THE SCHOOL OF PUBLIC POLICY

UNIVERSITY OF CALGARY

FUTURE OF MUNICIPAL GOVERNMENT SERIES

Volume 15:43

March 2023

ALBERTA MUNICIPALITIES

CLIMATE RISK ASSESSMENT AND ADAPTATION CONSIDERATIONS FOR MUNICIPAL GOVERNANCE

Mary-Ellen Tyler

Acknowledgement: Financial support for this discussion paper was provided by the School of Public Policy (SPP), at the University of Calgary as part of a research partnership between the SPP and Alberta Municipalities (https://www.abmunis.ca/) on the future of municipal governance)

TABLE OF CONTENTS

FIGURES

TABLES

CLIMATE RISK ASSESSMENT AND ADAPTATION CONSIDERATIONS FOR MUNICIPAL GOVERNANCE

Mary-Ellen Tyler

EXECUTIVE SUMMARY

Within the last 10 years, four of the 10 most extreme and extremely expensive weather-related disasters in Canada have occurred in Alberta, and climate modelling for Western Canada projects increasing changes and weather extremes. Changing and extreme conditions will continue to affect many aspects of municipal operations over the next 10 to 30 years. The major risks and impacts of changing climate conditions directly affecting municipalities involve infrastructure performance, increasing water stress, land use change and asset management.

Long-term seasonal temperature and precipitation changes punctuated by extreme weather conditions are a costly combination affecting local governments and communities. Alberta has a diverse range of climate risks, and risk assessment, adaptation and disaster response needs to reflect this diversity. Surveys done in 2019 and 2021 identified common barriers affecting municipal effectiveness in managing and adapting to climate risk which include: available staff time; access to climate risk and adaptation expertise; access to financial resources; and access to locally relevant and credible climate information and data. Municipalities in Alberta with populations less than 10,000 are more likely to experience these barriers than larger and urban municipalities better positioned to have access to the specialized resources necessary.

All Alberta local authorities are required to have an emergency management plan to respond to extreme weather events of relatively short duration. However, longer term, extreme shifts in seasonal temperatures and precipitation are projected over the next 20 to 30 years that will continue to impact municipal land use planning, water availability and infrastructure costs. Climate risk and adaptation need to be integrated into municipal plans, infrastructure maintenance, capital budgets and asset management to strengthen local resilience. Municipalities in Alberta have a provincial statutory framework that can address climate risk assessment and adaptation. Eight opportunities are identified that can be used within Alberta's municipal government model to increase municipal effectiveness including: greater use of Intermunicipal Collaboration Frameworks (ICFs) and development of a Climate Adaptation Research and Decision Support (CARDS) network to provide multi-disciplinary decision support to local government decision-makers in different geographic areas of Alberta.

PROJECT BACKGROUND AND RELEVANCE

The Alberta Municipalities (ABMunis) is involved in discussions with the provincial government, member municipalities and associated municipal organizations to better understand issues and options related to future municipal governance. Discussions about possible municipal futures have been ongoing in some form both prior to and pursuant to Alberta's *Modernized Municipal Government Act* (Bill 21, 2017) which introduced Intermunicipal Collaboration Frameworks (ICFs) into legislation. Since 2017, there has been renewed policy interest in the future of municipal governance resulting from increasing concerns about both short-term and long-term financial and administrative viability of Alberta municipalities. Specifically, the loss of oil and gas revenue in certain locations, together with provincial financial restraint and increasing infrastructure and servicing costs, have raised concerns. Other pandemic and geopolitical stressors have also emerged, producing widespread economic, social, cultural and environmental shifts and uncertainties which continue to affect costs, interest rates and revenue generation.

The future of municipal governance is critical to Alberta's future and a major public policy issue. To this end, Alberta Municipalities established a research partnership with the School of Public Policy at the University of Calgary to co-ordinate the production of independent research and discussion papers in specific areas such as finance, demographics, infrastructure and governance. As one of these discussion papers, this topic is somewhat different insofar as climate change has not traditionally been viewed as primarily a local government activity. To date, federal and provincial policies and programs have focused on reducing carbon and other greenhouse gas emissions, as have municipalities pursuant to specific federal and provincial programs. This has not been without controversy in Alberta given that oil and gas has been the bedrock of the province's economic success.

PURPOSE AND OBJECTIVES

The focus of this paper is how municipalities can adapt and develop resilience to extreme climate conditions which are projected to increase. The purpose of this report is to discuss ways in which municipalities can effectively integrate climate risk assessment and adaptation into their statutory responsibilities and the objectives are to:

- Identify the main climate change risks for Alberta;
- Outline the provincial legislative framework that enables municipalities to take climate risk action; and
- Identify available opportunities for increasing capacity and effectiveness of Alberta's local governments to undertake climate risk assessment and adaptation.

WHY MUNICIPALITIES AND WHY NOW?

Major infrastructure projects related to natural resource management, including irrigation canals, dams and reservoirs for flood control and agriculture, have mainly been the funding responsibility of the provincial government. Similarly, disaster relief and emergency management related to extreme weather events have mainly been funded by provincial and federal government agencies and both public and private insurance companies. Municipalities in Alberta are responsible for 10 per cent of any emergency management-related disaster recovery costs and, depending upon the circumstances, these costs can be exceptionally high. For example, four of the 10 most expensive extreme weather-related disasters in Canada over the last 10 years have occurred in Alberta:

- The 2013 southern Alberta floods ($3.5 billion);(Insurance Bureau of Canada, 2021)
- The 2016 Fort McMurray wildfires ($3.7 billion) (Statistics Canada 2017);
- The 2020 hailstorm in northeast Calgary ($1.2 billion) (Canadian Underwriter 2020); and
- The 2021 Alberta drought ($1 billion in insurance payouts) (Canadian Underwriter 2021).

Unfortunately, these are not one-off events. Projected increases in seasonal temperatures and precipitation increase the likelihood of more frequent extreme weather events in Western Canada. In addition to public safety concerns, municipalities are faced with increasing recovery costs and costs related to risk assessment and adaptation (specifically related to infrastructure). Alberta's local authorities are facing a financial threat from a combination of factors:

- Provincial funding is limited and increases uncertainty;
- Additional revenue-generation capacity from municipal taxes is limited;
- Infrastructure capital and operational costs continue to increase,
- increasing costs and limitations of public and private insurance.

Financial risk is a pragmatic driver, if not a forcing function, for rethinking how municipalities can effectively and efficiently adapt to climate change. Given the twin certainties of increasing climate risk and the increasing costs of infrastructure and service delivery, it is critical for municipalities to start thinking now about how financial risk can be reduced, shared or offset.

THE CLIMATE AND WEATHER CONNECTION

The intent of this section is to provide a brief overview of the global climate-weather connection as a context for understanding the type of changes expected over the next 20 to 30 years. The United States Geological Survey describes climate as referring generally to very large-scale atmospheric conditions and processes averaged over hundreds of years. In contrast, weather refers to short-term conditions experienced at local scales.

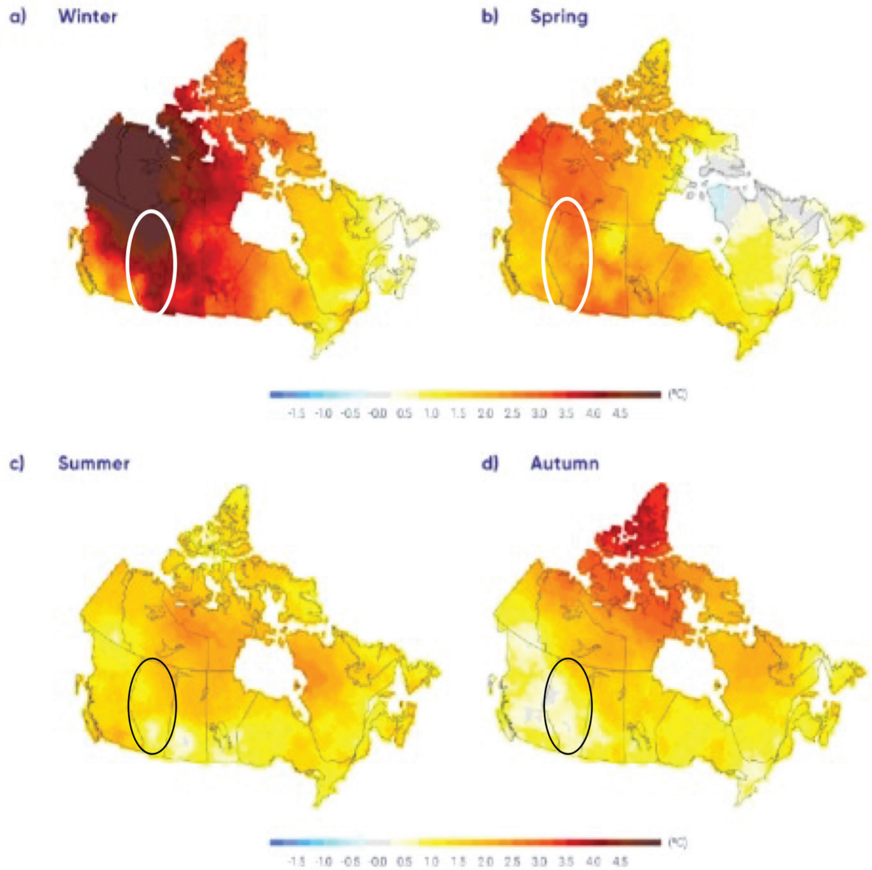
The original political and scientific debates which emerged following the release of the initial International Panel on Climate Change (IPCC) 1990 and 1992 reports focused primarily on the degree to which greenhouse gas increases could be attributed to human activities and fossil fuel burning. However, over the past 32 years, there has been significant development in climate science thinking as well as the analytical tools and methods used in climate science. One example of the specialized mathematical techniques that have developed is the ability to move beyond climate change detection and towards climate change attribution. Specifically, detection involves the use of available databases (historical and contemporary) to identify statistical changes in multiple planetary climate system indicators. In contrast, attribution establishes the most likely causes for detected changes relative to a defined level of statistical confidence (Le Treut et al. 2007). The World Meteorological Organization's (WMO) "State of the Global Climate Report 2021" states: "It is becoming increasingly possible to carry out near-real-time attribution assessments that use peer-reviewed methods to reach conclusions within just a few days of a weather record being broken" (WMO 2022). Such rapid attribution studies have most recently been carried out for the heat dome in British Columbia in June and July 2021 and the British Columbia floods in November 2021. The WMO (2022) concluded these events "...would have been virtually impossible without climate change."

Notwithstanding the progress made in modelling methods and understanding and interpreting climate change modelling projections, knowledge is still incomplete. Global system models are limited by the level of spatial resolution (detail) they can provide and the degree of uncertainty involved, especially for small area studies that are usually the focus of municipal assessments (Bush and Lemmen 2019).

Several datasets and reports can be found that are relevant to regional/localized climate change studies. The North American Regional Climate Change Assessment Program (NARCCAP) and the Coordinated Regional Downscaling Experiment (CORDEX) are the primary sources of downscaled projections for North America. Downscaled projections for Canada are available at a 10-km scale resolution (Pacific Climate n.d.) which is considered "... better suited for regional and local use ..." (Bush and Lemmen 2019). This scale of resolution is available through Environment and Climate Change Canada's Climate Data Portal and the Canadian Climate Atlas. These are the primary sources for regional and local data and projections. A more detailed explanation of current climate science and climate change assessment methods is available in the federal government's publications: "Canada's Changing Climate Report" (Bush and Lemmen 2019), "Regional Perspectives Report" (Sauchyn et al. 2020) and "Canada in a Changing Climate: National Issues Report" (Warren and Lulham 2021).

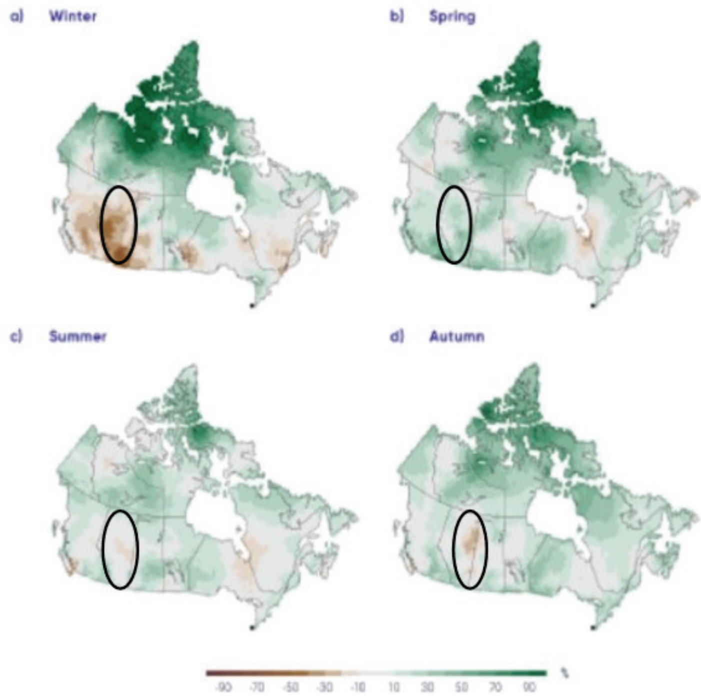
While the focus of these reports is on future climate extremes, there have already been significant seasonal temperature and precipitation changes recorded in Western Canada since 1948. These are not hypothetical or projected changes; they have already happened and are based on daily monitoring of calibrated weather stations. Figures 1 and 2 illustrate the significant seasonal temperature increases and precipitation decrease that have occurred in Alberta between 1948 and 2016.

