations (e.g. the north) o Employment loss, employee care o Critical of decision-makers o Taxed government resources, emergency responders o Evacuations o Health impairment (smoke inhalation) – this can occur hundreds of kilometers or more away from fire source o Lack of experience of responders affect human risk o Coordination response problems - poor interagency communication o People are challenged to deal with the aftermath **ii. Industry and Economic Impacts** o Individual, industry economic impact o Mines, forestry, other business activities shut down, lost income for industry and employees (for event and post-recover) o Impairment of water system, utilities o Agricultural and livestock losses o Cascading infrastructure losses o Loss of communications towers **iii. Infrastructure and Resource Impacts** o Power supplies o Water and wastewater supplies o Homes, buildings, industry, commercial infrastructure, roads o Human resources reach limited capacity as focus on firefighting leads to less capacity to address other issues	**i. FireSmart, Knowledge and Communications** o Strengthened FireSmart programming, especially additional funding o Risk assessment o Education and Awareness (local and public); communications pre-event, during-hazard and post-hazard to keep all informed o Critical infrastructure identified o Partner with industry and local responders; training of responders o Maintain access, egress o Plan for water supplies, pumps, pipelines o Municipal fire bans, fire permits o Public education on fire risk, and emergency plans, including economics o Better exchange of information, with local input and decision-making contributions o Clearer leadership and communications during hazards o Strengthen local resilience, stand-by fire crews, succession-planning for responders **ii. Proactive Planning and Partnerships** o Emergency preparedness plans in place and understood, emergency planners, local responders working with provincial/federal responders o Evacuation plans in place and understood o Air purification systems o Create incentive for risk reduction o Establish the ability to make and implement difficult or tough decisions o Mobilization of neighboring fire departments and responders

o Water resource impacts as there is less water available to fight fires (water shortages or limited supplies) o Challenges to evacuate parks and recreational communities	o Incorporate climate change into natural hazard risk assessment and preparedness planning **iii. Coordination of institutions and emergency responders** o Critical Incident Command/Response o Communications between Incident Command and Emergency Social Services o Data-sharing between agencies o Mutual aid agreements in place o Coordination with provincial institutions o Cross-training, inter-disciplinary response **iv. Management, Policy, Infrastructure** o Landscape-scale forest management o Firebreaks in southern lands/agricultural lands to reduce grass fire risk o Industry fire breaks o Emergency management plans in place and enforcement (implementation) o Zoning, Development, Regulatory tools, e.g. property, industry set-backs o Control burns, policy incentives, insurance incentives **v. Identify water supplies for fire suppression** o Groundwater protection o Access to surface water/groundwater o Readily-accessible water maps identifying water sources for fire suppression (in all areas: e.g. fires during droughts may make it difficult to access water sources).

The stakeholders also identified Other Natural Hazards (i.e. beyond droughts, floods, wildfires). They believe the Province of Saskatchewan is susceptible to risks from other natural hazards identified in Table 4 as follows.

Table 4: Other Natural Hazards as identified in all six workshops

OTHER NATURAL HAZARDS (all workshops; grouped under thematic titles)
SEVERE WEATHER AND STORMS **Heat and Convective Summer Storms** - excessive heat (intensity and duration) with extreme temperatures over prolonged periods of time (affecting people, plants, animals, energy consumption, etc.) - rapid changes in weather with wind, rain, hail (greater storm intensity) - extreme summer storms with intense rain and wind and hail - excessive moisture causing land slumping - plough winds (affecting infrastructure, forests, etc.) - tornados - lightning storms (affecting power distribution, communication systems, causing fires)

- hail (intensity and frequency)
- severe weather, severe summer storms

Winter Storms, Blizzards, Snow and Ice

- snow storms (intensity and frequency)
- severe snow storms (which may cause casualties, particularly with transportation)
- heavy wet snow
- winter ice storms (affecting people, infrastructure, power, transportation, etc.)
- ice storms combined with wind
- blizzards with greater frequency and intensity
- severe weather, severe winter storms

ENVIRONMENTAL CHANGES, including ECOSYSTEMS and DISEASE VECTORS

- changing ecosystems (biology, insects, plants, trees, animals) i.e. microbiology, flora and fauna
- beavers, rodents, other ecosystem biota changes
- pest infestations, ecosystem shifts
- landscape changes (e.g. caused by changes to ecosystems, forest health, etc.)
- invasive species changing natural ecosystems and affecting aquatic life, water quality, plants, animals and human health
- exotic plants, insects, animals, invasive species (not common to the local region)
- aquatic invasive species; invasive plant species (i.e. including microbial species, viruses, parasites, bacteria)
- quagga mussels, zebra mussels
- Mountain Pine Beetle
- Diseases (human, crop, livestock, wildlife, plants, forests)
- Livestock diseases such as foot and mouth disease, BSE /Mad Cow disease [BSE is Bovine Spongiform Encephalopathy, a variant of Creutzfeld-Jakob disease] and associated risks to human health
- unique specialized diseases
- West Nile virus
- Lyme disease
- Insects
- Plant and tree diseases (affecting natural ecosystems, plants, trees, forest health)
- New vector-borne diseases [. e.g. health of humans, crops, livestock, wildlife, plants may be affected by new microbiological and biological disease vectors]
- Deteriorating water quality (in the natural environment)
- Excessive moisture causing slumping or swelling of land (e.g. at slopes, shorelines, etc.) and causing damage to infrastructure such as buildings, roads, rail lines, etc.
- Cascading effects of environmental changes; natural hazard “shocks”
    - e.g. rapid changes from drought to flood, as experienced in the 2009-10 summer to winter drought with extremely dry soils, followed by rapid changes with excessive moisture and flooding causing severe shifting and heaving soil, impacting infrastructure such as homes, natural gas lines, dams, culverts, bridges, etc.

- e.g. floods and flood runoff causing contaminant runoff from human wastewater, livestock runoff effluent, industrial pollution, and other contaminants

OTHER NATURAL HAZARD RISKS

- Land slumping and swelling (e.g. from excessive wet conditions)
- Earthquakes
- Volcanic eruptions (in other regions) and ash migration
- Solar flare (affecting communications systems)
- Atmospheric winds (transporting global contaminants from other regions in the world)
- Drought and dry conditions in northern regions impairing forest health, changing northern ecosystems and landscapes, and increasing forest fire risks
- Excessive, prolonged multi-year drought

Policy Implications:

The workshops identified strong stakeholder awareness of the diverse types of natural hazard risks, current mitigations, and potential for strengthening resilience. Stakeholders have implicit and vested interests in better understanding local and regional risk. Knowledge exchange and stakeholder participation is desired, along with longer-term planning, emergency preparedness and emergency response. Stakeholders identify an interest in improved knowledge and communications, natural disaster risk awareness, emergency response planning, better inter-agency collaboration with local input, longer-term planning, and integration of the science of climate change as some of the key factors in natural disaster preparedness, emergency response and strengthening capacity and resilience. There was strong support for enhanced inter-agency communication and coordination, including clear and strong engagement with local stakeholders.

Introduction

The Saskatchewan Flood and Natural Hazard Risk Assessment is assessing Saskatchewan's resiliency and vulnerabilities to natural disasters. Stakeholder knowledge is crucial in identifying current natural hazard risks and mitigation. Stakeholder knowledge is also critical in establishing priority risk reduction strategies and hazard mitigation measures for current and anticipated future risks. This chapter summarizes key findings from diverse stakeholder groups in six regional workshops held across Saskatchewan in May-June 2017. For more details, please see the separate Saskatchewan Flood and Natural Hazard Risk Assessment Stakeholder Insights Report (Corkal, 2018).

Natural disasters have affected human populations in the Canadian prairies for millennia. First Nations populations were particularly affected by water scarcity and drought, and their responses were driven by their critical needs for food and water. They adapted their hunting activities and nomadic social communities to live sustainably within the prairie landscape and its ever-changing climate and water supply (Daschuk, 2009; Toth et al. 2009).

Today, natural disasters affect Saskatchewan's people, industry and economic activities, territorial security, wildlife, and the ecosystems that support life in this province. The most common natural disasters in Saskatchewan are *water scarcity and drought*, *excessive wet conditions and floods*, and *wildfires in forested lands and grasslands*. However, there are other significant natural disasters that also cause serious impacts, including storms, hail, wind, tornados, and pest infestations.

Globally, natural disasters are increasingly affecting people, communities and economic activities. Public Safety Canada states that "natural disasters are increasing globally in number, frequency and intensity" and that Canada is no exception to this trend (Public Safety Canada, 2017). Disaster recovery responses may cause serious social and economic hardships, and require significant investments. This trend towards greater economic impacts from natural disasters is due in part to global growth, but there is also increasing evidence that climate change is affecting the intensity and frequency of extreme weather events (Insurance Bureau of Canada, 2014; Swiss Re, 2013).

Historically, populations have typically responded and reacted to natural disasters after the event occurs. Modern approaches are shifting away from only considering response, relief and recovery activities. Societies around the world are now being encouraged to proactively undertake "cost effective, evidence-based disaster mitigation" activities to mitigate risks in advance of a disaster, and to adapt to present and future risks from climate change impacts (National Emergency Risk Assessment Guidelines, 2010; Swiss Re, 2013). The goals of proactive planning and emergency preparedness are to reduce risk exposure, to reduce social and economic damages and losses, and to enhance society's overall coping capacity. Mitigation and adaptation includes emergency preparedness and other actions that strengthen overall local, regional and national resiliency when natural disasters occur.

Natural disaster risk assessment and mitigation require stakeholder participation and scenario planning, to identify impacts, mitigation measures and adaptation approaches. It is critical to include perspectives from stakeholders representing broad interests: industry and user groups, citizens and special interest groups, local communities, institutions, academia, non-government organizations, environmental interest groups, and all orders of governments. It is also important to understand and incorporate stakeholder values in determining mitigation and adaptation responses that integrate science with specific local knowledge (Corkal et al, 2009; Diaz et al, 2009; National Emergency Risk Assessment Guidelines, 2010; Nelson et al, 2008.).

Communication and Consultation

A key element in the natural hazard risk assessment requires stakeholder consultation to identify impacts and mitigation approaches. It is critical to include broad perspectives with stakeholders from industry and user groups, citizens and special interest groups, local communities, institutions, academia, non-government organizations, environmental interest groups and all orders of governments (National Emergency Risk Assessment Guidelines 2010, Diaz et al. 2009).

Six regional workshops were held in May and June 2017 to gather local and expert knowledge from diverse groups of stakeholders. Different geographic locations were selected to capture local knowledge within various regions and places across Saskatchewan:

- Yorkton
- Saskatoon
- Prince Albert
- La Ronge
- Swift Current
- Regina.

The Saskatchewan government sent out direct invitations by email, and followed up with telephone conversations with about 300 individuals representing targeted stakeholder groups, including:

- Communities and Rural Municipalities, including their associations (Saskatchewan Urban Municipalities Association, Saskatchewan Association of Rural Municipalities)
- First Nations communities, and respective associations (e.g. Tribal Councils)
- Government agencies (local, provincial, federal)
- Academia, Subject Matter Experts and Specialists (in disaster risk reduction, mitigation and climate change adaptation)
- Industry (forestry, mining, agriculture, energy, road and rail transportation, etc.)
- Non-government organizations (e.g. emergency management organizations, insurance providers, watershed groups, environmental groups, agriculture and engineering associations, industry groups such as irrigation associations, etc.)

The invited stakeholders were selected based on their local knowledge and expertise; each represented targeted stakeholder interests in natural disaster risk reduction and mitigation.

The invitees were also invited to submit their own input on disaster risk reduction following a pre-workshop form (Appendix 4.1). This allowed all invitees to contribute to the risk assessment, should they not be able to attend the workshops. About 75 respondents provided data on their experiences with natural disasters: impacts, mitigation, current and future risk exposure, and mitigation measures needed to improve preparedness for future risks.

About 200 stakeholders attended the six workshops (58 was the largest number attending and 21 the smallest). They had expertise and/or interests in local disaster response and recovery, human health and safety, community protection and public safety, infrastructure and transportation, natural resource management, environmental health and protection, and expertise on social, economic and industrial development.

Each workshop was conducted in one day, with a morning and afternoon session (Appendix 4.2). The project team set the stage with short presentations to establish the workshop context, and define the scope of the Saskatchewan Flood and Natural Hazard Risk Assessment project. They presented an overview of natural disasters common to Saskatchewan, focussing on droughts and water scarcity, excessive moisture and floods, and wildfires in forests and grasslands. Modeled climate change for the year 2050 was also correlated to help stakeholders consider potential climate change impacts affecting future natural disaster risks (intensity, frequency and variability).

Each workshop was facilitated. Most discussions were conducted in small groups, followed by some large group plenary discussions. The goal was to encourage all attendees to contribute their knowledge, and to elicit stakeholder experiences and knowledge of natural disaster risks, current mitigation, future risks as they may be affected by climate change, and future mitigation or adaptation that would help reduce disaster impacts.

Plausible scenarios were developed for drought, floods, and wildfires (Appendix 4.3). The morning scenarios addressed current experiences. Visual graphics, posters, extracts from scientific publications and newspaper articles, and other references were available throughout the sessions, to stimulate thought and discussion of natural hazards, impacts and mitigation. Discussions occurred in small groups; each theme was discussed twice, with different stakeholders, to capture broader input. The stakeholders' discussions often related and referred to personal experiences or other local knowledge. The afternoon future scenarios presented natural disasters with greater intensity, often overlapped by multiple hazards occurring simultaneously and over a prolonged timespan. Because the severity of future hazards was more extreme, the stakeholders were challenged to consider how such events might impact their interests, and what, if any, mitigation might be possible.

The workshop scenarios and stakeholder discussions elicited broad input of the impacts of natural hazards and current mitigation measures. They considered effects to human health and safety, social systems and communities, public administration and institutions, infrastructure, and economic and environmental impacts. Stakeholders also provided input on future scenarios or changing scenarios of impacts and mitigation, considering climate change trends. Stakeholders also identified what other hazards they perceived could be problematic, along with some sensitive geographic locations that could be "at risk" or "vulnerable" to natural hazards. And finally, stakeholders identified some key priorities for impacts and mitigation.

The participants were also invited to complete a workshop evaluation form, and offer any additional insights or comments on natural disaster risks (Appendix 4.4).

Synthesis of all Stakeholder Workshops – the stakeholders input

"[natural hazards] are imminent and preparedness is crucial"

"We cannot reduce the risk of natural hazards to zero. Benefit/cost assessment is important to consider."

"The people of this province have the right attitude and demeanour to endure these hardships [natural hazards in Saskatchewan] and improve upon them. They need good vision and science to help them make the best decisions."

"The proposed scenarios at the scheduled workshops are an excellent method to convey and subsequently discuss future hazards."

"Climate change…will change the playing field for all of these natural hazards."

"how would we respond should large numbers of people experience loss of electricity and/or heat during a blizzard that restricted …ability to travel and our ability…to respond?"

"Public education providing plausible scenarios of what changes are expected with respect to future natural hazards…. will aid and enable stakeholders to design their own mitigation measures."

"During a natural disaster communication is probably the most challenging part."

"this study is on the right track, getting the people's view."

"[I] would like to see results incorporated into long-term government planning."

(quotes from Anonymous Stakeholders)

The six workshops identified unique impacts, mitigation and priorities for each regional area, and also identified many points and themes common to all regions. The following synthesis sections identify workshop insights for the drought, flood and wildfire natural hazards. Attendees represented most of the targeted and invited stakeholder groups. The diversity of stakeholder interests was noted and appreciated by the participants. Some suggested that representation from more industries and health services would have been beneficial (both groups were invited).

The stakeholders were committed participants at each workshop. They asked for the results from this project once it is complete, and they believe that disaster risk assessment along with proactive planning, mitigation and action plans are necessary. They indicated a desire to keep the following types of activities on-going:

- share information, current science and knowledge
- improve natural disaster preparedness planning and response plans
- continue to engage local stakeholder discussions with future planning and actions
- work together to develop proactive, long-term plans and actions to reduce risk and strengthen local and regional resiliency.

Stakeholders learned from each other, and the unique perspectives that each brought to the discussions. The ***FireSmart*** programming is viewed as a model, helping develop preparedness plans, protection plans, emergency response plans, improving infrastructure, coordinated fire response and recovery approaches, public education and awareness, training for emergencies, coordinated/integrated and cooperative disaster responses, effective communications, etc. Stakeholders valued such proactive long-term planning for local and senior levels of governments, the formalized mutual aid agreements and institutional arrangements, and the on-going and continuous review to ensure FireSmart programming is kept current and enhanced year after year. Some suggested similar programs and principles are needed for water scarcity and drought (i.e. a ***DroughtSmart*** program), and excessive moisture and flooding (i.e. a ***FloodSmart*** program). All stakeholders supported the concept of long-term planning and preparedness and coordinated responses. Public protection (individuals and communities) is seen as the top priority. Economic and environmental protection are also recognized as key elements to consider with natural disaster risks.

Note: This entire chapter is based on stakeholder contributions and perspectives, and does not attempt to evaluate confidence levels in stakeholder perceptions. Highly subjective perspectives or a lack of data backing up perspectives may affect confidence levels. Selected quotations are from anonymous stakeholders' statements, predominantly from the pre-workshop input with some from the workshop evaluations.

Drought and Water Scarcity - Insights from six workshops

"We are probably due for a much worse drought in the coming decades."

"widespread drought is one of the most severe natural hazards to impact the prairies."

"the slow onset of drought can make it difficult."

"Drought is insidious, and it is easy to become complacent during "normal" or wet periods."

"low flows [in transboundary rivers] are challenging for interprovincial water sharing."

"Develop more drought resistant [crops]…discourage the breaking of marginal lands. Develop best practice irrigation capacity…encourage novel forms of agriculture."

"While floods get the media attention, they can be largely mitigated through proper planning and flood proofing. The bigger long-term risk is drought, which has been experienced in the past, but climate models suggest these could be longer and more severe in future."

(quotes from Anonymous Stakeholders)

Stakeholders clearly identified drought's primary impacts to water availability (scarcity of both surface and ground water) and impaired water quality. Water scarcity affects critical human needs for communities, industries, and economic activities. There are also negative impacts to river and lake ecosystems, with deteriorated water quality, less water flow in streams and depleted water supplies in lakes and reservoirs. Recreational uses of rivers and lakes become impaired and economic losses occur with loss of tourism. Drought causes serious economic impacts to agriculture and other water dependent industries. Drought causes both direct and indirect economic impacts to rural economies, communities and prairie cities which are in large part dependent on healthy agricultural economic activities. Should hydropower generation suffer, alternate or backup energy sources may be required during droughts. Drought is a slow-onset phenomenon, and should drought persist in time (e.g. multi-year water scarcity) the impacts of drought increase and may extend over a wider geographic region, as in the 1920s-30s or the 1850s.

Accordingly, there are increasingly significant impacts on water managers, increased water competition, social challenges, and potential conflicts between water users, industry, competing sectors or problems between sectors and communities (e.g. hydropower versus irrigated agriculture versus community supplies); there may even be administrative, social and governance problems within institutions and between government agencies (local, provincial, federal). As drought severity increases, there is greater economic and human impact. During extended droughts, the province could become a net food importer rather than an exporter, challenging regional food security. Market confidence may be impaired by extended drought, and loss of markets is possible. And yet, warmer conditions (with global warming), may also lead to opportunities, if higher-value or drought- tolerant crops can be established with effective water management (soil water conservation and expanded irrigation). Such anticipatory changes in agricultural production or economic activities will take significant research, development and proactive long-term transitional planning. Changes to agriculture would also need to factor in risks (e.g. when insufficient water supplies are available for irrigation, or when excessive heat stressors may impair agricultural activities with crop and livestock production).

Drought mitigation largely relates to water security during times of scarcity, and will include water management processes (including setting priority-of-use hierarchies), watershed management and source water protection (surface and ground water), enhancements in water storage and conveyance infrastructure, and improving water use efficiencies for all water users. Drought risks, as they intensify, rely on the expertise and support of provincial and federal government agencies – the problem is recognized to be much larger than what can be addressed solely by local communities or industries. Accordingly, drought mitigation and greater water security are strongly correlated to effective institutional arrangements that can provide technical and policy expertise, guidance and programming by provincial and federal governments (e.g. monitoring of climate, hydrology, agricultural water management research), and including the participation and application of academic knowledge of best management practices (current, innovative, and/or experimental).

Social and economic adaptation will be challenged by persistent droughts, and will require proactive planning (e.g. drought coping responses for people, communities and affected industries, including ecosystems impacts). New types of animal and human diseases may occur, stressing the health of people, livestock, wildlife and ecosystems. During extreme multi-year droughts (the future scenario), there was recognition that social, economic and environmental impacts could be more severe than the droughts of the 1920s-30s. Society and modern economic activities have changed, and impacts will be different, worse, and potentially more global in nature as there is more development and activity in the region. Human migration is a risk during severe prolonged droughts. Human health and mental health will be impacted, and may pose stress on medical systems should new types of diseases or disease vectors occur with a warmer climate. Mitigation may therefore need to include capacity to address health impacts, social issues, and ecosystems impacts.

Changes to ecosystems are expected with global climate change. Existing or new flora and fauna, exotic plants, insects, animals and non-native species may move or migrate into new geographic areas. New types of microbiological diseases, pests and invasive species could become problematic. Ecosystem alteration may impair economic and recreational activities. Resource protection and ecosystem conservation measures are therefore, unique mitigation that should also be considered in drought planning preparedness.