Figure 1. Seasonal Temperature Changes 1948 to 2016



Source: Bush and Lemmen (2019).

Figure 2. Seasonal Precipitation Changes 1948 to 2012



Source: Bush and Lemmen (2019).

PROJECTED CHANGES FOR ALBERTA AND WESTERN CANADA

There is an emerging consensus on the nature and extent of changes expected for Alberta's climate future. The government of Canada's "Changing Climate Report" (Bush and Lemmen 2019) and "Regional Perspectives Report" (Sauchyn et al. 2020), together with "Canada's Top Climate Change Risks" (Council of Canadian Academies 2019), all project the following 12 changes likely to occur and continue to occur over the next 20 to 50 years:

- Seasonal temperature variability and extremes;
- Extremes in daily temperature (day and night);
- Long duration heat events;
- Rare hot extremes (one in 20-year extreme becomes one in five-year extreme);
- Seasonal precipitation changes (increases and decreases);
- More frequent heavy precipitation events;
- Rare precipitation events (expected to be twice as frequent);
- Increases in winter streamflow;
- Decreases in mean annual streamflow (specifically in Alberta and Saskatchewan);
- Decrease in the duration of snow and ice (mountain and coastal regions);
- Increases in maximum snow accumulation at northern high latitudes (due to increase in cold season precipitation); and
- Decreases in lake ice cover duration by one month.

Future projections for the Prairie Provinces indicate much warmer seasonal temperatures. According to Zhang et al. (2019), increasing temperatures will be accompanied by increases (in both amount and intensity) of annual precipitation totals with most of this increase occurring in winter and spring as both rain and snow events. Increasing temperatures will also affect and increase rates of water and moisture evaporation and plant water loss through increasing transpiration. This in turn creates conditions for "… more frequent and intense droughts and soil moisture deficits" across the southern prairies in summer months" (Cohen et al. 2019). Given 80 per cent of Canada's agricultural land and much of Canada's irrigated agriculture occurs in the prairies, these ongoing temperature and precipitation increases will have a direct and cumulative effect on water resources, ecological systems and agriculture (Sauchyn et al. 2015).

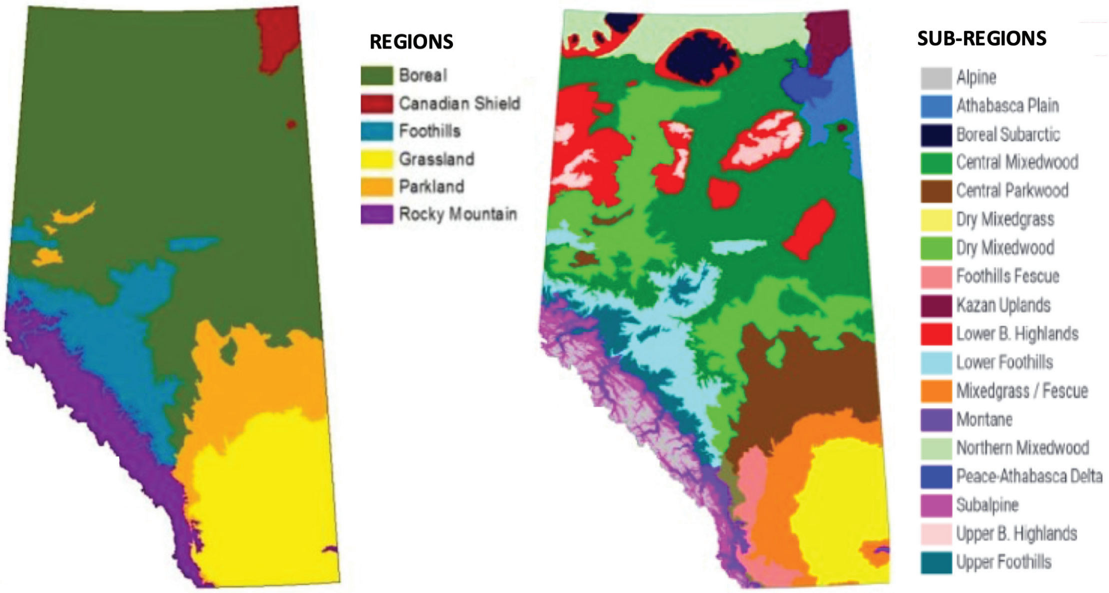
ATMOS Research and Consulting (Hayhoe and Stoner 2019) identifies projected changes for Alberta on a "per degree of global mean temperature increase" as follows:

- "A 2 degree C increase in average winter and 1.5 degree C increase in average summer temperature";
- "An increase of about 3 degrees C in the temperature of the coldest day of the year and an increase of about 2 degrees C in the temperature of the warmest day of the year";
- "A two-week lengthening of the frost-free season, and between a two to four-week lengthening of the growing season, with greater changes for more southern locations";
- "A 5-10% increase in September-April precipitation, with between 5-10% more falling as rain compared to snow";
- "A 50% increase in the number of very wet days (more than 25mm in 24 hours) and a 20% increase in the amount of precipitation on the wettest day of the year"; and
- "Proportional decreases in heating degree-days and increases in growing degree-days and other cumulative heating indices."

It is important to note that changes in "actual number of days per year experiencing extreme high and low temperatures are projected to increase exponentially, rather than linearly, as global mean temperature increases" (Hayhoe and Stoner 2019). Exponential growth occurs when an increase in a quantity over time is proportional to the quantity itself (Bernstein and Reznikov 2003). Unlike linear growth, which increases by a fixed or constant amount, exponential growth increases by a constant percentage over a fixed time interval. This means, in some locations, the number of days per year above 30 C could double per degree of global warming (Hayhoe and Stoner 2019).

Shifts in temperature and precipitation over the next 30 years will continue to affect ecological landscape processes. Changes in moisture, growing-degree days and seasonal temperature extremes (both hot or cold) all physiologically affect plant and animal species, habitat quality, food web relationships and soil nutrient availability in different ways and at different scales. Alberta has six natural regions that represent colder northern influences, hotter southern, a central transition zone and the Rocky Mountains on the west, as illustrated in Figure 3. However, 18 natural subregions also occur within these regions (Figure 3). This represents a significant degree of local diversity and variability that needs to be understood and incorporated into interpreting long-term changes in temperature and precipitation.

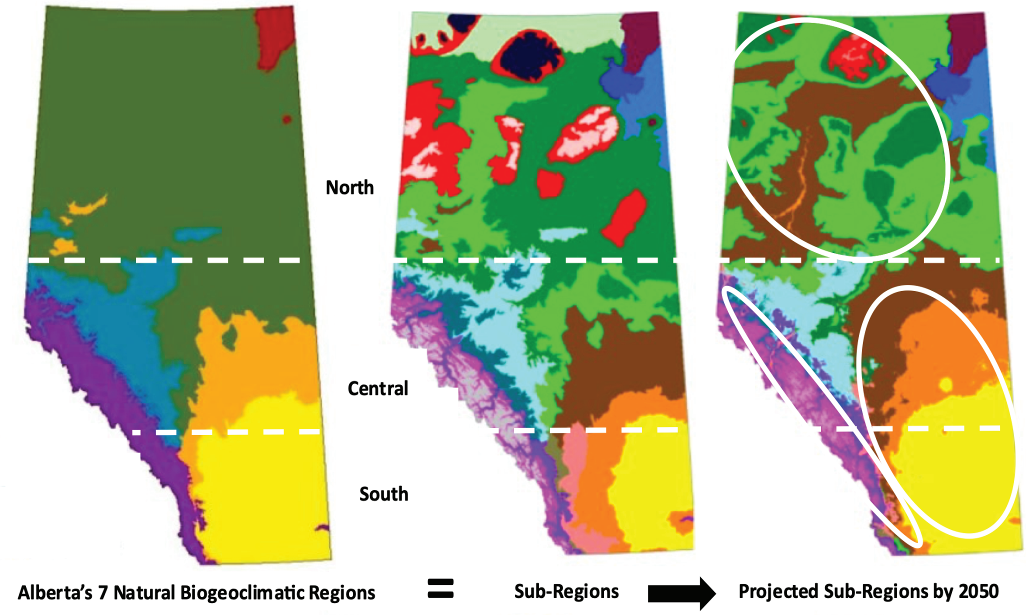
Figure 3. Alberta's Natural Regions and Subregions



Sources: Shank and Nixon (2014) and Sauchyn et al. (2020).

As illustrated below in Figure 4, the subregions are projected to undergo significant change over the next 30 years in response to changing seasonal temperature and precipitation patterns. These ecological changes are likely to have significant implications for forestry, agriculture, wildlife and water resources at both a local and regional level.

Figure 4. Projected 2050 Climatic Transition of Alberta's Natural Subregions



Sources: Shank and Nixon (2014) and Sauchyn et al. (2020).

THREE MAJOR ISSUES AND THREE MAJOR RISKS

The climate change research done by government agencies, the insurance sector and academia has identified a number of common issues and climate change risks. Warren and Lulham (2021) examine both issues and risks for seven areas of concern:

- Cities and towns/rural and remote communities;
- Ecosystem services;
- Water resources;
- Economic sector impacts;
- Litigation;
- Finance; and
- Costs and benefits of adaptation.

This report also identifies three major issues:

- "Large gaps remain in our preparedness for impacts of climate change as demonstrated by extreme weather events, such as floods and wildfires;"
- "There is abundant research indicating that current efforts to adapt are insufficient in the face of rapidly accumulating social and economic losses from current and future climate change impacts;" and
- "Local action to reduce climate-related risks is increasing, although limited capacity is challenging the ability of many communities to act" (Warren and Lulham 2021).

If not addressed, these issues are likely to continue to increase the risk of climate change impacts related to extreme weather. The Council of Canadian Academies' (2019) Expert Panel on Climate Change Risks and Adaptation Potential identified three types of climate change risk as having the highest priority:

- Risks to physical infrastructure and lifecycle maintenance from changing seasonal temperature and precipitation conditions and from extreme weather events increase the likelihood of power outages, grid failures and the risk of cascading infrastructure failures;
- Risks to water systems and water supplies, including reduced water quality and declining access for communities, industry and utilities due to changing precipitation patterns, glacier melt, diminishing snowpack and earlier or more variable spring runoff;
- Risks related to governments' ability to effectively provide new or improved policies, programs and budgets to respond to and manage climate risks, including addressing the costs of extreme event recovery.

These risk priorities highlight the need for specialized decision-making, risk management and asset management in dealing with the local and regional effects of a changing climate. The risks associated with infrastructure, water and governance capacity are described in more detail below.

INFRASTRUCTURE

Infrastructure risk has significant consequences because of the dependency of virtually all socio-economic activities on one or more types of infrastructure. The assessment of infrastructure risk is complicated by the state of existing municipal infrastructure which can be highly variable based on age, lifecycle stage, condition and infrastructure deficit. The term "infrastructure" in the context of municipal responsibilities is used generally and specifically to refer to a range of possible services and built components. Infrastructure can include buildings, roads, pipelines, bridges, dams, water and sewer pipes and treatment facilities, storm-water drainage systems, electricity, natural gas and telecommunication delivery systems. For example, the "Canadian Infrastructure Report Card" (Canadian Infrastructure 2019) includes the following infrastructure categories: roads and bridges, culture, recreation and sports facilities, potable water, wastewater, solid waste and, in some cases, energy and communication utilities. Approximately two-thirds of all public infrastructure in Canada is owned and maintained by municipal governments and an estimated one-third of this is in "relatively poor condition," needing retrofit or replacement (Warren and Lulham 2021). Municipal infrastructure construction and maintenance has significant financial cost and land use implications related to capital funding, lifecycle maintenance and insurance. Infrastructure deficits occur when the costs of constructing, maintaining, upgrading or replacing infrastructure are greater than available capital reserves and related tax revenues. Major natural disasters (such as floods) and shifting climate conditions can physically damage or destroy infrastructure, but increasing frequency and intensity of smaller events also disrupt function and performance.

All types of built infrastructure are carefully designed and engineered to set specifications to achieve the desired level of performance. Performance decreases and the risk of failure increases when established operating conditions are disrupted by unanticipated changes. For example, electrical transmission towers are built to withstand expected wind speeds, roadways are constructed for a range of seasonal temperatures and precipitation runoff and storm-water systems use pipes that are sized to convey the estimated timing and volume of runoff. Climate risk for infrastructure in Alberta is multi-faceted, but includes at least the following considerations:

- The scale of emerging problems created by increasingly unpredictable infrastructure performance;
- The loss of infrastructure asset value;
- Increased maintenance needs and retrofitting costs; and
- Uncertainty about what new engineering standards should be established to adapt to future conditions in very diverse geographic locations and conditions.