Drought was also recognized to be strongly linked to wildfires in any forested location (northern or southern Saskatchewan) as well as across prairie grasslands. For example, hot, dry conditions and strong prairie winds cause grass fires to spread rapidly. A significant risk involves insufficient access to water for fire suppression in the south during a prolonged dry period with depleted water supplies. A warming climate that increases hot, windy days and water scarcity, will also increase fire risk. Grassland fires are now seen as risking southern rural populations, communities, agricultural producers (crops, livestock) and other industries. There are also impacts to emergency management systems (Emergency Management and Fire Safety, Fire Commissioners, Forest Fire Commissioners). Stakeholders noted a mitigation idea to link or integrate forest and grassland fire suppression response programs, as they tend to be addressed with separate support systems and initiatives, and may compete for resources (e.g. aerial fire suppression may assist with grass fires as well as forest fires).

Stakeholders stated that mitigation for droughts requires proactive long-term planning, learning from the past where possible, and being careful to be prepared for drought in advance. Emergency management plans for drought need to be developed similar to flood management planning (e.g. establishing priority of water use, considerations for alternate supplies). As drought severity increases, people and regions affected become increasingly reliant on provincial and federal support and programs, as individual and regional coping capacity become exhausted. Funding may be needed for relief and development investments to strengthen resilience. Drought is recognized as a natural characteristic of the prairies, and stakeholders recognize drought will recur (even though much of the region has been wet between 2010-2016). Stakeholders believe one of the key risks of drought is not being prepared for its slow onset (it is out of sight and out of mind in years with normal precipitation). Stakeholders recommend that proactive planning and revisiting drought preparedness planning is key, and should be done regularly, even during "normal" or "wet" years. Taking cues from Saskatchewan's successful FireSmart program, stakeholders stated it would be wise to establish a "*DroughtSmart*" planning program and to plan and budget for a "*non-rainy*" day. With the risks of climate change posing greater climate variability, mitigation for drought, will require complex research coupled with water and climate modeling to consider options for affordable, sustainable mitigation and adaptation. Not all mitigation are costly, though. Drought planning may start with thinking about and completing a preparedness plan for improved water security, and perhaps identifying alternate available water supplies for critical needs during times of water scarcity.

People noted that the time to start regional planning is now (and not during the actual drought event). They stated that leadership is needed from provincial and federal governments because these issues are at a grand scale. And there was recognition that there is a challenge to "personalize" risk, largely to motivate individual and institutional planning to mitigate drought risk.

Drought may also affect and change economic systems; for example, conventional agricultural activities such as rain-fed agriculture may be at high risk for repeated years, and may require agriculture to adapt to new production and water management systems. Mitigation such as irrigation expansion to reduce water scarcity risk, requires long-term planning and investment. Drought, while a natural characteristic of our region, tends to not be considered during non-stressed times. So, it is critical to strengthen individual and agency capacity (e.g. Water Security Agency, watershed groups). Stakeholders also emphasised we need to learn from past successful institutional arrangements/programs (e.g. the federal government's soil and water conservation programming delivered through the former Prairie Farm Rehabilitation Administration (PFRA) [*The former PFRA was a branch of Agriculture and Agri-Food Canada. it was created in 1935 in response to devastating multi-year droughts; PFRA assisted prairie agricultural adaptation with sustainable farming practices and soil and water conservation programming and research; PFRA operated during 1935-2013*]). Knowledge and public education are critical needs for drought mitigation and preparedness measures. Stakeholders identified that better knowledge and public education will help with economic decisions and social awareness to avoid complacency during non-stressed times – they stated continual awareness and mitigation strategies are needed even during non-stressed times.

Flood and Excess Moisture/Wet Conditions - Insights from six workshops

"Flood damage could be substantially reduced through education and responsible planning and development…. No new developments should be allowed in flood risk zones, and all existing developments should be flood proofed."

"We are going to be dealing with significant climate change impacts…that will tax the current economic and social structure…"

"Without a solid basis for mitigation and collaboration, there will tend to be losers and winners."

"The best approach to adaptation is regional – a cooperative approach…do the hard work to identify the most promising options for a community and region [and watershed]"

(quotes from Anonymous Stakeholders)

Stakeholders identified common, current flooding impacts, including: flooded communities, flooded agricultural lands (which may have long-term impacts on production), damages and losses to personal and public infrastructure (buildings, equipment, other property), transportation systems (rural roads, highways, railway lines), community water and wastewater systems, landfills and industrial storage sites or waste sites, SaskPower and SaskTel lines (i.e. above-ground electricity and telecommunications utility lines), dams and reservoirs, damages to economic activities including agricultural losses (crops, livestock), oil and gas production losses, damages to power grids, impaired industry activities, conflict between neighbours and neighbouring regions (particularly where drainage projects or illegal drainage have been implemented historically or during a flood event), etc. Impacts to infrastructure also include "soft infrastructure" including data systems, computers and digital media, books and files, administrative and legal records, financial documents, photographs, historic archives, and other critical perhaps irreplaceable materials. Mitigation for these items is challenging, and relate to infrastructure design, storage management, and backup copies or systems in another site, where that may be possible.

Due to the nature of flooding, most flood impacts are relatively obvious, often happen quickly, and generally occur during a relatively short time frame (in contrast to the slow onset and long duration of persistent droughts). In some cases, flood impacts and losses are catastrophic. There is no disputing that response actions must be undertaken immediately to repair, rebuild and recover from flood losses and damages (e.g. road washouts, building flooding, loss of property, etc.). The challenges in recovery involve economic costs, time and duration of rebuilding, and the design concepts for rebuilding (e.g. to the existing past state as required by the Provincial Disaster Assistance Program, or to consider "building better" by rebuilding to an improved and more resilient state, with due considerations for broader and more regional upstream or downstream consequences that could be caused by changes). Changes clearly require regional thinking and planning within the affected community and watershed.

Stakeholders understand that floods impact the natural environment, parks and recreation areas. This may include land and water degradation by contamination from human wastewater, industrial sources of pollution, runoff of agricultural chemicals and livestock waste, etc. Other environmental risks relate to various erosion problems, slumping of river banks, stream banks and lake shorelines, contamination of water wells and ground water supplies (aquifers). All of these effects will have spin-off impacts on people, homes, industry, and economic activities in the vicinity. In some cases, there may be rerouting of river flows should banks overflow to such an extreme as causing formation of a new channel. Sediment and silt transport may also impair aquatic ecosystems. Mitigation may involve deliberate attempts to preserve wetlands, incorporate green infrastructure, and to encourage land use practices that recognize environment benefits (alternative land use services for agriculture, and industry or community development projects that incorporate ecosystem benefits and ecosystem services).

Floods may impact human health, with disease transfer in drinking water or other sources of water pollution. Water and wastewater treatment systems may not be effective, or may not be functioning at all. Hygiene and disease transfer in evacuation sites may also be problematic. There will also be stress and mental health issues, particularly with those who have suffered large-scale losses, were evacuated from homes or communities, and even with responders who have suffered demanding emergency response activities. Mitigation includes existing medical and mental health support systems, and these may be taxed by the sheer number of affected people during the event and the recovery phase.

Institutional programs such as the Saskatchewan Provincial Disaster Assistance Program and the Emergency Management and Fire Safety Program (both within Saskatchewan's Ministry of Government Relations), and the Emergency Flood Damage Reduction Program (Saskatchewan's Water Security Agency) have been very beneficial in flood response and recovery, as have local and provincial emergency responders. Flood insurance, a very new product in Canada, is also critical for individuals, communities and industry.

Zoning, engineering and insurance mitigation were emphasised. It is recognized that some communities (e.g. Moose Jaw) have done well by buying-out properties in high-risk floodplain lands, as it is not wise to have homes, buildings, structures and economic activities in areas that repeatedly flood. New developments across the province need to consider drainage and run-off impacts. Structures (private, public, industry) also need to be designed for appropriate flood protection events; considering climate change and variability, engineering designs may require the consideration of constructing to cope with more extreme precipitation and flood events than what has been used historically. [Note that Engineers Canada has, for some time now, been investigating these issues with their program *Public Infrastructure and Engineering Vulnerability Committee*, PIEVC: https://pievc.ca/]. During the last decade or more, insurance agencies have experienced an increasingly higher and more costly number of flood claims related to sewer backup; they are now establishing new approaches and new guidance to individuals and communities, and new insurance programs and risk management for flood protection and other natural disasters [e.g. See the Insurance Bureau of Canada: http://www.ibc.ca/on/disaster, and http://www.ibc.ca/on/disaster/water, and the IBC's *Municipal Risk Assessment Tool*: http://www.ibc.ca/nb/disaster/water/municipal-risk-assessment-tool]. Improved zoning, engineering and insurance were recognized as needing effective legislation and enforcement (e.g. to ensure illegal drainage is not allowed nor occurring).

Mitigation for flood protection will also require ensuring better, continued infrastructure maintenance (road and highway culverts, canals and water diversions, dams and reservoirs, water and wastewater systems, landfills, etc.). Improved knowledge is also essential with development of improved flood-risk mapping. This may include conventional surveys to identify flood-risk zones, and unique or specialized lidar surveys to improve topographic knowledge [LiDAR is Light Detection and Ranging – a remote sensing technique using laser light to define topography]. Better topographic maps would be useful in determining flood inundation risks, drainage flows and patterns, and can help guide flood protection needs, as well as flood mitigation measures for new development projects and land use practices. As well, improved hydrological monitoring, forecasting of flows and precipitation events and related impacts would be useful for early warning systems as well as for appropriate mitigation and response/recovery practices.

Stakeholders emphasised a need for mitigation measures that included improved protective systems (dyking, better and effective legal drainage systems), adherence to existing building codes, consideration for enhanced building codes, improved water management approaches and improved infrastructure that is more resilient to flooding (buildings, highways, railway lines, utilities, etc.). They also indicated that knowledge exchange and communications between local stakeholders is critical to ensure a mutual understanding of flood risks and how water and flood management measures (including institutional decisions) will interact with their own local flood protection preparedness and response activities.

Stakeholders emphasised that mitigation measures include emergency preparedness and response plans, public education and awareness of these plans before and during flood events, and effective communications during flood events and recovery. Strong leadership and clear decision-making are critical especially during the event. Stakeholders indicated concern with some communications (e.g. social media); concern was expressed about incorrect or inaccurate information being propagated, and causing serious problems in the protection of people, property and recovery responses. Stakeholders also recognized that individuals (rural or urban) also have responsibility for protection and preparedness. Self-sufficiency is seen as being greater in rural areas, where by necessity people often must address problems on their own. The concept of a 72-hour emergency supply (food, water, heat, etc.) is seen as a good mitigation concept for all individual rural or urban properties, and even for communities that may be cut-off by a disaster.

Cross-training and emergency response coordination between orders of government, local responders and different agencies is critical, and essential for all emergency flood response and recovery. This is seen as particularly critical for northern communities, which also requires local expertise and knowledge of their local conditions, communities and people. Mutual aid agreements are often already in place, but can always be strengthened. Public education is important. The role of watershed agencies, and public knowledge and awareness of watershed issues and activities (e.g. water management, source water protection, wetland preservation, etc.) are important mitigation measures. The better and more informed the public is, the better and more coordinated the flood disaster response will be, as people and agencies work together more effectively.

Depending on scale and flood intensity, evacuations may be problematic, and people will experience significant stress levels. People and human resources will be taxed during floods and the recovery period, which can drag out for very long periods of time for proper clean-up and rebuilding. In some cases, chaos can occur during the event, and will need to be managed for public protection. Certain people and communities are more vulnerable to flood impacts: this includes the elderly, people in seniors' homes or hospitals, and residents of remote or rural communities including First Nations communities and those in the north. Evacuations will be especially problematic when road, rail access is damaged or impaired by flood events. There may be only one good road into/out of the affected communities, so access/egress becomes very challenging. This will also be an issue during the flood recovery phase.

Stakeholders identified that established emergency preparedness plans, communications plans, and training of responders, are instrumental mitigation that must be established with local responders in advance of events, to be more effective in resiliency, response and recovery of flood events. Such mutual preparedness is a governance challenge, and requires significant institutional awareness, strategic planning, coordination and implementation involving all orders of government (including rural municipalities), and should include industries that may be capable and willing to assist in flood protection and response.

Wildfires (Forest Fires and Grassland Fires) - Insights from six workshops

"Saskatchewan has many communities at risk from wildfire…. Forest fringe and northern communities face the greatest risk…but …we have seen an increase in the number and size of prairie [grassland] fires in the last few years"

"Severe droughts in 2001 and 2002 resulted in busy fire seasons with fires in 2002 that burned down into the peat bog areas making them very destructive and very difficult to suppress. El Nino winters have resulted in extreme fire seasons the following spring & summer...droughts mean more fires."

"many programs do not account for future hazards exacerbated by climate change"

"Research involves working with First Nations…. Indigenous people have different values at risk."

"Good communication plans need to be developed and clearly communicated to all residents"

(quotes from Anonymous Stakeholders)

Wildfires, forest and grass fires naturally occur in all areas of the world. Unfortunately, about 50 percent of forest and grass fires in Saskatchewan are human-induced (e.g. improper extinguishing of campfires, discarded burning materials, arson, etc.). Important elements of addressing fire risk involves: advanced planning and emergency response measures; inter-agency coordination; public education; data-sharing and exchange of information; and, effective inter-active communications between decision-makers and locally-affected people and communities. Early warning systems, access, egress and evacuation planning are critical factors in responding to wildfire disasters.

Mitigation for wildfires (forest fires and grass fires) and disaster preparedness include larger-scale management, policy, and infrastructure responses. Landscape-scale forest management is practiced. Development, property line set-backs, fire breaks, controlled burns, insurance incentives are all used in wildfire disaster preparedness. Programs established by emergency management systems (Emergency Management and Fire Safety, Fire Commissioners, Forest Fire Commissioners, Public Safety Canada, Wildfire Management Branch of Saskatchewan's Ministry of Environment, FireSmart programming) are recognized as being extremely useful for managing fire protection practices, developing emergency fire response plans, ensuring the plans are current and practiced, public education, training, and proactively designing fire response procedures and practices.

Forest Fires

"Wildfires are a natural part of the Boreal Forest ecosystem."

"Effective fire suppression combined with new development within the wildlands has resulted in large areas of over mature and unhealthy forests, parklands, and grasslands that lead up to and into many communities."

(quotes from Anonymous Stakeholders)

Stakeholders identified a broad scope of wildfire impacts with forest fires, including impacts to power supplies, grids and distribution networks, water and wastewater supplies, buildings, roads, bridges, railroads, etc. Another significant issue with forest fires relates to communications systems; northern fires risk damage to communications systems (which may be destroyed), and will impact the infrastructure and the important communications connections needed to suppress the disaster. Mitigation require backup communications systems for local and regional communications.

First Nations people and traditional practices (hunting, fishing, agriculture), northern recreational activities (hunting, fishing, camping), and northern economic activities (tourism, mining, forestry, power generation, oil and gas production, agriculture and northern farming activities) may be seriously impacted by forest fires. Depending on the extent of exposure and damage, recovery responses may be challenged. Depending on the remoteness of the location, rebuilding and recovery costs may be very costly and take long periods of time to complete. Mitigation generally involves fire risk reduction practices, preparedness, and emergency response planning.

Impacts to human resources were also seen as significant, as responders are under significant physical and mental stress, often taxed with workloads and little time for rest, and face real challenges working with inexperienced responders or with responders who are not familiar with the geographic area and/or local cultural practices. Outside resources can be helpful, but need to be coordinated by those familiar with the region (and preferably by local leaders and decision-makers). There was a suggestion that the deployment of the federal Department of National Defence should be implemented more frequently, as scale and need requires; however, such deployments require training and guidance from experienced wildland firefighters, and those with specific local knowledge of the region. Furthermore, should any provincial or federal help be deployed, stakeholders were emphatic that local stakeholder knowledge, expertise, input and participation were essential factors in any fire disaster risk reduction preparedness planning and response activities. Larger-scale provincial and federal responses require effective coordination, and need to include effective integration with local leaders and authorities. Advanced preparedness for integrated responses is needed, with an emphasis of incorporating local knowledge, expertise, leadership and personnel.

Mitigation measures to address complex coordination challenges include mutual aid agreements, FireSmart programs which help to prepare fire protection and emergency responses to fires, education programs and learning from past events, risk assessments and fire risk reduction programs, identification of critical infrastructure and means to protect them, coordination of emergency measures for fire response, etc. A significant emphasis of FireSmart programming is that it is designed to reduce the risk of human-induced fires by reducing fire hazard risks in and around communities (e.g. vegetation management, designing and using fireproof building materials in building infrastructure, etc.). Stakeholders recognized that industry may have large-scale impacts from fire. Industry also stated that they may have capacity in helping mitigate fire response (providing firefighting equipment, communications systems and additional human resources to help responders).

A significant issue in responding to forest fires relates to incident command and communications with those affected. Often there is confusion, chaos, and uncertainty, or even unacceptance of decisions taken in response to the fire, and fire suppression activities. Sometimes it is unclear who is in charge of making the decisions, and/or there is confusion about the course of actions taken by different agencies. Stakeholders expressed a need for clear levels of authority during fires, and the need to ensure that local authorities are engaged in the decisions, that there is effective and timely data-sharing of the fire risk, and that local people are informed of the decisions, particularly when outside help and support may be coming from far away distances (e.g. provincial, federal responders implementing aerial fire suppression activities). Local communications with affected citizens and the public is essential, and needs to occur in a safe and timely means to help advance best public safety protection and fire suppression actions. Local understanding and awareness is essential, and may require different communications strategies and frequent continual initiatives and attempts by officials – common, clear information must be disseminated to those affected to maintain credibility and public safety.

An impact to northern communities also involves the concept of "prepare and defend." This relates to the local fire responders who wish to be ready to suppress fires and remain in the affected location as long as is possible. However, if this approach is implemented, significant investment in training of local firefighters will be required, and additional best practices would need to be developed to achieve maximum protection of firefighters and others involved in any "prepare and defend" approaches. Mitigation measures require safe housing, air purification systems, effective communications systems, and integrated incident command systems to accept mutual local/external inter-agency decision-making in fire suppression and evacuation.

A major impact with forest fires is the evacuation of people in at-risk communities or those living near the fire zone. Evacuation is an important decision, but not always accepted by those affected.

Fire movement can be unpredictable, and when evacuation is decided or ordered by authorities, the next challenge is to do so effectively. Road or air evacuation may be affected by the fire (road access may be cut off; air evacuation will be affected by smoke and visibility). There are significant challenges evacuating vulnerable people in care homes, hospitals, retirement homes, etc. Psychological stress and loss also often occur for those affected by evacuations.

Health impacts from smoke inhalation may be significant with forest fires, and can extend hundreds or even thousands of kilometers away. Pressures on medical facilities are intensified particularly in directly-affected communities.

Social impacts include security, higher risks of looting, crime and maintenance of law and order. People suffer personal economic impacts when their jobs are terminated by forest fires (forestry, or other employment by industries such as mining or tourism that may be affected by forest fires). Northern communities and First Nations communities affected by forest fires may have a widespread human impact, due to remote locations of affected communities. Economic problems could be widespread within a community, and there may be feelings of isolation. Recovery operations from fire-affected communities and industries can be very long-term, and in some cases, may not occur (e.g. permanent shut-down of an industry or business). The social impact is significant in these cases both to individuals and the affected communities. Emergency social services during the fire event, as well as longer-term targeted social services supports "post-recovery" are also important mitigation considerations.

Changes to ecosystems increase fire risk (e.g. Mountain Pine Beetle, diseased forests, drought occurrences, etc.). And major ecosystem changes can result from wildfires, as landscapes and hydrology may be changed on a widespread scale (invasive species, including aquatic organisms). Wildfires may also have significant effects on habitat for species at risk (e.g. woodland caribou). It is recognized, however, that forest fires are also a natural process that aid in ecosystem regeneration. Mitigation should include zoning and by-laws for development and economic activities in forested areas.

Large-scale forest fires have a significant economic and environmental impact, as well as serious impacts to local, provincial and federal governments, as they attempt to suppress the fire, and plan recovery post-event. Budget impacts to local, provincial and federal resources are significant, and will have additional impacts for future budgetary planning. Spending priorities may require adjustments. Large-scale forest fires may be significant enough to impact future taxation.

Grassland Fires

"Major grass fires [have been] fuelled by dead grass in the spring and standing crops in the fall."

(quote from Anonymous Stakeholder)

Stakeholders identified a broad scope of fire impacts. Stakeholders in the south tended to focus on southern geography (grassfires, bush, crops). Nevertheless, risks are similar to larger scale forest fires. In hot dry times, grassland fires can be extensive, rapidly burning, threaten human and animal populations, and destroy agricultural land, crops, community buildings, infrastructure and transportation systems. One unique problem with grass fires is the challenge to construct firebreaks (e.g. continuous cropping and/or natural grasslands leave few or limited interruptions/firebreaks).

When grassfires are combined with excessive winds, grassfires may easily spread with a continual fuel source and little to no natural or man-made impedances that slow the fire down. Grassfires are also more significant during times of drought, so a strong correlation exists between both natural disasters. Another operational impact relates to competing resources and institutional arrangements, where grassland fires are treated with different responses to forest fires, yet may benefit with similar responses (stakeholders believed there was a need for greater aerial fire suppression, yet understood this was difficult to implement should forest fires be occurring during the same period of time).

Economic impacts from grassland fires can be severe, and have broad impacts to agriculture, industry, transportation and energy systems, water and wastewater systems, etc.

There are often impacts to local human resources, most of which tend to be volunteer fire fighters, and impact to regional and provincial emergency management responders, when their resources are taxed.

Mitigation includes emergency management planning and communications strategies. Many communities have established plans, and there are usually trained responders that work with the volunteers. Industry is also often available to help. Industry may also have firefighting emergency plans (e.g. railway operators take steps to minimize fires from ignition from wheel sparks).