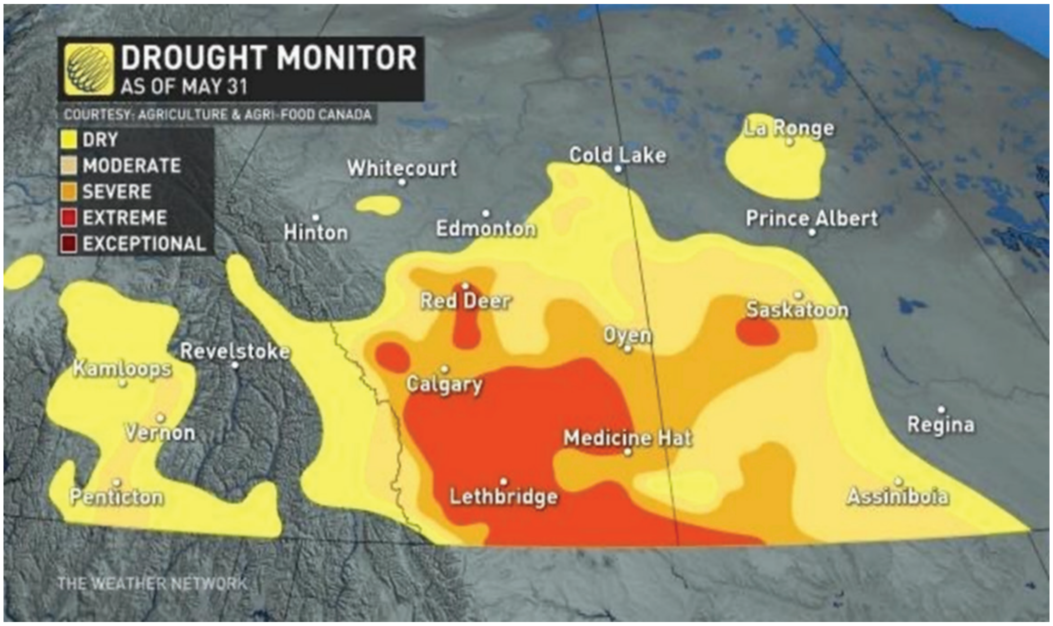
While the focus in this paper is on public infrastructure in a municipal context, private infrastructure (including privately owned homes and businesses) is also at risk. Insurance is a primary consideration in risk management but the degree to which either private or public insurance covers climate change risks and natural disasters is highly variable and there are limits to disaster recovery funding.

WATER

Alberta has 17 river basins (involving approximately 2,000 sub-basins) and 13 irrigation districts (Government of Alberta 2005). The water source for both northern and southern river basins is the snowpack and glaciers in the Rocky Mountains supplemented by seasonal precipitation. The province is economically, environmentally and socially dependent upon water. Thus, climate change poses a serious economic risk to many areas of Alberta. For example, approximately 57 per cent of Alberta's irrigation water is provided from southern and chronically water-stressed basins and approximately 75 per cent of the water used in Alberta's oil and gas activities is from northern basins (Sauchyn et al. 2015; Faramarzi et al. 2017).

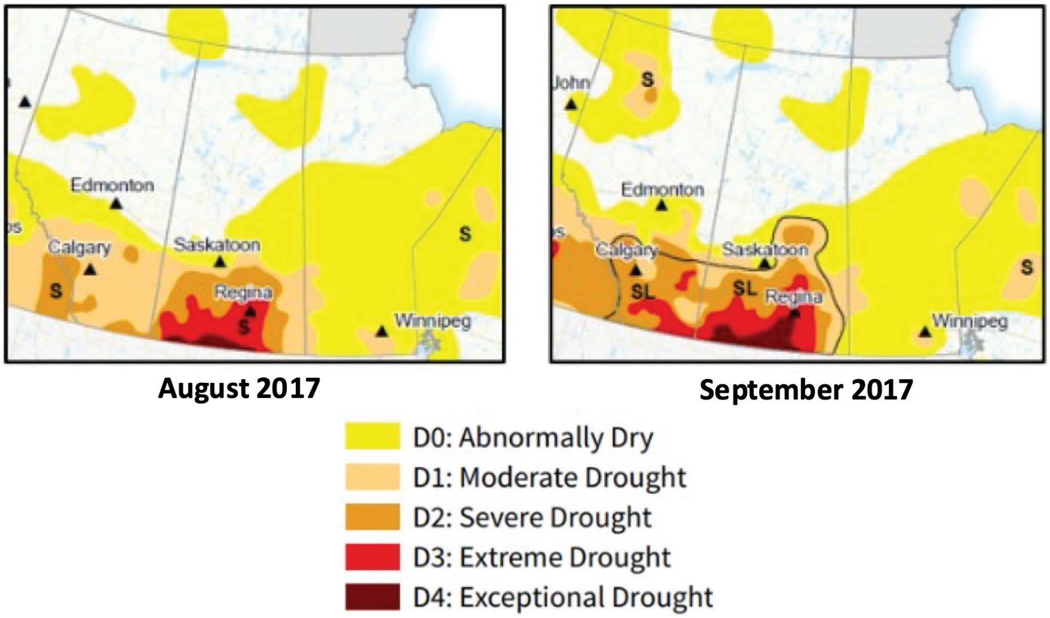
Water risks are related to current and future infrastructure design standards, lifecycle maintenance, upgrading and renewal costs. The future sources of water supply and the quality required to meet household, commercial, industrial and agricultural demands are also significant risk components. Projected temperature and precipitation changes and related events will increase the risk of flood and drought events throughout Alberta and risks related to seasonal water supply and demand vary with geographic location, population size, type of economic base and infrastructure capacity. Water stress, common in many Alberta river basins on a seasonal basis, occurs when demand exceeds supply for a specified time period. The terms "water scarcity" and "water shortage" refer to a physical lack of available water and are primarily driven by meteorological drought. While much of southern Alberta is a historically dry region, meteorological drought conditions are projected to continue to increase. Figure 5 illustrates drought levels in Alberta as of May 2022 and Figure 6 illustrates the seasonal drought conditions present in 2017.

Figure 5. Alberta Meteorological Drought Areas May 31, 2022



Sources: Agriculture and Agri-food Canada and the Weather Network (2022).

Figure 6. Meteorological Drought in the Prairie Provinces 2017



Source: Hadwen and Schaan (2021).

The Bow, Oldman and Milk River basins in southern Alberta experience severe water scarcity more than 40 per cent of the year (Faramarzi et al. 2017). However, Alberta has also experienced severe flooding from extreme seasonal precipitation and runoff events in both northern and southern basins. The changing temperature and precipitation patterns over the last 68 years (Figures 1 and 2) are a large part of the increasing seasonal frequency of flood and drought events. These long-term changes have been magnified by the population growth, urbanization and economic intensification that Alberta has experienced over the same time period. The effects of land use on runoff coefficients, the increasing sewer and water infrastructure needed for rapidly growing population centres, the provincial expansion of agriculture and the doubling of oil and gas sector activity over the last 60 years have also significantly impacted water use, seasonal supply and demand dynamics in river basins and sub-basins. The cumulative effect of this period of growth resulted in the closure of the South Saskatchewan River Basin to new water licences in 2006.

Historically, Alberta's water licence system has not been calibrated to the actual capacity of the water source to supply the designated licence amount and is based on a principle of first-in-time, first-in-right. This gives priority to the oldest licences for the right to use the water in times of a water shortage. Created in the early 1900s, this system originally provided licences primarily for agricultural use and ensured priority over subsequent licences. However, since the early 1900s, Alberta's rapid population growth and often booming economic development have required water licences for other uses with fewer historical rights. Alberta's water transfer system addresses some concerns by enabling the provincially regulated redistribution of water among different water users under certain conditions. For example, Irrigation Districts (IDs) can amend the terms and conditions of their water allocation licences to provide water to municipalities and hamlets in their area. However, while individual IDs may be willing to participate in future water allocation transfers, there are no legal obligations for them to do so. Table 1 identifies the incentives and disincentives for water licence transfers in Alberta.

Table 1. Current Incentive and Disincentives for Water Licence Transfer

Possible Incentive	Water Act Dis-incentive
No longer using all or part of an allocation	'Use it or lose it' threat of provincial cancellation of unused allocation
Money for future expansion or change of use	Need water for future expansion of existing operations – (new purposes require licence amendments)
Good neighbour agreements	10% Provincial holdback when an allocation is transferred
	Temporary assignment of all or part of the licence must be upstream or immediately downstream of the same water source as the existing licensee and usually for the same type of use (agriculture, municipal)
	Water Act does not enable sharing of water allocation,
	Rules for transferring are difficult (cannot transfer from surface supply to groundwater supply unless groundwater is proven to be directly under the influence of the surface supply, upstream to downstream is not always possible, etc.)

Source: Government of Alberta (2014).

Water risk will continue to be a high priority concern as the Rocky Mountains' snowpack and glacial sources continue to decline due to changing seasonal temperature and precipitation patterns. As a result, the historical seasonal water stress and scarcity experienced in four southern river basins (Bow, Milk, Oldman, Battle) will continue to increase. Ultimately, water risk affects infrastructure, frequency of flood and drought conditions, water supply and demand dynamics, land use and the capacity of existing legal and policy frameworks to manage water risk. Increasing seasonal water stress and scarcity (especially in southern Alberta) will increase the pressure for change in Alberta's historical water licencing system.

GOVERNANCE CAPACITY

Governance refers to all processes of governing, the institutions, processes and practices through which issues of common concern are decided upon and regulated. For example, the *Municipal Government Act* (MGA) states that the first purpose of all municipalities in Alberta is "to provide good governance." Governance capacity can be thought of as the ability of municipalities to provide good governance. In the context of extreme weather risk, governance capacity deals with what a municipality needs to do to address emergent climate change effects capable of significantly impacting people's lives, livelihoods and municipal physical infrastructure, services and programs, including land use and taxation. Historically, Alberta's municipalities have generally had the capacity to deliver their legislated responsibilities. However, the risk of emergent climate-related extreme weather impacts for municipal operations and how to best manage these risks in the context of municipal responsibilities is not yet well understood. Because this is still a relatively new and emerging issue for municipal governments, it can't just be assumed that all Alberta municipalities have the specialized resource capacity to deal with the impacts of extreme climate and weather events. The risk of extreme weather impacts increases if there is limited capacity to address the issues.

The frequency of wildfires, floods and droughts, extreme seasonal storms and temperature and precipitation changes will all continue to increase in Western Canada (Zhang et al. 2019). However, these risks will continue to manifest differently over different timeframes, in different locations and within different social and economic contexts. Therefore, risk assessment and adaptation need to be context-specific and reflect the diversity of geographic conditions, resource availability and community values characteristic of Alberta's 344 municipalities (Government of Alberta 2021).

As shown in Table 2, there are different types of municipalities in Alberta — cities, towns, villages and summer villages, specialized municipalities, municipal districts, improvement districts, special areas and Métis settlements (Government of Alberta 2021). Each type is covered by Alberta's *Modernized Municipal Government Act* (2016), *Special Areas Act* (2000) and *Métis Settlement Act* (2000) which outline respective roles and responsibilities. Alberta also has 403 hamlet and urban services areas, 77 service commissions, 52 First Nations, 138 federal government First Nations reserves, eight local government associations and 12 emergency districts.

All municipalities have the same responsibilities under Alberta's *Municipal Government Act* and they must be compliant with all other applicable provincial legislation. However, Alberta's municipalities represent a wide range of differences in population size, land area and natural and financial resources. This diversity is part of Alberta's strength and success. But this diversity in size, location, population, resource availability and social identity also makes it very difficult for one-size-fits-all policies and programs to be effective.

Table 2. Number of Municipalities in Alberta as of January 5, 2022

Type	Number
Cities	19
Specialized Municipalities	6
Municipal Districts	63
Towns	106
Villages	80
Summer Villages	51
Improvement Districts	7
Special Areas	4
Metis Settlements	8

Total = 344

Source: Government of Alberta (2021).

Alberta's geographically and economically diverse municipalities also have distinct cultural and religious settlement histories. There are First Nations and treaty lands, Métis people and Métis settlement lands throughout Alberta that all operate under different and generally independent jurisdictional, administrative and cultural systems of governance. Table 3 shows urban and rural municipal population changes between 2016 and 2021. Over those five years, rural municipalities experienced a population decline of approximately six per cent. In contrast, the highest population increase occurred in summer villages in the urban category. There is a massive size difference between urban and rural land areas that is also shown in Table 3. Rural municipalities are responsible for a total land area approximately 116 times larger than the land area of urban municipalities. Conversely, the total population urban municipalities are responsible for is seven times greater than the population of rural municipalities. Thus, municipal responses to extreme weather impacts will reflect their different geographic locations, sizes, resources, local values and vulnerability to risk.

Risk is not absolute and can range from low to extreme. The type and level of risk depends on multiple factors including vulnerability to and frequency and intensity of risk conditions or events. Local government capacity to deal with climate change involves risk assessment to identify types and levels of risk, adaptation potential and the ability to manage both risk and adaptation in the context of municipal development plans, infrastructure, emergency plans and existing physical and financial assets. Financial risk, infrastructure risk and climate risk are different types of risk that involve different types of risk assessment. However, they are also interconnected and need to be integrated into municipal planning and management responsibilities.