One of the unique challenges in the more "water scarce" southern region, is fighting fires when water resources are either limited or depleted (often the case when fires occur during drought or extremely dry periods and fuel sources are higher risk with dry grasslands). Accordingly, water access may be an issue and water sourcing for fighting fires must be anticipated or sought with expertise from water agencies (WSA- Saskatchewan's Water Security Agency, databases of the former PFRA). There is a need for additional mapping of emergency water supplies. Deliberate firebreak planning was suggested for grasslands in the south, to reduce risks from grassland fires (akin to a forest firebreak).

Coordination of local responders (the primary emergency responders for southern fires), provincial responders and the centralized provincial Emergency Coordination Office, aerial support when needed, and federal assistance from Public Safety Canada are all helpful mitigation, when needed. FireSmart is a successful program, and could be extended to education of individuals (e.g. private homes, farms, etc.). Mutual aid agreements are extremely beneficial where formal arrangements are established to get assistance from others trained in specific emergency response as well as disaster recovery (particularly from other areas or neighbouring areas that are not affected by the fire disaster).

Northern Saskatchewan First Nations and Non-First Nations: local knowledge and expertise

"Northern evacuations imposed on our [First Nations] communities represent unique impacts including culture shock and long-term displacement. Family reunification issues are also among those mentioned by evacuees."

"[mines and mining operations] have been under [wildfire threats] several times"

(quotes from Anonymous Stakeholders)

Stakeholders from the La Ronge workshop were emphatic about the unique nature of the north – its geographic location and natural resources, its unique mix of First Nations and non-First Nations peoples, and the strong and special cultural characteristics and approaches towards life, communities and survival in the north. The north is more remotely populated, and geographically distant from "centres of power" and senior levels of government. Most northern people, including many of those in northern communities, have much stronger skills in self-sufficiency and resilience than most southern people. In part, this is driven by necessity for northern life and survival. Life in the north is an intimate relationship with the water and land, the landscape and extreme climate, the harsh winters, summer rains, the wildlife and nature, and the types of economic activities in the north: hunting, fishing, gathering, tourism, forestry, and mining, all of which are intertwined with northern natural resources and northern ecosystems.

Northern stakeholders, therefore, are a special and unique group of stakeholders with highly vested interests in their place of residence. They strongly expressed an essential need for local engagement in natural disaster preparedness planning and response, and that without effective, continued integration, cautioned that natural disaster risk reduction and mitigation strategies would not be properly designed nor implemented. Therefore, they were passionate in stating a need for local leadership and involvement in disaster risk management and mitigation responses, including (and perhaps especially) when senior levels of provincial or federal government agencies were required, and even when activities were the responsibility of other agencies (e.g. aerial fire suppression activities). They emphasised the need for local and regional forest firefighter training so that they would be prepared to help defend their communities and property, and build local capacity. Education, training, communications of emergency preparedness plans, responses, and evacuations must always include information exchanges, data-sharing, and inter-active communications with northern peoples including First Nations, to ensure local knowledge, local interaction, local leadership and local guidance for implementation of mitigation, disaster responses, and recovery actions. This was, to some extent, a recommendation at all six workshops, insofar as local stakeholder knowledge and expertise is essential for place-based solutions. However, the northern geography and population are far more unique because of its people, its geography, and the fact it is much further away from the senior levels of government.

Other Natural Hazards – a summary of risks identified by Saskatchewan Stakeholders

"people with resources can recover from a disaster, people without resources cannot"

[current mitigation measures] "are adequate for what we have faced in the past. They are not adequate for what we may face in the future"

"***the entire province is at risk from future climate extremes"***

"This is not a site-specific issue [to Saskatchewan], rather an issue of national significance"

"I laud the Government for forums such as this to compile the knowledge of stakeholders so that we can better understand how we should adapt and/or mitigate the worst effects of climate change going forward."

(quotes from Anonymous Stakeholders)

The workshop discussions focused on droughts, floods, and wildfires, but one session involved the stakeholders identifying what other types of natural hazards were likely risks in their region.

It is worth noting that the stakeholders recognized links between the natural hazard risks and human responses or interventions. Most saw these "other types of natural hazards" to be potentially changing with intensity, frequency or duration, when looking ahead into the future. Many commented that the recent wet phase (2010-2016) has been unprecedented in their memories, yet they recognize that drought is natural to the prairies, and will recur. The stakeholders expressed concern that people tend to be so focused on current exposures, to the extent that other natural disasters are "out of sight" and "out of mind." Yet they stated that disaster risk planning and preparedness is valuable, and needs to be proactively managed, even if the disaster is not on-going. They also noted that there are challenges with human mitigation and jurisdictional issues [i.e. likely related to natural hazard responses such as coordination of federal/provincial responses]. Stakeholders indicated that the public needs to take natural hazard risks and warnings seriously. There was a sense that the present variability in frequency and intensity of storms and floods is different than what has occurred in their past experience, and that the future will require greater planning, preparedness and mitigation for even more types of natural disasters, and for even greater variability in frequency, intensity and duration.

Other natural hazards identified by the stakeholders are listed below.

Other Natural Hazards as identified in all six workshops (all workshops; grouped under thematic titles

SEVERE WEATHER AND STORMS

Heat and Convective Summer Storms

- excessive heat (intensity and duration) with extreme temperatures over prolonged periods of time (impacting people, plants, animals, energy consumption, etc.)
- rapid changes in weather with wind, rain, hail (greater storm intensity)
- extreme summer storms with intense rain and wind and hail
- excessive moisture causing land slumping
- plough winds (affecting infrastructure, forests, etc.)
- tornados
- lightning storms (affecting power distribution, communication systems, causing fires)
- hail (intensity and frequency)
- severe weather, severe summer storms

Winter Storms, Blizzards, Snow and Ice

- snow storms (intensity and frequency)
- severe snow storms (which may cause casualties, particularly with transportation)
- heavy wet snow
- winter ice storms (affecting people, infrastructure, power, transportation, etc.)
- ice storms combined with wind
- blizzards with greater frequency and intensity
- severe weather, severe winter storms

ENVIRONMENTAL CHANGES, including ECOSYSTEMS and DISEASE VECTORS

- changing ecosystems (biology, insects, plants, trees, animals) i.e. microbiology, flora and fauna
- beaver, rodents, other ecosystem biota changes
- pest infestations, ecosystem shifts
- landscape changes (e.g. caused by changes to ecosystems, forest health, etc.)
- invasive species changing natural ecosystems and affecting aquatic life, water quality, plants, animals and human health
- exotic plants, insects, animals, invasive species (not common to the local region)
- aquatic invasive species; invasive plant species (i.e. including microbial species, viruses, parasites, bacteria)
- quagga mussels, zebra mussels
- Mountain Pine Beetle
- Diseases (human, crop, livestock, wildlife, plants, forests)
- Livestock diseases such as foot and mouth disease, BSE /Mad Cow disease [BSE is Bovine Spongiform Encephalopathy, a variant of Creutzfeld-Jakob disease] and associated risks to human health
- unique specialized diseases
- West Nile virus
- Lyme disease
- Insects
- Plant and tree diseases (affecting natural ecosystems, plants, trees, forest health)
- New vector-borne diseases [. e.g. health of humans, crops, livestock, wildlife, plants may be affected by new microbiological and biological disease vectors]
- Deteriorating water quality (in the natural environment)
- Excessive moisture causing slumping or swelling of land (e.g. at slopes, shorelines, etc.) and causing damage to infrastructure such as buildings, roads, rail lines, etc.
- Cascading effects of environmental changes; natural hazard “shocks”
    - e.g. rapid changes from drought to flood, as experienced in the 2009-10 summer to winter drought with extremely dry soils, followed by rapid changes with excessive moisture and flooding causing severe shifting and heaving soil, impacting infrastructure such as homes, natural gas lines, dams, culverts, bridges, etc.
    - e.g. floods and flood runoff causing contaminant runoff from human wastewater, livestock runoff effluent, industrial pollution, and other contaminants

OTHER NATURAL HAZARD RISKS

- Land slumping and swelling (e.g. from excessive wet conditions)
- Earthquakes
- Volcanic eruptions (in other regions) and ash migration
- Solar flare (affecting communications systems)
- Atmospheric winds (transporting global contaminants from other regions in the world)
- Drought and dry conditions in northern regions impairing forest health, changing northern ecosystems and landscapes, and increasing forest fire risks
- Excessive, prolonged multi-year drought

Insights from the Pre-workshop Input

The pre-workshop exercise identified key points made from diverse stakeholder groups. The excerpts below are samples of some of the responses. The following statements are quoted from anonymous individual submissions representing the invited targeted groups, and are identified by an anonymous stakeholder number (e.g. S3).

A snapshot of Stakeholders' Views on Drought

- "the slow onset of drought can make it difficult to identify, which means that program supports may not come at the time they are needed" S3
- "We are probably due for a much worse drought in the coming decades" S8
- "Incentivize windrows, dugouts and tree planting in the wake of the loss of the PFRA….. Reinstate wetlands in the southern farmland, in conjunction with organizations like Ducks Unlimited…Develop more drought resistant hay strains in conjunction with the UofS [*University of Saskatchewan*] …Discourage the breaking of marginal lands…. develop best practice irrigation capacity…and encourage novel forms of agriculture." S8
- "low flows are challenging for interprovincial water sharing…. Alberta or Saskatchewan may be unable to meet interprovincial or international apportionment objectives" [*apportionment objectives relate to water apportionment when a river or stream crosses international and/or provincial borders*] S20
- "We need to better understand our resilience to future drought, and develop mitigation, adaptation or contingency plans. Drought is insidious, and it is easy to become complacent during "normal" or wet periods such as we have experienced in recent years." S20
- "While floods get the media attention, they can be largely mitigated through proper planning and flood proofing. The bigger long-term risk is drought, which has been experienced in the past, but climate models suggest these could be longer and more severe in future." S20
- "widespread drought is one of the most severe natural hazards to impact the prairies. The drought of 2002 resulted in approximately one-billion-dollar payout under Saskatchewan Crop Insurance." S49
- "many programs do not account for future hazards exacerbated by climate change. Market-based programs like crop insurance may no longer be sustainable/affordable as costly disasters increase." S3
- "[animal disease in agriculture] …could devastate the entire livestock industry, as well as those communities that depend on it." S49
- "we are in a wet cycle currently, that could change into a drought cycle quite quickly and… I do not feel that the there are many people that would be prepared for that switch." S2

A snapshot of Stakeholders' Views on Flood

- "we have no knowledge whether the valley slope is unstable" [in areas throughout the Qu'Appelle Valley and Last Mountain Lake] S4
- "at the regional level, more needs to be done to assess resilience in public infrastructure." ...municipalities need to conduct risk assessments on their infrastructure to focus preparedness work and then complete that work to ensure their investment in current infrastructure is not lost." S7
- "Quill Lakes region and Qu'Appelle watershed are at great risk due to the flooding of that salt lake. Measures need to be taken to reduce the water and/or release it in a way that doesn't devastate downstream ecosystems." S8