Table 3. Municipal Population Change 2016-2021

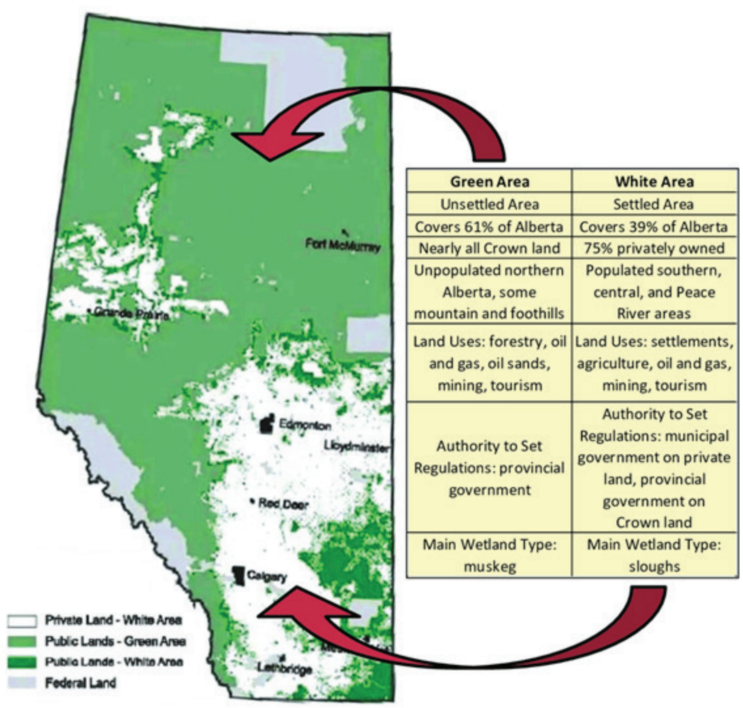
MUNICIPALITIES IN ALBERTA	POPULATION (2021)	POPULATION (2016)	CHANGE (%)	LAND AREA (km2)	POPULATION DENSITY (/km2)
Cities	**3,023,641**	**2,838,191**	**+6.5**	**2,572.21**	**1,175.5**
Towns	**471,028**	**455,389**	**+3.4**	**1,294.84**	**363.8**
Villages	**32,753**	**33,800**	-3.1	**146.36**	**223.8**
Summer Villages	**5,955**	**6,171**	**+15.2**	**38.93**	**153.0**
Municipal Districts	**470,620**	**470,304**	**+0.1**	**383,878.12**	**1.2**
Improvement Districts	**2,024**	**2,055**	-1.5	**59,375.72**	**0.0**
Special Areas	**4,238**	**4,295**	-1.3	**19,964.19**	**0.2**
Specialized Municipalities	**202,461**	**199,298**	**+1.6**	**155,463.32**	**1.3**

Sources: Statistics Canada (2022); Government of Alberta (2021).

ALBERTA'S MUNICIPAL FRAMEWORK

In a Canadian constitutional context, neither the federal nor provincial levels of government have exclusive decision-making authority over environment and climate. The federal and provincial governments have "overlapping jurisdiction and responsibilities" to regulate and control human activities that may negatively impact the environment at their respective national and provincial geopolitical scales (CanLII 1992). Climate change is recognized as an emergent issue of national concern that affects all scales of environmental governance (*Greenhouse Gas Pollution Pricing Act*, 2020 ABCA 74). In Canada, municipalities are not a level of government but creations of provincial law. In Alberta, the legal extent of municipal authority over land use, development and infrastructure is organized within a context of green and white areas, as illustrated in Figure 7. The green areas represent public lands under provincial control. The white areas represent privately owned lands, the legal authority for which has been delegated to municipalities through Part 17 of the MGA. However, some uses are exempted from municipal authority, such as highways, pipelines, intensive livestock operations, forestry, mining and oil and gas extraction. In the white areas, the province controls and regulates exempted uses through legislation and regulatory bodies. In such cases, if a licence, permit, approval or other authorization is given by the Natural Resources Conservation Board (NRCB), Energy Resources Conservation Board (ERCB), Alberta Energy Regulator (AER), Alberta Energy and Utilities Board (AEUB) or Alberta Utilities Commission (AUC), a municipality is responsible for compliance with these provincial agencies' decisions and to enact whatever relevant statutory plan amendment, land use bylaw amendment, subdivision approval, development permit or other authorization is necessary.

Figure 7. Alberta's White and Green Areas of Authority



Green Area	White Area
Unsettled Area	Settled Area
Covers 61% of Alberta	Covers 39% of Alberta
Nearly all Crown land	75% privately owned
Unpopulated northern Alberta, some mountain and foothills	Populated southern, central, and Peace River areas
Land Uses: forestry, oil and gas, oil sands, mining, tourism	Land Uses: settlements, agriculture, oil and gas, mining, tourism
Authority to Set Regulations: provincial government	Authority to Set Regulations: municipal government on private land, provincial government on Crown land
Main Wetland Type: muskeg	Main Wetland Type: sloughs

Source: Locky (2011).

There are statutory responsibilities and tools available to Alberta municipalities that can be used in reducing climate risk impacts. The MGA provides municipalities with delegated authority and tools to participate in environmental governance, namely a general jurisdiction to enact and enforce bylaws regulating the local matters listed below:

- “The safety, health and welfare of people and the protection of people and property”;
- “People, activities and things in, on or near a public place or place that is open to the public”;
- “Nuisances, including unsightly property”;
- “Transport and transportation systems”;
- “Businesses, business activities and persons engaged in business”;
- “Public utilities”; and
- “Wild and domestic animals and activities in relation to them.”

Municipalities also received delegated special powers under the MGA “to pass bylaws and regulate and control roads within municipal boundaries” and “provide a suite of public utilities.” Public utilities are defined under the MGA as including “systems or works used to provide one or more of the following for public consumption, benefit, convenience or use, as well as the thing that is provided for public consumption, benefit, convenience or use.” As above, the following list of public utilities included in the MGA are also likely to be affected by extreme weather:

- Water or steam;
- Sewage disposal;
- Public transportation operated by or on behalf of the municipality;
- Irrigation;
- Drainage;
- Fuel;
- Electric power;
- Heat;
- Waste management; and
- Residential and commercial street lighting.

Over the last 10 years, changes to the MGA have included the following:

- Growth management boards in 2013 with significant amendments in 2019;
- City charter legislation and regulations for Edmonton and Calgary in 2015;
- New municipal purposes in 2016–2017;
- Intermunicipal Collaboration Frameworks in 2016 with significant amendments in 2020; and
- Broad authority to enact land use bylaw provisions through changes to section 640 of the MGA through section 28 of the *Red Tape Reduction Implementation Act,* 2020 (RTRIA).

These changes delegated authority to municipalities to enact bylaws and develop programs for environmental protection, but none directly addressed the development of municipal climate adaptation. The creation of growth management boards involved municipalities within the metropolitan areas surrounding the cities of Calgary and Edmonton. These growth management boards are required to create, adopt and implement a metropolitan region growth plan. Both Calgary's and Edmonton's growth management boards have metropolitan growth plans approved by the minister which include subsections addressing climate change policy statements. Calgary's plan includes the following policy goals:

> "Policies 3.3.3.1 Municipal Development Plans shall address Climate Change resiliency, which will include:
>
> a. a commitment to reduce municipal greenhouse gas emissions and water consumption; and,
>
> b. policies to identify and mitigate risks within the municipality due to Climate Change, including impacts to:
>
> (i) built environments (including the local economy and infrastructure); and
>
> (ii) natural systems."

The Edmonton plan includes climate adaptation policies in subsection 2.3.4.

2.3.1 planning, design and construction of new development and infrastructure in greenfield areas and built-up urban areas will incorporate low-impact development and green building practices.

2.3.2 Energy conservation, energy recovery and the use of green energy will be integrated in community design and development to reduce energy consumption and greenhouse gas emissions, including but not limited to: bio energy, district energy systems and renewable energy.

2.3.3 In accordance with the Alberta Land Stewardship Act, member municipalities shall adhere to the Air Quality Management Framework for the North Saskatchewan Region. Improving ambient air quality in the Region will be pursued through the use of local community programs, statutory plans and non-statutory plans addressing best practices in land use planning and community design.

2.3.4 Adapting to climate change and climate variability will be pursued through risk prevention and management by:

> a. supporting ecosystem- based adaptation approaches including but not limited to flood plain, wetland and forest management solutions; and,
>
> b. developing and promoting investment in climate adaptation tools and initiatives to address climate change risks and ensure resilience."

The municipal purpose "to foster the wellbeing of the environment" was added to the MGA in 2017. However, this addition did not come with a definition of environment. However, environment is defined in Alberta's 2000 *Environmental Protection and Enhancement Act* (EPEA) as meaning "the components of the earth and includes:

(i) air, land and water;

(ii) all layers of the atmosphere; and

(iii) all organic and inorganic matter and living organisms, and the interacting natural systems that include components referred to in subclauses (i) to (iii)."

This definition includes people (as living organisms), human activities and the various institutions that have been put in place to regulate and control human activities. It is also inclusive of the atmosphere and the general weather conditions prevailing in an area over a long period (climate). This definition can be applied to environment in the context of MGA revisions through the principle of statutory interpretation or statutes *in pari materia,* which means that different statutes dealing with the same subject can be used to assist in the understanding of each other (CanLII 1981).

In the creation of the new 2018 city charters for Calgary and Edmonton, provision for bylaws for the well-being of the environment were included in section 4(2)(a) subsection 7(1) (h.1):

"(h.1) the well-being of the environment, including bylaws providing for the creation, implementation and management of programs respecting any or all of the following:

(i) Contaminated, vacant, derelict or under-utilized sites;

(ii) Climate change adaptation and greenhouse gas emission reduction;

(iii) Environmental conservation and stewardship;

(iv) The protection of biodiversity and habitat;

(v) The conservation and efficient use of energy;

(vi) Waste reduction, diversion, recycling and management."

However, to date, subsection (h.1) has not been added to section 7 of the MGA to provide this same authority to all Alberta municipalities.

The second set of municipal purposes added to the MGA ("working collaboratively with neighbouring municipalities to plan, deliver and fund intermunicipal services") enables two or more adjacent municipalities to perform three specific functions (Part 17.2):

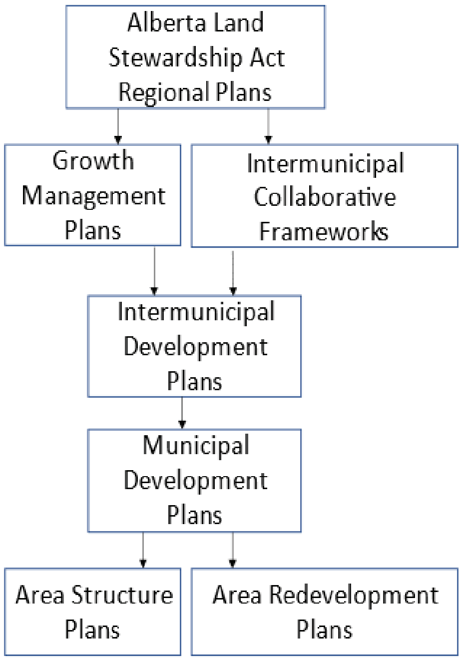
- to provide for the integrated and strategic planning, delivery and funding of intermunicipal services;
- to steward scarce resources efficiently in providing local services; and
- to ensure municipalities contribute funding to services that benefit their residents.

This enables ICFs to be established that could include climate risk assessment, adaptation planning, infrastructure management and emergency planning. Prior to this change, municipalities provided services outside their own boundaries through contractual agreements in accordance with Section 54 of the original MGA. As well, intermunicipal servicing was also available through regional servicing commissions (RSCs), which have been in place for many years under Part 15.1 of the MGA. RSCs enabled municipalities lacking in sufficient personnel or financial resources to create corporations to deliver services across municipal boundaries.

Alberta's 2020 "Intermunicipal Collaborative Framework Workbook: Resource Guide for Municipalities" encourages municipalities to include climate change adaptation services (climate resilience) in an ICF. The guide states: "Many topic areas are well suited to intermunicipal and/or regional collaboration and should be considered for inclusion and evaluation when preparing an ICF and include: land use planning; economic development; environmental protection; agricultural preservation; climate resiliency**,** etc."

The primary municipal statutory tools for land use and development are municipal development plans (MDPs), area structure plans (ASPs), area redevelopment plans (ARPs) and land use bylaws. These are established in a hierarchy of statutory planning authority, as illustrated in Figure 8, with regional plans developed under the *Alberta Land Stewardship Act* (ALSA) having the highest authority, followed by growth management plans (created by the Edmonton and Calgary regional growth boards) and ICFs, then intermunicipal development plans (IDPs), then MDPs and then ASPs and ARPs.