- "Require flood-proofing to 0.5 m above the 1:500 flood elevation." S14
- "planning measures are a highly cost-effective means of addressing the future impacts of flooding. However, it doesn't do much for existing assets already vulnerable to flooding." S15
- "In our experience, communities and regions don't have a good grasp of relating extreme events to floodwater distribution, damage and damage cost. Nor do they have a good grasp of the influence that adaptation options might affect that. So they are shooting arrows in the dark in terms of identifying promising planning, infrastructure and other adaptation alternatives…. The best approach to adaptation is regional – a cooperative approach….do the hard work to identify the most promising options for a community and region. Well worth the effort" S15
- "vulnerability to any particular hazard may be highly location-specific. So, ranking these hazards in a general way might prove a bit misleading…Sound decision-making is hard work…hard work is needed to deliver great solutions for vulnerable communities and regions." S15
- "many dam owners are not aware of the flood risk associated with their projects" S20
- "flood risk for urban areas is generally well mapped and understood…[but] local government (cities and towns, RMs, resort communities, etc.) frequently ignore this information when planning and approving developments. Much of the flood damage in the news in recent times has resulted from flood events well below design standards (1:500 in Saskatchewan) and should not have produced the damages that did occur." S20
- "Flood damage could be substantially reduced through education and responsible planning and development by local government. No new developments should be allowed in flood risk zones, and all existing developments should be flood proofed." S20
- "no generally accepted methodology exists to evaluate the effect of climate change on flood frequencies" S20
- [some useful mitigation measures are] the Municipal Risk Assessment Tool (http://www.mrat.ca/) S21
- "we need to rethink infrastructure in light of changing conditions [due to climate change]" S33
- "one of the major needs is a willing government that will intervene and deal with problems both at the regional and watershed level….more collaborative planning….build positive long-term relationships." S35
- "We are going to be dealing with significant climate change impacts on the prairies…. droughts..storms…floods….will tax the current economic and social structure…Conflict will inevitably result unless there are social planning skills and experience to coordinate a short or long-term response." S35

A snapshot of Stakeholders' Views on Wildfire

- "Severe droughts in 2001 and 2002 resulted in busy fire seasons with fires in 2002 that burned down into the peat bog areas making them very destructive and very difficult to suppress. El Nino winters have resulted in extreme fire seasons the following spring & summer…droughts mean more fires…" S1
- "Effective fire suppression combined with new development within the wildlands has resulted in large areas of overmature and unhealthy forests, parklands and grasslands that lead up to, and into, many communities….Forest fringe and northern communities face the

greatest risk from wildfires, but with continuous cropping being the standard, we have seen an increase in the number and size of prairie fires in the last few years also."S1

- "The Fort McMurray TV fire coverage last year resulted in a significant decrease in the number of human caused wildfires that happened in Saskatchewan and within other jurisdictions last year."S1
- "Major grass fires [have been] fueled by dead grass in the spring and standing crops in the fall." S14
- "Wildfires are a natural part of the Boreal Forest ecosystem." S16
- "The ability to reduce the number of evacuations is paramount to human safety and this can only be done if we ensure that communities, industry and individuals incorporate the proper mitigation technique to reduce wildfire risk and develop response zones around values at risk where wildfires suppression work can take place." S16
- "Research involves working with First Nations in Saskatchewan who have been evacuated due to wildland fire. Many communities have been evacuated multiple times, including Lac La Ronge Indian Band….Indigenous people have different values at risk…[e.g. concerns with] Let-It-Burn policy, because it impacted traditional lands and cultural values…" S19
- [some useful mitigation measures are] Firemap http://firemap.rmwb.ca/ , Climate and Canadian Prairies (Agricultural Land Use) for regional climate variability S21
- "Good communication plans need to be developed and clearly communicated to all residents" S22
- "more of an effort for government ministries to work together" S32
- "Northern evacuations imposed on our [First Nations] communities represent unique impacts including culture shock and long-term displacement. Family reunification issues are also among those mentioned by evacuees." S39
- "[mines and mining operations] have been under [wildfire threats] several times….there…needs to be clear understanding of when and how [Wildfire Management Branch] will support mines with wildfire threats." S46
- "media and social media exaggerate real conditions, for example, in 2015…air quality was actually better in Waskesiu than in Saskatoon or Regina....Local economy lost approx. 30 percent of business, with some losing 50 percent." S52

A snapshot of some of the Stakeholders' broader Views on Natural Disasters

- [with my work], "I have found that underlying structural stressors (e.g. economic issues, social inequality, lack of access to resources and services) play a major role in shaping people's experience of disaster." S3
- "people with resources can recover from a disaster, people without resources cannot" S3
- "I would like to see more focus on the deeper structural issues that make hazards into disasters." S3
- [current mitigation measures] "are adequate for what we have faced in the past. They are not adequate for what we may face in the future" S8
- "The people of this province have the right attitude and demeanour to endure these hardships [natural hazards in Saskatchewan] and improve upon them. They need good vision and science to help them make the best decisions" S8
- "…. many of the proposals listed here [to respond to natural disasters] are not necessarily expensive, [they] just simply require resolve and energy or reallocating funds from existing forestry/agricultural programs." S8

- "During a natural disaster, communication is probably the most challenging part" S11
- "the best approach to adaptation is regional – a cooperative approach" S15
- "the entire province is at risk from future climate extremes" S20
- "I laud the Government for forums such as this to compile the knowledge of stakeholders so that we can better understand how we should adapt and/or mitigate the worst effects of climate change going forward." S20
- "Better planning at regional scales needs to be done to support the effectiveness of local mitigation measures. Scenario Planning exercises are required to understand the range of variance associated with severe weather events and their effects on natural hazards. Natural hazards need to be viewed in combination and not as isolated events in order to understand cumulative effects and dependencies.... This is not a site-specific issue, rather an issue of national significance…. Practices on the ground need to be linked to broader initiatives at a wider scale, such as provincial and federal policies and reporting." S21.
- [we need] "a comprehensive holistic plan that is properly funded…more working together rather than in small groups…regional emergency measures….and structures to deal with natural disasters…."S28
- [we need] "policies and institutional capacity to ensure that all communities (i.e. all people) have access to the information and tools they need to adequately plan and respond to climate extremes. Setting a strong comprehensive strategic direction is the essential first step." S29.
- "we may not understand that there are likely limits to economic and population growth that this land can support. Ignoring this will only make impacts of future climatic extremes more severe. Are we prepared as a society to both understand those limits and to implement policies that will respect them?" S29
- "Across Canada natural disasters and requests for Disaster Financial Assistance Arrangement funding have been increasing in frequency and cost. We often see statistics mentioned that for every $1 spent on mitigation measures it saves us $4 in recovery costs down the road." S30
- "There needs to be continued investment in infrastructure to control risks. There needs to be an attitude of individual responsibility to prepare for risks by implementing practices that mitigate risks…There should be continued education about the risks…and what individuals can do to mitigate the risks." S31
- "We are tending to build an economy that does not have the inherent capacity to mitigate or deal with issues of climate change like an inadequate or excessive water regime. Without a solid basis for mitigation or collaboration, there will tend to be losers and winners. This is not the inherent nature of Saskatchewan or its residents. We need to get back to our cooperative and collaborative roots." S35
- "work needs to [be done] to recognize budget limitations, the cost or the risk to human life, infrastructure damage and the loss to the economy as a whole…Communication is the major component of the development and implementation of [planning]. All Levels of Government, NGO's Industry etc., etc. all have to be included [to determine where it makes sense to spend infrastructure dollars…drought-proofing…flood protection] …. identify problem areas province wide…perform…cost benefit analysis which also looks at environmental, social and other considerations…then the decisions to make changes proactively will follow" S36
- "[natural hazards] are imminent and preparedness is crucial" S44

- [to strengthen capacity to natural hazard risks:] "Public education providing plausible scenarios of what changes are expected with respect to future natural hazards…. will aid and enable stakeholders to design their own mitigation measures…The proposed scenarios at the scheduled workshops are an excellent method to convey and subsequently discuss future hazards." S48
- "how would we respond should large numbers of people experience loss of electricity and/or heat during a blizzard that restricted …ability to travel and our ability…to respond?" S53"
- "We cannot reduce the risk of natural hazards to zero. Benefit/cost assessment is important to consider." S56
- "This study is on the right track, getting the people's view." S60
- "Climate change…will change the playing field for all of these natural hazards…. [concerns I have about natural hazards include] lack of political will to acknowledge climate change risks, lack of capacity in municipal and provincial governments to develop adequate mitigation measures in a timely fashion." S68

Regional Stakeholder Workshop Summaries

The next section summarizes the major points identified by the stakeholders, with a summary of some of the regional priorities. For more details, please see the separate Saskatchewan Flood and Natural Hazard Risk Assessment Stakeholder Insights Report (Corkal, 2018), which lists more of the stakeholder data at each regional workshop, structured as follows:

- a brief overview of each regional workshop
- a grouped summary of the priorities identified for each drought, flood and fire natural hazard scenario discussion
- a tabular detailed list of the natural hazard impacts and mitigation identified by the stakeholders for the current and future scenarios
- a table identifying the other natural hazards noted by the stakeholders.

As noted earlier, this chapter is based on stakeholder contributions and perspectives, and does not attempt to evaluate confidence levels in stakeholder perceptions. Highly subjective perspectives or a lack of data backing up perspectives may affect confidence levels.

Yorkton – 29 Stakeholders

Yorkton's stakeholders provided a view of industry and ecological interactions to address natural disasters. Specifically, agriculture and rural communities are most "at risk" from natural disasters such as droughts and flooding. There were also clear connections made between drought and fire (e.g. water scarcity being problematic for both scenarios). The geographic area has been through a fairly continuous wet phase setting historic records during 2010-2016. Extremely wet conditions and flooding have been top-of-mind and challenging to address. The stakeholders identified issues related to infrastructure damage, illegal drainage, water movement and conveyance systems, and the need to learn from past experiences. The idea of mutual aid agreements is extremely beneficial for all natural disaster types, and is one way of helping cope when local and regional people are taxed beyond their capacity to address severe natural disasters. Yorkton stakeholders also identified heavy winds, plough winds and tornados as problematic natural disaster risks for this region.

The priority setting exercise targeted drought impacts on resources (agriculture, economic impacts, rural communities) with mitigation being long-term planning, effective resource management, planning (e.g. water management) and public education. For flooding, stakeholders identified major impacts to infrastructure, institutions, and policies; mitigation were identified as knowledge and awareness (e.g. including hydrology), local capacity and infrastructure design. For fires, impacts were identified as infrastructure and resource impacts (power lines, water and wastewater, water resources), with mitigation prioritizing a need for effective coordination of institutions and emergency responders, and safeguarding of water resources. The stakeholders emphasised the importance of effective warning and alert systems, communications, and well-coordinated well-integrated responses.

Saskatoon – 39 Stakeholders

The Saskatoon stakeholders identified a broad suite of risk impacts and mitigation. There was a strong emphasis on flooding and fire risk reduction, and the need for proactive planning in advance of natural hazard occurrence. Stakeholders suggested that broader, perhaps unique partnerships with industry and across agencies, be developed both for natural disaster preparedness and for disaster recovery.

The stakeholders identified a number of priority areas of concern. Drought impacts included impairment of community and municipal water supplies and related impacts to people, social and institutional impacts, and ecosystem impacts (including deteriorating water supply and water quality and increased fire risk). Agriculture and agricultural industry is the most affected sector during drought, with related impacts to communities. For flooding, major damage to infrastructure, buildings and transportation systems, utility lines, and land slumping are concerns, with related social impacts. Mitigation are seen to be improved planning and preparedness, better zoning, policy and infrastructure design, public education and knowledge, and incorporation of ecosystem management (e.g. wetland preservation, green infrastructure). Wildfire impacts were identified largely as social, industrial and economic. There was concern about law and order, security, isolations, economic slow-down, and stressed systems for decision-making. Wildfire mitigation were identified as FireSmart programming and knowledge, partnerships with planners, industry, institutions, and integrated response teams. Management, policy and infrastructure were identified as crucial for disaster preparedness, response and recovery.

Prince Albert – 31 Stakeholders

The Prince Albert stakeholders prioritized fires and floods as natural hazards of concern, but they were also clear in seeing a relationship between droughts and fires. They strongly recommended proactive long-term planning in advance of natural hazards, and proactive emergency response planning with effective implementation of emergency measures during the occurrence of natural hazards. The city of Prince Albert is a critical and important community link with northern Saskatchewan, and is recognized as an evacuation center or transportation hub for northern citizens affected by wildfires.

Drought impacts were prioritized largely as an information and infrastructure concern, with communications, drainage, transportation systems identified (e.g. roads can be better maintained during lower water levels, which has been a concern during wet phases). Drought mitigation were seen as opportunities for fire management (e.g. fire break construction), water management, and proactive long-term planning. Flood impacts are a significant concern, with damages to infrastructure (highways, communities, commercial and private property/buildings). Floods also impact the social structures (directly affecting people, institutions, responders). Environmental impacts were also recognized (e.g. issues with animal carcass disposal). Flood mitigation include inter-agency planning, watershed educations, effective leadership and decision-making and critical infrastructure (including buildings, roads, soil erosion protection). Zoning and by-laws are also recognized as critical mitigation efforts. Wildfire impacts clearly affect the forested lands and economic activities (forestry and recreation), but the Prince Albert stakeholders prioritized wildfire impacts largely as social: evacuations of people, stress on evacuees and responders, challenges and stress on wildfire disaster responders. Mitigation are recognized as effective programs (e.g. FireSmart, with an emphasis on the response and recovery activities, communications and data sharing between people in the affected areas and authorities involved in the decision-making. Emergency response plans, warning systems, training and preparedness are critical mitigation for wildfires.

La Ronge – 21 Stakeholders

La Ronge stakeholders highly emphasised the critical need for local participation and involvement in all phases of natural disaster preparedness and response. In particular, the northern region is highly vulnerable for limited access and egress by road and transportation distances. The northern communities and populations are more vulnerable due to remoteness. First Nations communities are at risk. When natural disasters occur, response plans, evacuations and communications are challenged and even more critical due to the northern realities of life and geography.

Northerners are, by necessity, typically more self-resilient then those in the south, and in many ways better prepared for natural disasters. They are accustomed to solving problems, and their local knowledge is essential in advanced preparedness planning and disaster responses. When the disaster is at a scale that requires outside help, the local knowledge is also essential in developing and implementing better communications plans and integrated responses. Local leadership is critical to convey the best, and most accurate information to local people and industries responding to disasters. Backup planning and infrastructure (for power, for access/egress, for human and equipment resources) is also extremely unique for northern people, their communities and northern industry. Capacities to deal with evacuations need to be considered (the how and the where, as northern capacities are also limited and stressed during disasters). Impacts to industry and recovery are costly, as supplies and transportation delivery have greater impacts with remote locations.

Some of the priority areas for flood impacts include planning and monitoring (hydrological information, real-time data of events, forecasting of risk and emergency response), access/egress into the north, with critical roads/bridges at risk of cutting off the region and/or affecting transportation systems for supplies and evacuations. Significant impacts from flooding occur on the economy, the communities and people, and infrastructure (buildings, roads, economic activities). Mitigation for flooding rely on effective communications as a disaster response, knowledge and best practices, and improvements to infrastructure and local capacity (including roads, bridges, drainage, development projects, alternate power supplies, etc. Wildfire impacts are clearly a main concern for stakeholders living in, and reliant on the forested landscape. Key impacts involve infrastructure damage (loss of power, water, heat, buildings, industrial activities), economic and social impacts affecting industry, forestry, recreation, tourism and local businesses. There may be widespread social impacts from wildfires affecting large regions and multiple communities. Wildfire mitigation is reliant on better evacuation plans, integration of local people and decision-makers, strengthened FireSmart programming, improved firefighting activities and communications. The integration of local capacity is seen as essential and critical in wildfire disaster preparedness planning, firefighting during a disaster, and response recovery. While drought was not specifically discussed, stakeholders recognized that northern drought relates to ecosystem changes, and increased risk of wildfires. Stakeholders also noted that the northern geography and ecosystems are susceptible to potentially significant impacts with natural disasters such as flooding, fires, and future climate change impacts, all of which affect the region's geography, communities, people and economic activities.

Swift Current – 21 Stakeholders

The Swift Current stakeholders identified agricultural losses and watershed impacts as key priorities for drought impacts, along with an increased risk of grassfires with drought. Mitigation relate largely to effective water management, source water protection and interaction with local stakeholders at the watershed scale. Flood impacts infrastructure, private property, dams and dam safety, buildings and transportation systems. The region is essentially a "water scarce" semi-arid climate, yet during recent wet years or flood events, runoff and drainage of floodwaters has become a consideration for landowners and communities. Emergency preparedness plans, along with improvements to engineering design and legislation on effective water management were seen as critical. Grass wildfires were seen as a high risk, and stakeholders were concerned about the rapid spread of grass fires, and the lack of aerial support to suppress grass fires. Improvements to incident command systems and social services responses were identified, along with dialogue between forest fire and fire commissioners for more effective disaster response.

Stakeholders identified drought and water shortages as common characteristics in this region. Water and watershed management are therefore crucial for this water scarce region. Education and awareness, and citizen engagement on watershed stewardship is seen to be essential. Droughts increase grassfire risks, and cause serious agricultural impacts affecting the industry, local economic activities and the communities in the region. Mitigation relay on effective water management, source water protection, public education and regional planning. While less common, recent floods and excessive wet conditions have caused very serious impacts to dams (threatening dam safety), highways, rural roads and transportation networks, as well as contaminating water sources. Flood mitigation rely on effective emergency preparedness and response plans, with local, provincial and federal planning. Engineering and legislation to ensure infrastructure is at current standards is also seen to be critical flood mitigation. Wildfires in the south are essentially grassland fires (although Cypress Hills and other forested and parkland areas may also be at risk). Wildfires have serious human resource impacts on local volunteers. Much of the area is remotely populated, so disasters may affect individuals and communities, and unique areas. For example, access/egress and evacuation of people in Cypress Hills parklands could be very difficult should a disaster cut-off transportation or communications networks. Wildfire mitigation rely on effective coordination of responders and equipment. Communications, mobilization, local and inter-agency coordination are challenging due in part to rural remoteness. Advanced planning and preparedness is essential, along with training and mutual aid agreements being established well in advance of disaster occurrence.

Regina – 58 Stakeholders

Stakeholders at the Regina workshop placed a strong emphasis on drought's broad impacts, including institutional challenges managing water, water competition, water scarcity and ecological impacts. Mitigation were identified as long-term water management planning and implementation. Flood impacts include damages to infrastructure, the economy, the environment and society at large. Flood mitigation rely on better preparedness plans, improved legislation, zoning and enforcement, and knowledge and education programs. Wildfires impact infrastructure, the economy, social structures and the environment. Mitigation were identified with FireSmart programming, knowledge and communications, zoning and development planning.

Regina's stakeholders were concerned about big-picture policy impacts, the danger or risk of dismantling past successful programs and institutional knowledge bases (e.g. the closure of the federal government's soil and water conservation programs developed and delivered by the former Prairie Farm Rehabilitation Administration of Agriculture and Agri-Food Canada [1935-2013]; the loss of historical knowledge from past water management and disaster risk reduction activities, etc.). Learning from past successes, continual advancement of science and policy, enhancing academic and institutional knowledge bases were seen as essential ingredients in dealing with natural disasters, especially with compounded impacts from climate change.

Stakeholders stated drought causes institutional challenges in management water, with water competition and conflict, water scarcity and ecological impacts. Stakeholders identified drought as having widespread impact to agriculture and regional economies. Most droughts slow down the economy, and are not generally "catastrophic" [although multi-year droughts could become so]. There is degradation on soil and ecosystem health, and improper development during dry times, when construction on dry floodplains may occur. Drought impacts infrastructure (soil shrinkage, foundation impacts) and causes ecosystem degradation with reduced water quality and water supplies. Ecosystem impacts from drought may affect drinking water supplies for people, and create water competition. Mitigation for drought involve proactive and effective watershed management, water resource management, public education and water stewardship, and an engaged, responsible citizenry. Severe droughts may require backup or alternate water supplies. Institutional responses are also critical in water management and water conservation.

Stakeholders identified flood impacts to infrastructure and economic activities, environmental degradation, and community and social impacts. Stakeholders identified flood impacts to agriculture, runoff and drainage problems in flatland areas, and water conflicts between neighbours (communities and landowners). Floods have significant impacts to major transportation systems, communities, buildings, dams, other infrastructure, industry, causing earth movement and slumping, soil swelling, stranding agricultural animals, and causing ecosystem degradation (e.g. pollutant transport). Mitigation involve protective infrastructure, engineering of infrastructure to current codes, flood risk planning, regional watershed management, zoning and enforcement of regulations and policies, responsible planning and development.

Wildfire impacts critical infrastructure, communications and transportations systems, cascading infrastructure losses, animals and livestock, and human health with smoke and degraded air quality. Mitigation include FireSmart preparedness programs, Mutual Aid Agreements, knowledge and communications and effective zoning and development.

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Saskatchewan Flood and Natural Hazard Risk Assessment (Ver. 170503)

Pre-workshop Input from Invited Stakeholders

Background:

Natural hazards affect people, places and the economy. Northern **fires** near La Ronge displaced over 13,000 people in 2015, and burned 1.6 million hectares of forest. From 2010 to 2016, **excessive wet conditions and flooding** affected many Saskatchewan people and communities (damaging infrastructure, impairing economic activities, flooding productive and recreational land). In the 1920s-30s **droughts** caused severe environmental damage as well as social and economic unrest; in 2001-02, **drought and water scarcity** caused a $5.8 billion drop to Canada's GDP, with a $1.6 billion drop to Saskatchewan's agriculture.