Figure 8. Hierarchy of Alberta Statutory Plans



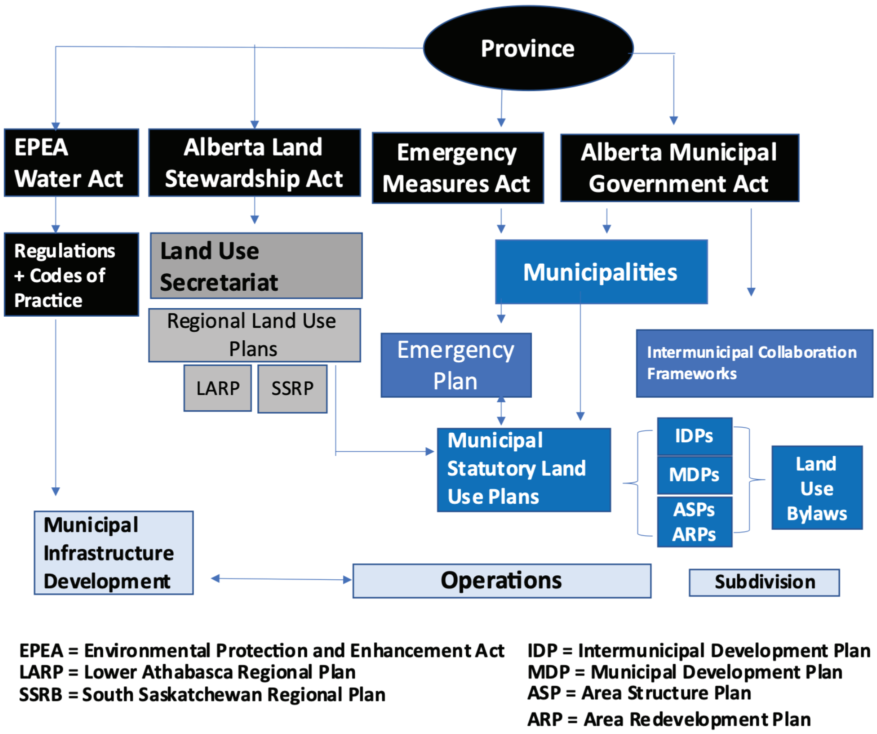
Subdivision proposals normally require outline plans and neighbourhood plans for purposes of municipal development approval. These are not statutory plans but must be consistent with the provisions of the MGA, all applicable municipal statutory plans, municipal land use bylaws and subdivision and development regulations. The subdivision planning process offers an opportunity for municipalities to ensure the new development and associated infrastructure can be developed in ways that reduce losses to extreme climate impacts. Subdivision plans do not generally reflect extreme weather adaptation, as this is not a requirement of Alberta's Subdivision and Development Regulation but could be addressed under the *Emergency Management Act* depending on the degree of risk involved. Subdivision plans may be simple —two lots created from a single parcel. But, they can also be very complex and involve new neighbourhoods, roads, public utilities, schools, parks, playgrounds, fire stations, libraries and commercial or industrial buildings. Such large-scale mixed land-use developments offer greater potential for incorporating climate adaptation measures.

Amendments to the MGA authorize municipalities to require subdivision developers to pay offsite levies in accordance with municipal offsite levy bylaws and, as of 2016, intermunicipal offsite levy bylaws are also possible. Both types of bylaws have very specific requirements and may be appealed in accordance with the regulations in the Land and Property Rights Tribunal. However, both offer potential as climate adaptation tools.

In 2017, the province amended the MGA to enable municipalities to require the dedication of certain lands as conservation reserves at the time of subdivision. In such cases, the municipality is required to reach an agreement with the landowner and pay market value for the lands to be dedicated. Conservation reserves are different from municipal reserves and not the same as environmental reserves, which refer exclusively to areas considered hazardous to develop for reasons provided in Section 664 of the MGA. Environmental reserves are often associated with steep slopes, unstable soil conditions or riparian lands. The municipality may require such areas to be dedicated to the municipality at no cost. At the time a subdivision plan is registered at Land Titles, such dedicated reserves become the property of the municipal corporation. A municipality has no authority to accept money in lieu of environmental reserves and there are specific rules for how environmental reserves may be used and disposed of, which assists in their protection.

The MGA requires that all municipalities have land use bylaws to regulate and control land use within their boundaries. The 2020 amendments to Section 640 of the MGA provided broader authority to municipal councils to regulate land use through land use bylaws. For example, land use bylaws can be used to protect riparian lands, establish locally appropriate development and building setbacks related to water bodies and floodplains, environmentally significant areas and other landscape features. Low-impact development (LID) bylaws can be used to manage extreme seasonal drainage and improve the quality of stormwater and meltwater. Although climate risk and the increasing frequency of extreme weather were unforeseen at the time the MGA was enacted, it has since been acknowledged that municipalities need to understand climate change and protect municipal assets and operations under the revised sections of the MGA and the *Alberta Emergency Act*. As outlined in this section, municipalities in Alberta appear to have an established set of statutory authorities within which to work. Figure 9 illustrates the provincial framework for municipal land use planning and development and emergency management.

Figure 9. Alberta Framework for Municipal Land Use Planning and Development

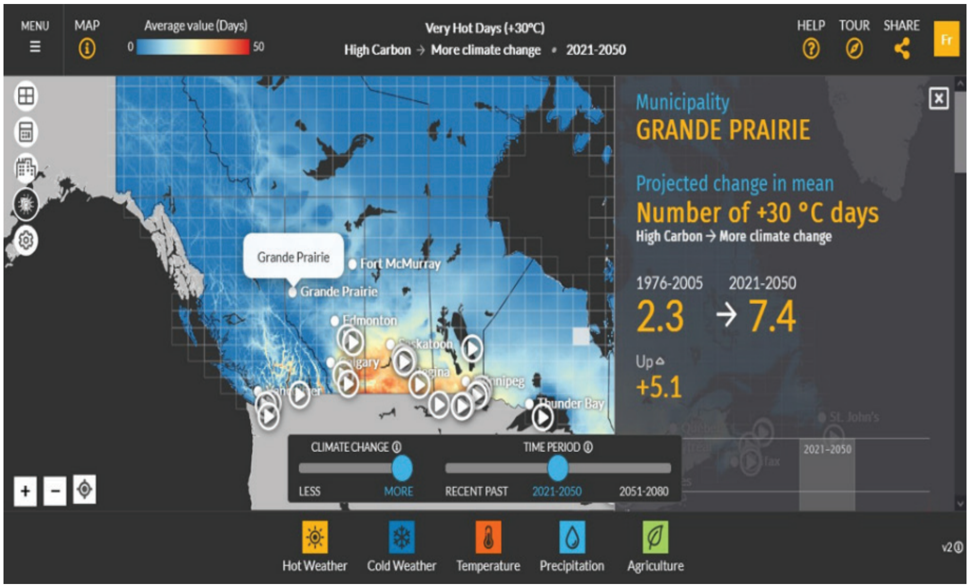


RISK, VULNERABILITY, ADAPTATION AND RESILIENCE

Climate change involves longer term shifts in temperature and seasonal weather patterns which contribute to the increasing frequency of extreme weather events. Emergency and disaster management situations are of obvious concern as sudden events threatening public safety and infrastructure. Government programs and agencies understandably target extreme weather-event emergencies. While ongoing longer term changes in temperature, precipitation and seasonal weather patterns do not have the same immediacy as extreme events, longer term seasonal shifts in temperature and precipitation are increasingly affecting terrestrial and aquatic ecosystems, water supply, energy use, land use and infrastructure lifecycle maintenance costs.

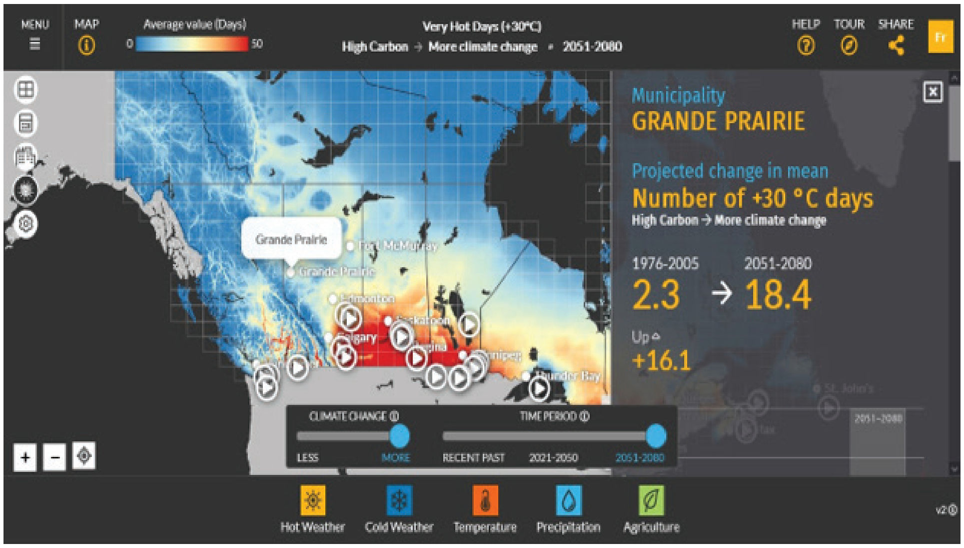
The Climate Atlas of Canada, developed by Environment and Climate Change Canada, provides an interactive website that identifies specific locations and specific conditions (including growing-degree days) projected over 30 to 50 years. For example, Figures 10 and 11 show the number of +30 C days for the Municipality of Grande Prairie between 2021–2050 and 2051–2080, respectively. The occurrence of +30 C days is projected to increase from 2.3 days in 1976–2005 to 18.4 days in 2051–2080.

Figure 10. Grande Prairie +30 Celsius Days 2021–2050



Source: Climate Atlas of Canada.

Figure 11. Grande Prairie +30 Celsius Days 2051–2080



Source: Climate Atlas of Canada.

While the projected increase in the number of +30 C days is evident, what is not are the implications this change has for municipal land use, water use and infrastructure. The impacts of changing climate conditions and the likelihood of extreme events have both public and private insurance implications. Feltmate and Moudrak (2021) suggest that insurance is likely to become more unavailable and unaffordable as climate risk and extreme events increase. This means that insurance companies, banks and other investors involved in financing land development and infrastructure will likely begin to require evidence of climate risk assessment for financing and insurance. There is a clear financial incentive to manage climate risk costs now and in the future. For example, local authorities in Alberta are required to pay 10 per cent of all damage and recovery costs pursuant to Alberta's 2020 *Local Authorities Emergency Management Act* regulations and this obligation is likely to increase with the increasing frequency of extreme weather.

There is a general expectation that provincial legislation protects municipalities from liability. But the area of climate risk and the law is evolving and a legal question exists regarding the duty of municipalities to adapt to climate change. Liability represents another reason to consider undertaking effective municipal climate risk assessment and adaptation planning. Saxe and James (2014) state:

> The steady growth of scientific evidence about the increasing risk of extreme weather, and the increasing frequency of such weather, should make it easier for plaintiffs to prove that their damage was "reasonably foreseeable." It should also increase the standard of care.
>
> In these circumstances, the owners and occupants of the specific private properties that are known to be particularly vulnerable could have a strong claim against the municipality for negligence.

Both financial risk and physical risk reduction are primary concerns for local governments.

Table 4 identifies the built, natural and social dimensions of climate impacts that municipalities can be vulnerable to with varying degrees of risk depending upon local circumstances. Effective adaptation strategies cannot be developed until specific and locally relevant risks are identified and assessed at scale. Methods for built environment physical risk assessment are generally well developed for insurance purposes, but there is less municipal experience with ecological and socioeconomic dimensions of climate risk assessment and adaptation practices.

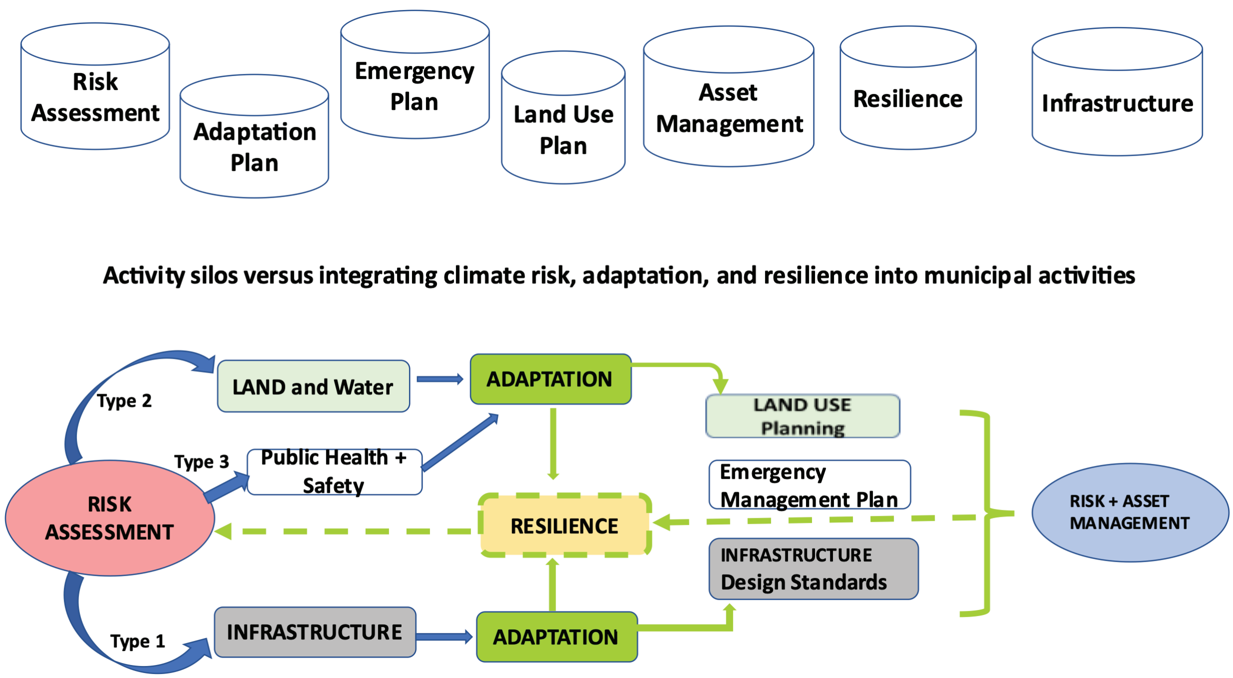
Table 4. Extreme Weather Impacts on Urban and Rural Municipalities

Built Environment	Natural Environment	Social Environment
Damage to Infrastructure	Shifts and changes in plant and animal habitats and species	Disruption to economic activities
Damage to Buildings and Property	Degradation of Ecosystem Services	Increase in climate related health problems
Disruption to energy Transmission and Telecommunications	Decline in quantity and quality of freshwater resources	Decline in quantity and quality of freshwater resources
Increased Maintenance Costs	Loss of Soil Nutrients and increase in pollutants	Loss of cultural and traditional practices

Source: Adapted from Municipal Climate Services Collaborative (2020).