The **Saskatchewan Flood and Natural Hazard Risk Assessment** project (see fact sheet provided) is investigating Saskatchewan's exposure and resiliency to **natural hazards**. This work will add knowledge to help prioritize **mitigation measures** to reduce risks and impacts from natural hazards.

Pre-workshop Input from Invited Stakeholders – Your input adds valuable information to this project

1. **Select the group or group(s) that best fit who you represent and identify who you represent:**
   - ☐ Communities (local municipalities; rural municipalities, etc.)______________________
   - ☐ First Nation(s)_________________________________
   - ☐ Industry (Business, Sectors, Industry Associations, etc.)_________________________
   - ☐ Provincial Government________________________________
   - ☐ Federal Government______________________________
   - ☐ Academia__________________________
   - ☐ Non-government organizations (SUMA, SARM, Watershed Groups, Environmental Orgs, Other NGOs, etc.)___________________________
   - ☐ Emergency Preparedness, Disaster Response, Insurance Industry____________________

2. **What historic natural hazards have directly affected your interests** (i.e. past experience)**:**
   i. Natural hazard:
      - ☐ Fires
      - ☐ Floods/Excessive Wet Conditions
      - ☐ Drought/Water Scarcity
      - ☐ Other (please define)

   ii. Provide any details you recall (date, season, area, how frequent it recurs)

3. **What Impacts did historic natural hazards have on you/your area of interest?** (describe the impacts, with examples if possible, and any unique factors/reasons for some impacts).

4. **What mitigation measures do you/your interest currently practice?** (e.g. flood/fire/drought preparedness measures/plans; list examples, explain how these mitigation measures help)

5. **Based on historic exposure, are current natural hazard mitigation measures adequate?** (e.g. existing protection, preparedness plans, infrastructure that reduces risk, institutional capacity and programs, etc.)?

    i. **Yes or No**
    ii. **Explain why and describe any geographic area at greater risk** (e.g. area and hazard):

    iii. **What do you think is needed to strengthen capacity to reduce natural hazard risks to people, the economy, the environment?** (give examples of what is needed, how it will help)

6. **Are you concerned about changing risk exposures into the future? Yes or No?**
    i. **Which natural hazards are you most concerned about for future risks (e.g. future trends)?**
        - ☐ Fires
        - ☐ Floods/ Excessive Wet Conditions
        - ☐ Drought/Water Scarcity
        - ☐ Other (please define)
    ii. **Explain why and describe any geographic area at future risk** (area and specific hazard):

    iii. **What mitigation measures do you think are needed to be better prepared for future natural hazards?** (provide examples to explain what is needed, and how it may help).

7. **What are the most significant natural hazards facing Saskatchewan's people, and economy and environment?** (List and briefly describe why)

8. **List any general comments, concerns you have about natural hazards in Saskatchewan:**

Saskatchewan Flood and Natural Hazard Workshop AGENDA

INTRODUCTION – 09:00-9:15

i. MGR Jason Rumancik
ii. Darrell Corkal PPT

HISTORIC NATURAL HAZARDS – our experiences and knowledge (plenary)– 09:15 - 10:15

i. **Drought** – Virginia Wittrock, Elaine Wheaton 15 min.
ii. **Flood** – Bob Halliday 15 min
iii. **Fire** – Mark Johnston (or Virginia Wittrock) 15 min
iv. Plenary Discussion – Q&A 15 min

HISTORIC NATURAL HAZARDS – LOCAL & STAKEHOLDER KNOWLEDGE Breakout Groups – 10:30-11:30

i. ***Drought*** – Facilitator: Elaine Wheaton; Recorders: MGR
ii. ***Flood*** – Facilitator - Bob Halliday; Recorders: MGR
iii. ***Fire*** – Facilitator - Mark Johnston (or V. Wittrock); Recorders: MGR

HISTORIC NATURAL HAZARDS - STAKEHOLDER INSIGHTS (Plenary) 11:30-12:00 – Darrell Corkal - facilitation

i. **Impacts:** variability, range, risk
ii. **Mitigation Measures**- challenges, needs
iii. **Concerns/Needs** – what would help for improved preparedness
iv. **OTHER NATURAL HAZARDS?**
   - Drought, Flood, Fire, Excessive Wet Conditions
   - Hail, Slumping/Landslides, Tornado, Wind
   - Ice/Snow/Blizzard, Insects and Diseases (crop, animal, human)
   - heat stress (crop, animal, human), earthquake, etc., other?
v. **Maps –** identification of risk areas
vi. **Priority ranking exercise** on all Hazard/Mitigation Stakeholder Input

Lunch 12:00 -13:00 (extend the Other Natural Hazards, Maps, Priority Ranking exercise/PosterViewing)

FUTURE NATURAL HAZARDS - WHAT MIGHT THE FUTURE PRESENT? 13:00 – 13:30

- **Presentation by Virginia Wittrock – 13:30, a future scenario for Saskatchewan**

FUTURE SCENARIOS – LOCAL & STAKEHOLDER KNOWLEDGE Breakout Groups – 13:30-15:00

i. ***Drought*** – Facilitator: Elaine Wheaton; Recorders: WSA, MGR
ii. ***Flood*** – Facilitator - Bob Halliday; Recorders: WSA, MGR
iii. ***Fire*** – Facilitator - Mark Johnston (or V. Wittrock); Recorders: WSA, MGR
iv. ***Other Natural Hazards*** – e.g. Ice Storm/ Tornado

FUTURE NATURAL HAZARDS - STAKEHOLDER INSIGHTS (Plenary) 15:00-15:30 – Darrell Corkal - facilitation

i. **Future Impacts:** variability, range, risk
ii. **Existing and Future Mitigation Measures**- challenges, needs
iii. **Future Natural Hazards Concerns/Needs** – what would help for improved preparedness
iv. **OTHER FUTURE NATURAL HAZARDS?**
   - Drought, Flood, Fire, Excessive Wet Conditions
   - Hail, Slumping/Landslides, Tornado, Wind
   - Ice/Snow/Blizzard, Insects and Diseases (crop, animal, human)
   - heat stress (crop, animal, human), earthquake, etc., other?
v. **Maps** – identification of risk areas
vi. **Priority ranking exercise** on all Hazard/Mitigation Stakeholder Input

CLOSURE – 15:30 – 16:00

i. Darrell Corkal Overview of Day's Findings
ii. MGR Jason Rumancik Adjournment

Consultation Scenarios

The scenarios used to stimulate stakeholder discussions are briefly summarized as follows:

Drought

Current scenario – 3-year drought, serious water scarcity, industry and urban water competition, deterioration of water quality (e.g. toxic algae), First Nations water shortages and quality problems, pressure on provincial/federal institutions, slightly worse than the 2001-02 drought which caused $1.6B agricultural GDP drop in Saskatchewan (across Canada this drought caused a $5.8B drop in Canadian GDP).

Future Scenario – severe 5-year drought, widespread water scarcity, heat stress, insect and disease vectors affect crops and human health, extremely low flows in streams and rivers impair aquatic ecosystems, water bans now affect diversified economic actors and communities, some agricultural producers are forfeiting on long-term contracts, significant economic impacts impair a broader and diversified economy, food security is being questioned. Old-timers or their relatives recall the multi-year droughts of the 1920s-30s.

Flood

Current Scenario – above average snowpack and seasonal rain events with very wet antecedent conditions in the prairies, reservoirs are overtopping, some water diversion structures are eroding, severe flooding has affected recreational lakes and cottages, 40 percent of southern agricultural land is flooded or waterlogged, water quality degraded with turbidity and contaminant runoff from industry and lagoon overtopping, 10 First Nations communities can no longer supply safe drinking water. Many towns and cities have had to declare states of emergency due to flooding. People recall the waterlogged, wet phase experienced from 2010-2016.

Future Scenario – extremely wet conditions have persisted for 3 years; wet snow and winter rains during a warm winter are causing flooding and ice damage during winter, health departments are reporting serious rise in injuries due to slipping on ice, hundreds of homes have suffered damage to roofs, two major industries were forced to stop production due to roof collapse, ice blockages washed out two major crossings affecting Highways 10 and 16, power lines have collapsed and communities have lost power, emergency management responses are taxed. People remember news stories of the 1998 Quebec Ice Storm.

Wildfire

Current Scenario – severe forest and grassland fires occur over several areas, over 1 million hectares of forest burned in June-July, 8,000 people were evacuated including 500 First Nations people in two communities and 1,500 campers in the Prince Albert area, oil and gas production in the northeast was shut down for 4 weeks in the St. Walburg area, 20,000 hectares of grassland fires occurred in parched prairies near Swift Current and Maple Creek, seniors have been hospitalized due to smoke and poor air quality. Emergency management responders are taxed and exhausted after an extended demand on their resources (June-September). People recall the devastating 2015 forest fires near La Ronge.

Future Scenario – extremely dry conditions over 4 years have significantly increased fire risk. Compounding matters, the Mountain Pine Beetle made a resurgence, infecting 2 million hectares of forest; another 2 million hectares of forest are actively burning, and smoke extends deep into the mid-U.S. states. Communities across Saskatchewan and Manitoba have sent hundreds of seniors to seek health care with smoke allergies. Severe winds have damaged many homes. Two tornadoes caused 10 deaths and destroyed 100 homes. Regional forest fires and grassland fires are also occurring near rural population bases in the southern portions of the province. Local economic and firefighting damages exceed $2 million. Provincial firefighting costs are estimated to be as much as $150 million. People recall past extreme fires, but recognize the mountain pine beetle infestation and major wind and tornado damages have caused devastating compounding impacts, with the most serious impacts to northern people, First Nations, tourism and northern economic activities.

Stakeholder Workshop Assessment Form

WALKER PROJECTS Consulting Engineers · Project Managers | R.Halliday & Associates Water Resources Management | Wheaton Consulting | src

Saskatchewan Flood and Natural Hazard Risk Assessment Stakeholder Workshop Assessment

Please answer the following questions to the best of your ability. We value your feedback and use it to continually improve our work. Please **circle the response** that best describes your level of agreement with each of the following statements.

1. **Overall, the workshop was a productive use of my time.**

Strongly Agree Agree Neutral Disagree Strongly Disagree

2. **I learned more about flood/natural hazards, risks and mitigation.**

Strongly Agree Agree Neutral Disagree Strongly Disagree

3. **As stakeholders, we contributed our knowledge on impacts and mitigation.**

Strongly Agree Agree Neutral Disagree Strongly Disagree

4. **The Small Breakout Groups were effective in stimulating discussion.**

Strongly Agree Agree Neutral Disagree Strongly Disagree

5. **The Plenary Sessions helped advance ideas for disaster risk & preparedness.**

Strongly Agree Agree Neutral Disagree Strongly Disagree

6. **I believe there is a need to increase resiliency for floods and natural hazards.**

Strongly Agree Agree Neutral Disagree Strongly Disagree

7. What did you like most about the workshop?

8. . What did you dislike about the workshop?

9. Other comments?

Saskatchewan Flood and Natural Hazard Risk Assessment