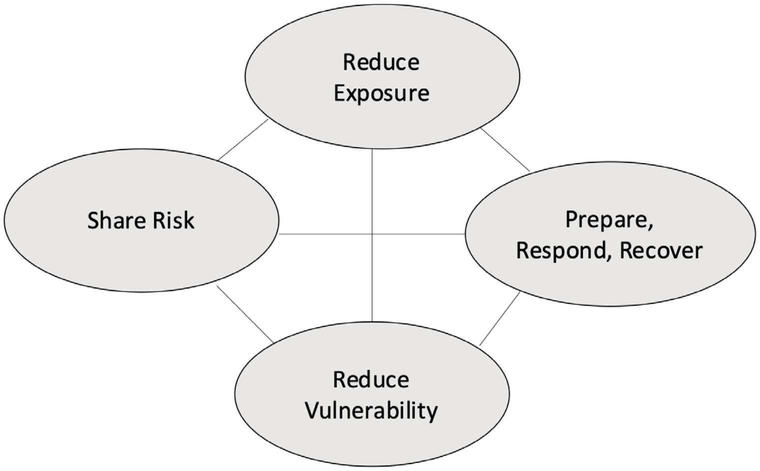
Canadian and provincial emergency measures and disaster recovery planning processes and protocols are in place to address the risk of extreme events (Public Safety Canada 2023; Government of Alberta 2023). However, there are also community health impacts related to climate change (including extreme heat, air quality, job loss and relocation) that impact well-being and have social costs. Emergency response to extreme weather is event specific and normally of short duration. Resilience, risk assessment, emergency management and adaptation plans can and have been treated as independent activities with independent results. However, climate risk assessment is also a more holistic and longer term approach to determining risk priorities and adaptation priorities in the context of municipal land use planning, infrastructure maintenance, capital planning and asset management. Rather than independent silos, it is necessary to integrate climate risk assessment, adaptation and resilience into municipal operations to maximize effectiveness and build resilience, as illustrated in Figure 12.

Figure 12. Integration of Risk Assessment and Adaptation to Increase Resilience



The Emergency Management Framework for Canada defines resilience as: "… the capacity of a system, community or society to adapt to disturbances resulting from hazards by persevering, recuperating, or changing to reach and maintain an acceptable level of functioning" (Public Safety Canada 2019). This definition reveals resilience as more than just an engineering response that requires social engagement that "encourages coordination, wider participation and a broader approach to risk management" to be successful (Woodruff et al. 2022). Climate change resiliency involves a broad range of actions including reducing exposure and vulnerability and increasing the capacity of infrastructure systems, land use systems, social systems and governance systems to cope with impacts and disturbance. Resilience is a critical but aspirational goal that needs to start with effective and integrated risk assessment and adaptation at the local level. Neither risk assessment nor adaptation can prevent extreme climate conditions from occurring, but they can reduce the impacts. Four adaptive actions can together reduce local impacts, as illustrated in Figure 13. It is important to prevent adaptation planning and emergency planning from becoming independent activities. The greater the co-ordination and integration among risk assessment, adaptation planning, emergency planning, land use planning, infrastructure maintenance and asset management, the greater the likelihood of reducing risk and increasing resilience (Lavell et al. 2012).

Figure 13. Adaptive Management Activities at the Local Level

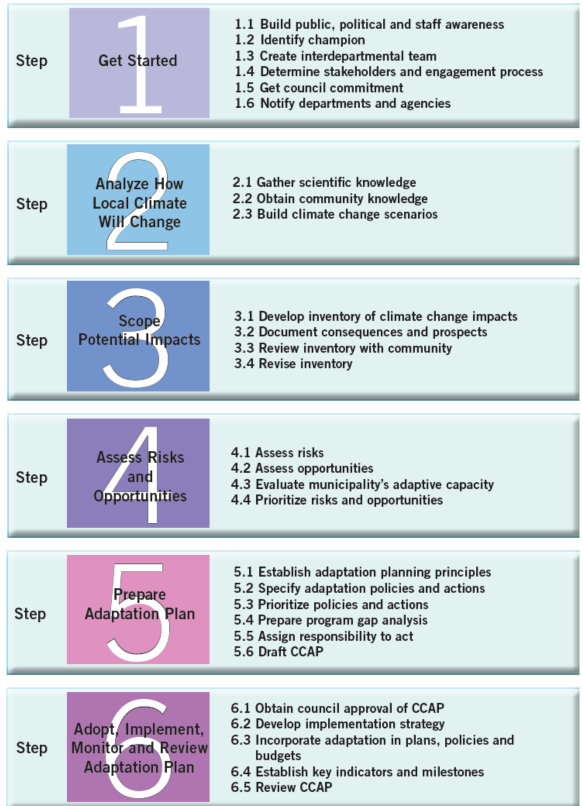


Source: IPCC (2012) (modified).

In a broader Canadian context, federal and provincial government agencies and non-government, not-for-profit environmental and local government organizations have promoted the development of municipal climate adaptation plans since at least 2008. Some adaptation plans initially focused on mitigation of GHG emission (Bizikova et al. 2008). Since then, adaptation plans have begun to focus on extreme weather impacts. The Canadian Institute of Planners (Bowron and Davidson 2011) has identified specific steps in adaptation planning for small communities and these are shown in Figure 14.

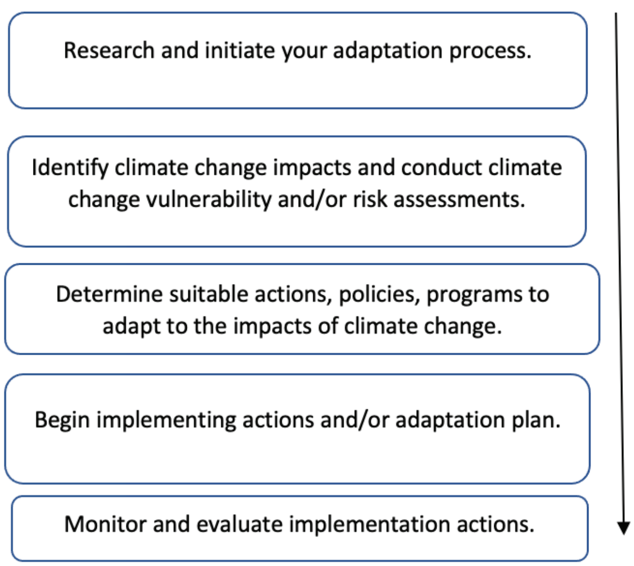
In 2020, the government of Canada's Canadian Centre for Climate Services and the Federation of Canadian Municipalities (FCM) jointly created the Municipal Climate Services Collaborative (MCSC). The MCSC produced a similar guide, "A Discussion Guide for Local Government Staff on Climate Adaptation," for local governments. The guide identifies five generic adaptation planning steps (Figure 15), seven guiding questions (Table 5) and a self-assessment matrix (MCSC, 2020 (https://publications.gc.ca/collections/collection_2021/eccc/En4-409-2020-eng.pdf)

Figure 14. Recommended Steps for Small Community Climate Adaptation Plans



Source: Bowron and Davidson (2011).

Figure 15. Five Stages in Local Government Adaptation Planning



Source: MCSC (2020) (modified).

Table 5. Six Guiding Questions for Adaptation Planning

1. What are the types of climate change hazards your community is experiencing?
2. What has your community done so far to adapt to climate change?
3. Who have you been working with and/or primarily engaged so far? (not necessarily on adaptation but on other environmental issues that you could leverage)
4. What do you want to accomplish through your climate adaptation efforts?
5. Which of the following areas would you prioritize to build additional capacity?
   - Access staff resources (fund applications, planning and monitoring)
   - Departmental buy-in
   - Obtain Council buy-in
   - Build community support
   - Build expertise on climate change impacts, vulnerabilities and risks, and adaptation options
   - Acquire information (both technical and capacity building via case studies and tools)
   - Secure funding or capacity to apply for grants/funding.
6. Who do you need to begin to have or continue having conversations with?

Source: MCSC (2020).

Both the 2011 CIP handbook and the 2020 MCSC guide provide a general road map for local government adaptation plan development. These prescriptive frameworks can be valuable but need certain conditions in place to enable them. Sufficient staff time and expertise, specialized and scale-specific data and information and funding resources are necessary to support risk assessment, decision-making and integration of results into land use planning, emergency management, infrastructure maintenance and capital budget planning. These conditions may exist in Canadian municipalities where specialized expertise and dedicated resources exist. However, when resources are lacking it may not be possible for all municipalities to successfully implement the frameworks provided.

Natural Resources Canada previously produced another general framework for adaptation planning not specific to municipalities. This seven-step process is illustrated in Table 6 and incorporates many of the "common elements of several adaptation frameworks" being used in Canada (Warren and Lemmen 2014). At that time, Warren and Lemmen (2014) concluded: "… there are few documented examples of adaptation being implemented specifically to reduce vulnerability to future climate conditions."

Table 6. Seven Common Steps in Adaptation Planning

1. **Awareness of Climate Change**
2. **Awareness of the need to adapt**
3. **Mobilize Resources**
4. **Build adaptation capacity:**
   - apply scientific information, financial resources, to issue screening, risk assessment, in-depth analysis, and informed decision making
5. **Implement targeted adaptation actions**
6. **Measure and evaluate progress:**
   - evaluate actions, related assumptions, and uncertainties and provide feedback
7. **Learning and sharing knowledge:**
   - transfer lessons learned to future adaptation actions

Source: Warren and Lemmen (2014).

BARRIERS TO EFFECTIVE MUNICIPAL RISK ASSESSMENT AND ADAPTATION

Communities do not prioritize climate risk assessment and adaptation for a variety of reasons. Climate risk is popularly framed as an environmental issue rather than an economic or social one. Similarly, communication around issues involving scientific complexity and uncertainty, notwithstanding efforts by international organizations and national governments to simplify, are often not well understood. There has been a general lack of science outreach activities necessary to communicate with and support non-scientist decision-makers (Sheppard 2012; Wu and Wu 2013; Warren and Lemmen 2014). Information needs to be specific to the user and climate risk data, forecasts and modelling need to be packaged in understandable and familiar formats. This requires engagement with information users, which often does not happen. More specific local government challenges have been identified through a recent review of municipal climate change plans and two surveys of municipalities and municipal planners in 2019 and 2021. Guyadeen et al. (2019) evaluated 63 Canadian municipal climate change plans, including Calgary, Edmonton, Red Deer and St. Albert. The plan evaluation process involved "… 46 indicators based on 8 plan quality characteristics: fact base, goals, policies, implementation, monitoring and evaluation, inter-organizational coordination, participation, and plan organization and presentation" (Guyadeen et al. 2019). The reviews identified these valuable insights:

- All plans prioritized mitigation of GHG over adaptation planning; and
- Implementation, monitoring and evaluation of plans were generally assessed as weak and stakeholder engagement was minimal.

In addition, findings from the evaluation of the eight plan quality characteristics used in the reviews showed three significant deficiencies:

- "Almost all plans failed to include an assessment of the municipality's vulnerability to specific climate change impacts";
- "The analysis indicates that many municipalities across Canada did not have a comprehensive fact base to inform their climate change plans"; and
- "Though most plans discussed the impacts of climate change in general terms (e.g., sea level rise, increasing temperatures), only twenty-six plans (forty-two percent) discussed impacts specific to their municipal context" (Guyadeen et al. 2019).

A quality ranking approach is not without critique and Tang et al. (2010) found that plans ranked as higher quality do not automatically lead to better implementation or outcomes. Table 7 identifies five types of organizational challenges affecting climate risk and adaptation planning not related to plan quality.

Table 7. Challenges to Organizational Adaptation Readiness and Capacity

Type of Barrier or Challenge:	Example(s):
Information and Communications	• Mismatch between spatial and temporal resolution of climate projections and management needs • Difficulty obtaining reliable projections at scales relevant to management needs • Lack of available guidance to interpret climate scenarios and modeling output into infrastructure and land use planning applications
Resources (financial, skills, technology)	• Few incentives for action beyond business as usual • Lack of expertise and understanding of local impacts of extreme weather and climate change on business operations
Governance and norms	• Influence of non-climate stressors, such as region-wide demographic changes and rural outmigration • Complexities related to other jurisdiction or stakeholders • Climate change projections and extreme weather require changes from current building codes and design standards
Values and Beliefs	• Perception of importance of climate change low relative to economic challenges • Uncertainty in future climate change projections hinders investment decisions on adaptation • Degree of optimism about capacity to overcome adaptation challenges. • Primary focus on replacement of aging infrastructure, capacity upgrades and changing requirements, codes, and standards.
Leadership	• Taking a 'wait-and-see' approach due to difficulties in deciding to wait for more information to inform future action and taking action in the short term based on available information.

Source: Warren and Lemmen (2014).

As an alternative to quality ranking, surveys and interviews with municipal planners and elected decision-makers can be used to identify gaps that need to be addressed to improve adaptation planning. Two significant surveys were undertaken by the Canadian Institute of Planners (CIP) in 2019 and by the All One Sky Foundation in 2020–2021 for the Prairies Regional Adaptation Collaborative (PRAC), now part of ClimateWest. The purpose of the CIP survey was to benchmark Canadian municipal planners' awareness of climate change impacts on planning issues and compare results to a similar survey done in 2009. The 2019 survey included 268 planners from Alberta (20 per cent of the total 1,457 survey responses). The purpose of the PRAC (ClimateWest) survey was to understand "… the current extent of local climate change adaptation planning needs" (Parry 2022). It involved over 300 municipalities and Indigenous communities in Alberta, Saskatchewan and Manitoba, with 22 per cent of responders from Alberta.

The CIP survey revealed the highest rated barriers identified by respondents to incorporating climate risk and adaptation into planning work. Eighty-five per cent of respondents identified competing priorities (including financial viability) as the number one barrier. Seventy-two per cent identified lack of political support as the second highest. Lack of funding and lack of expertise were the third and fourth highest rated barriers (CIP 2019). In addition, three important benchmark results that emerged from the survey were:

- The primary information sources used by municipalities for climate risk assessment in municipal development plans were identified as "… national data, modelling and mapping and national non-government guides";
- Municipal planners rated "… high rain/snowfall, inland flooding, and high temperatures" as the highest-ranking climate risk and adaptation issues their communities are facing now and in the next 10 years; and
- Only 15 per cent of planners surveyed felt they have access to the requisite tools and information necessary to incorporate climate change into their work.

The PRAC (ClimateWest)/All One Sky survey included "… municipalities and Indigenous communities with a population of fewer than 10,000 people." Eighty per cent of respondents stated their community had experienced extreme weather ("flooding, extreme winds, and extreme rainfall") within the last 10 years (Parry 2022). Other key survey findings included the following:

- Seventy-five per cent of the respondents expressed concerns that their communities will be significantly impacted over the next 20 years by "… more intense rainfall and storms … more frequent extreme wind events … an increase in the frequency and severity of droughts … more frequent and severe floods" and "… less predictable weather patterns";
- Fifty per cent of respondents also identified "changes in lake and water levels, a greater likelihood of heat waves and wildfires, and changing freeze-thaw patterns" as a major concern;
- Respondents identified negative impacts on "built infrastructure (buildings, stormwater management, energy systems, and transportation)" as their greatest concern;
- Thirty-four per cent of all survey respondents stated their community was preparing for the local impacts of climate change through: "Considering climate change in emergency management and/or asset management … awareness raising within local government" and "… developing or implementing individual projects to build back better after a recent climate event";
- Fifty per cent of Alberta respondents stated their municipalities were "preparing for local climate change impacts";
- Seventy per cent of communities with a population greater than 10,000 people said they were preparing for climate change; but only 30 per cent of smaller communities (less than 10,000) were preparing;

- Fifteen per cent of Alberta communities stated they had completed a "climate risk and vulnerability assessment"; and
- Only nine per cent of Alberta communities "reported that they had completed a climate adaptation plan or strategy."

Survey results indicated a difference in views based on community size and state of preparedness. Large communities (greater than 10,000) expressed more interest in receiving technical information than small communities. Small communities (especially those in Alberta) identified limited staff skills and lack of access to information as major barriers much more frequently than larger communities. Larger communities expressed greater interest in receiving additional support than smaller communities. The top four common barriers to climate change preparation identified by communities that had not yet started to prepare were:

- Limited staff time;
- Limited staff skills;
- Lack of financial resources; and
- More pressing issues (including financial viability).

Similarly, 50 per cent of communities involved in preparing a climate change plan also identified limited staff time, limited staff skills and lack of financial resources as barriers. Seven out of 10 survey respondents identified "… gaining greater knowledge of how local infrastructure will be impacted by climate change as the greatest need to support climate change preparation planning." Fifty per cent of respondents from each province in the survey (Manitoba, Saskatchewan and Alberta) identified the need for greater access to the following information:

- "Climate trend data specific to their area";
- "Projected changes in climatic extremes";
- "Analysis of how economic sectors will be affected"; and
- "Assessment of the consequences for human health and wellness."

Three-quarters of all survey respondents identified funding as the most useful way to support their community's efforts in preparing for climate change and 30 per cent identified four other ways to help communities prepare for climate change:

- Support networking and knowledge sharing between communities;
- Provide training on topics related to climate change preparedness;
- Clarify existing government policies, strategies and/or plans regarding climate change preparedness; and
- Share information on how to assess community risk or vulnerability to climate change (Parry 2022).

A similar climate adaptation survey was previously done in Australia with local governments as part of developing the Australian National Agenda for Climate Adaptation Decision Support Strategies. The Australian survey identified four specific areas local government decision-makers felt needed to be improved to effectively address climate change (Webb et al. 2014):

- "… more confidence in, and quality assurance of available knowledge and sources." Specifically, local government councils are "… looking for greater confidence and trust in adaptation processes, data/modelling products and providers that they use; and in the relevant skills and experience of external and internal advisers";

- "… access to enhanced knowledge brokering and collaboration." Importance of combining "… understanding of user-specific context and needs, and relevant knowledge sources, usage and interpretation — a form of 'knowledge brokering' and 'collaboration' and facilitating the co-development of knowledge between experts and users." For this process to be successful, "… it requires not only translation of knowledge but also mediation to ensure that the best balance of 'salient, credible and legitimate' knowledge is brought to bear";

- "… better engagement with the community, policy makers and influential leaders" to include better working relationship among "… practitioners and decision-makers and stakeholders (community, policy makers, other influential leaders)"; and

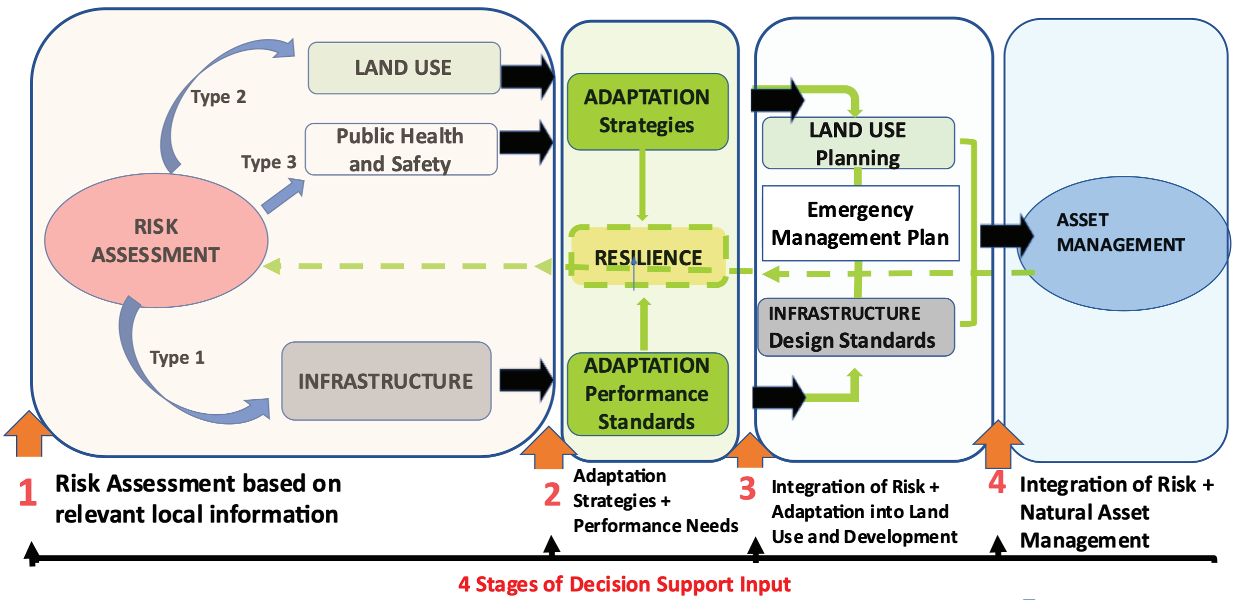
- Better translation and mediation of knowledge into more accessible formats to support engagement and decision-making. This need was identified as "… one of the least developed activities in most adaptation projects" and "… especially important for local government decision-making."

Other reasons given for limited engagement in the Australian survey included:

- Elected officials feeling a need to be well advanced in their own understanding prior to engaging with others;
- Lack of clarity as to the useful scope and intent of engagement;
- Anticipation of, and concern over, negative stakeholder responses;
- Limited knowledge of the best ways to communicate complex information;
- They called for more concise reports and alternative forms of communication (such as visual communication); and
- Local councils are often understaffed and under resourced.

Whether a coincidence or not, the Australian local government survey results are very similar to the municipal survey results from PRAC (ClimateWest)/All One Sky, CIP and Table 7. The consistency of these results suggest local governments would benefit from greater access to decision support in dealing with climate risk assessment and adaptation planning. The results also show there are common operational barriers related to limited resources and expertise and size (smaller populations) which limit local governments' effectiveness in climate adaptation planning. Reducing these barriers (especially for smaller municipalities) could in turn increase municipal effectiveness. As Figure 16 illustrates, there are four stages where municipalities would benefit from specialized decision-support input to incorporate and integrate climate risk and adaptation information into their operations.

Figure 16. Four Decision-Support Input Stages to Increase Municipal Effectiveness



OPTIONS/OPPORTUNITIES FOR INCREASING MUNICIPAL EFFECTIVENESS

The following options/opportunities are available to provide input and support for municipalities in Alberta to reduce the barriers identified. Operationalizing these options/ opportunities will depend upon municipal collaboration, access to specialized information and resources, leadership from provincial associations (Alberta Municipalities and the Rural Municipalities Association of Alberta) and supportive provincial government policies and resourcing. All but the final option (alternative municipal structures) are based on the current Alberta context.

ACCESS TO CLIMATE ADAPTATION RESEARCH AND DECISION SUPPORT (CARDS)

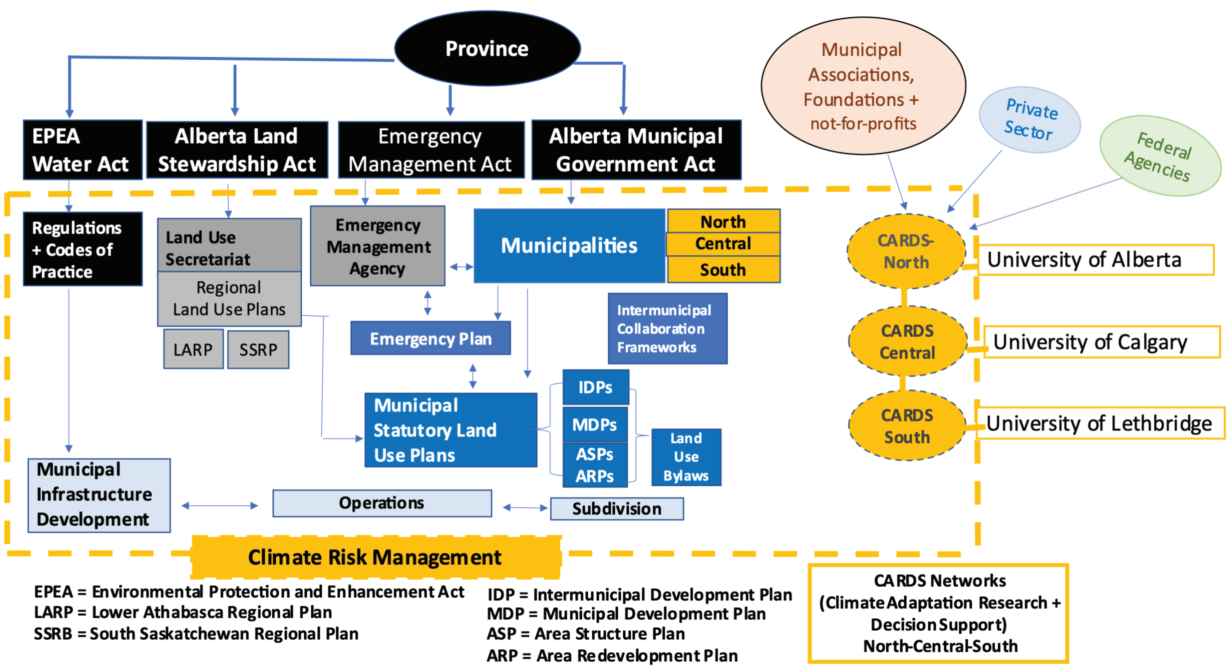
Decision support involves linking information users and information producers in an applications context that involves building trust and incorporating learning. It is most effective when it is specific to the context in which decisions are being made

(Jones et al. 2014). Specifically, "… knowledge is central to governance and of critical importance to decision-making associated with climate resilience" (Beauchamp et al. 2020). However, as Jones et al. (2014) point out "… while good scientific and technical information is necessary, it is not sufficient, and decisions require context-appropriate decision-support processes and tools." If municipal decision-makers are unsure what their information needs are relevant to their local situations, then decision support can play an important role.

Local decision-makers are more likely to use information they view as relevant, credible and available at a scale and in a format that addresses local needs and priorities. This is not easily done given the range of scale and diversity represented by local governments in Alberta. Local governments are constantly making trade-offs for available funds. While it is unlikely this will change, local governments still need to be able to access relevant and credible climate risk assessment and adaptation information without having to entirely trade off climate risk against more immediate service delivery and viability priorities.

The Climate Adaptation and Research Decision Support concept or CARDS is based on establishing collaborative networks (online and/or physical) among provincial agencies, municipal associations, Alberta universities involved in climate risk and adaptation and collaborative organizations in the private and public sectors with expertise and resources related to community climate risk and adaptation planning. CARDS networks/centres would have the outreach capacity to broker and interpret expert knowledge and expertise at regional and locally relevant scales in the southern, central and northern thirds of the province. Figure 17 illustrates how the CARDS concept could complement the provincial municipal legislative framework.

Figure 17. The CARDS Network Concept



Each CARDS network would be university associated but not to a specific unit of the university. These research networks would enable collaboration among academic researchers engaged in ongoing work related to different aspects of climate change research and application including modelling, risk assessment, infrastructure design, natural resource management, policy, social impact, built environment, hydrology and governance, as well as planning, finance, law, engineering and management. CARDS networks would also have a strong community outreach component and engage student researchers from different disciplines in preparation for future work in government and consulting roles.

There is no budget proposal for CARDS at this stage as it is a concept for discussion. However, if Alberta municipalities or the Municipal Climate Change Action Centre are interested in developing a demonstration of the CARDS concept, a financial strategy could be developed as part of a pilot project with a community outreach and research centre associated with a university such as the Community Building and Development Lab in the School of Architecture, Planning and Landscape at the University of Calgary. There are three successful university-associated climate research centres operating in Canada that could provide insight into both partnership agreements and operational and financing precedents that could assist in formulating a demonstration of the CARDS network.

Pacific Climate Impacts Consortium

The first example is associated with the University of Victoria. Its focus is on the "delivery of regional climate services to key stakeholders in the Pacific and Yukon Region ..." The specific services delivered are climate data, data analysis, mapping products and software for government, private companies and regional authorities (https://pacificclimate.org).

Prairie Adaptation Research Collaborative (PARC)

This second example has been associated with the University of Regina over the past 20 years. It has provided much of the original climate change modelling for Saskatchewan, Manitoba and Alberta. In 2021, PARC became part of ClimateWest, a new non-profit organization created to deliver climate information, data and adaptation guidance. ClimateWest involves a partnership of PARC, the International Institute for Sustainable Development (IISD) and the Prairie Climate Centre (PCC) at the University of Winnipeg (https://climatewest.ca/).

Intact Centre on Climate Adaptation

The third national example is associated with the University of Waterloo in Ontario. This centre focuses on applied research at the national level and is primarily sponsored by Intact Financial Corporation, a major insurance company, for the goal of reducing insurance risks for infrastructure and built environment associated with extreme weather events, especially flooding.

EMERGENCY MANAGEMENT

Under Alberta's *Emergency Management Act*, all municipalities are required to have an emergency plan reviewed annually by the Alberta Emergency Management Agency (AEMA). There is potential for greater integration between emergency management planning and longer term climate risk assessment and adaptation integration into municipal land use, infrastructure and asset management. As a provincial agency, the AEMA can facilitate information sharing and expertise among municipalities and provide additional decision support. A focus on integrating emergency planning with municipal statutory planning functions rather than statutory silos can increase the efficiency of limited resources.

INTERMUNICIPAL COLLABORATION FRAMEWORKS

The purpose of ICFs in the *Modernized Municipal Government Act* is: "(a) to provide for the integrated and strategic planning, delivery and funding of intermunicipal services, (b) to steward scarce resources efficiently in providing local services, and (c) to ensure municipalities contribute funding to services that benefit their residents" (CanLII 2016). A greater use of ICFs for integrated climate risk assessment, adaptation and emergency management could support increasing municipal effectiveness through shared risk, specialized information, decision-making, funding and operations. Specific demonstration ICFs for specific climate risk assessment, infrastructure emergency management and land use and infrastructure adaptation through the Municipal Climate Action Centre (possibly with CARDS assistance) could be developed in different parts of Alberta to better understand their potential and best practices in diverse circumstances.

NATURAL ASSET MANAGEMENT

Natural asset management has emerged as a recognized local government practice that offers opportunities to assign value to significant landscape and hydrological features (such as wetlands, forests and grasslands) that provide ecological services such as water storage, runoff management and carbon sequestration. Both the International Public Sector Accounting Standards Board (IPSASB) and the Canadian Public Sector Accounting Standards Board (PSAB) are evaluating the inclusion of natural assets/ecosystem services into financial reporting as an asset class, and the Insurance Bureau of Canada (2022), the Global Risk Institute (2022) and the Auditor General of Canada (2022) have all identified support for the use of natural asset management. A commonly used method in natural asset valuation is to assess value based on what it would cost to replace or provide the same service through alternative sources such as engineering. For example, for natural assets like fresh water or wetlands for flood control, the replacement costs can be extremely high. Asset management that incorporates natural assets can provide a significant financial and functional contribution depending upon geographic location and previous land use. The Municipal Natural Asset Initiative (2022) is working on natural asset management with a number of municipalities across Canada. Two examples of where natural asset management is part of municipal asset management practices are the city of Saskatoon, Saskatchewan and the town of Gibsons, B.C. Saskatoon produced its own "Natural Capital Asset Valuation Report" in 2020 and Gibsons adopted "… an asset management plan that explicitly recognized natural assets alongside traditional capital assets" in 2014 (Blaze Baum 2021). While the Engineers and Geoscientists of British Columbia (2020) have created and approved natural asset management guidelines, to date the Alberta Professional Engineers and Geoscientists have not taken similar action. Although natural asset management is not widespread at the municipal level, there is an opportunity to incorporate it into existing training courses in municipal asset management available through Alberta Municipalities, Rural Municipalities of Alberta and the Federation of Canadian Municipalities.

MUNICIPAL CLIMATE CHANGE ACTION CENTRE

In 2009, Alberta Municipalities (then AUMA) and the Rural Municipalities of Alberta worked with the province to form the Municipal Climate Change Action Centre (MCCAC or the Centre). In 2020, the Alberta government provided $4.5 million to the centre's Climate Adaptation Program to assist Alberta municipalities and Indigenous communities in improving local climate resilience. The All One Sky Foundation (2021) and the centre developed the "Climate Resilience Express Planning Guide." At the same time, the Canadian Council of Ministers of the Environment produced the report "Guidance on Good Practices in Climate Change Risk Assessment" as a resource for municipal decision-makers. Similarly, the Federation of Canadian Municipalities (FCM), as Canada's national municipal organization, provides programs and resources related to climate change adaptation to support municipalities and municipal staff through the Municipalities for Climate Innovation Program (MCIP). FCM also provides asset management educational materials to municipalities and municipal organizations including Alberta Municipalities and Rural Municipalities Association of Alberta. As a coalition of two provincial municipal associations and the province of Alberta, with strong ties to the national Federation of Canadian Municipalities, the centre is in a strong position to assist in orchestrating and facilitating government climate adaptation programs and intergovernmental funding support for key areas such as infrastructure and nature-based solutions. However,the Climate Resilience Capacity Building Program is scheduled to end in March, 2023 and as yet there is no provincial funding commitment to continue this work.

INFRASTRUCTURE DESIGN STANDARDS

Climate risk and extreme events directly affect municipal infrastructure. The costs of impacts and adaptation are significant. Given the limited revenue situation of many local governments, access to additional financial resources to deal with infrastructure maintenance, repair, replacement and adaptation is uncertain. The Public Infrastructure Engineering Vulnerability Committee (2021) is an international partnership involving the Institute for Catastrophic Loss Reduction, the Climate Risk Institute and the German Society for International Cooperation. It has created a climate change infrastructure assessment protocol applicable to Canada which is available on their website. However, only the cities of Edmonton and Calgary have done PIEVC reports. Most importantly, Infrastructure Canada and the National Research Council (2022) are involved in completing a Climate-Resilient Buildings and Core Public Infrastructure Initiative targeted for completion in 2027 and intended to result in new national codes and guidelines for infrastructure to address changing climate conditions. Once completed, Canadian municipalities will then be expected to upgrade infrastructure standards. As these are national standards, they will need to be customized for specific regional and local conditions. However, the mechanisms and resources required for doing so have not yet been identified at either the federal or provincial level. Given the financial costs likely to be involved in changing municipal infrastructure standards across Alberta, creative funding mechanisms such as a public infrastructure bank may be needed (Marois 2022).

INSURANCE

Insurance is an important tool for municipalities in managing risk and recovery from extreme events. Access to insurance options that can support a range of municipal needs is financially necessary (Feltmate and Thistlewaite 2012). Both Alberta Municipalities and the Rural Municipalities Association of Alberta offer insurance and risk services to their members but there are opportunities for more risk-sharing partnerships specific to the implementation of expected new and revised national and regional infrastructure standards.

BROADBAND CAPACITY

Communications technology and digital applications including spatial analysis and modelling are increasingly important tools in managing climate risk and extreme weather events. However, there are still areas of Alberta where local authorities have limited access to high-speed internet. Alberta is in the process of expanding broadband internet coverage to underserved areas and this is expected to be completed by 2027 (Government of Alberta 2022). Digital infrastructure has become critical for economic development as well as for providing municipalities with access to specialized digital information and decision support for climate risk assessment, planning and management.

ALTERNATIVE MUNICIPAL STRUCTURES

There have been previous discussions in Alberta (as well as other provinces) about the use of alternative models of local government (Burke et al. 2015). The consideration of alternatives has been mainly driven by economic and demographic changes and a desire for greater funding efficiencies (Diamant 1996; Hebdon and Jalette 2008; Finn 2008; Burke et al. 2015; Latimer 2019). There may well be future circumstances requiring change to an alternative local government model; however, within the foreseeable future this seems unlikely (RMA 2022). More importantly, the results of the PRAC (ClimateWest)/All One Sky, CIP and Australian survey results do not identify structural specific issues. The main barriers and challenges identified were related to the availability of specialized and dedicated resources to provide local decision support. Arguably, any model that lacks the necessary resources and specialized support to undertake the tasks required is not going to be effective. Just changing the model does not guarantee it will be more effective if it lacks the necessary level of resource support. B.C. provides a cautionary tale in this regard.

In 1965, B.C. moved to a regional district, or two-tiered municipal model. This created 27 regional districts in B.C. ranging in size and population between 2,000 and 119,337 square km and 4,000 to two million people respectively. The regional district restructuring reportedly functioned well in balancing urban-rural and local-regional tensions and perspectives (Province of British Columbia 2006). However, in 2003, the B.C. government brought in the *Flood Hazard Statutes Amendment Act* which transferred responsibility for flood management to regional districts. This resulted in the downloading of responsibility for flood management and flood risk management to the regional districts without accompanying staffing expertise or funding (McClearn and Hunter 2021). While some regional districts and some of their municipal members did establish local capacity for flood management (including diking system infrastructure construction and maintenance), many others did not or could not because of a lack of resources. Over time, this inequity resulted in areas of the Lower Mainland and the Southern Interior becoming increasingly vulnerable to flood risk. When the climate change-related atmospheric river precipitation events occurred in November 2021, the results were disastrous in areas that were vulnerable due to a cumulative lack of resources.

This crisis was not the result of a regional district model per se, nor did having a regional district model prevent the crisis. The problem resulted from the unanticipated consequences of provincial downloading of flood risk management responsibility without the necessary specialized resources to enable the model to work as expected.

No model is likely to be effective if it lacks supportive provincial policy, informed and timely decision-making, equity considerations, sufficient resources and meaningful communication and engagement. These are the critical tools necessary for local government climate risk management effectiveness and providing necessary resources to municipalities is key to successfully managing climate risk.

REFERENCES

Agriculture and Agri-food Canada and the Weather Channel. 2022. Accessed May 20, 2022. https://www.agr.gc.ca/atlas/maps_cartes/canadianDroughtMonitor/en/2022/cdm_2202_en.pdf.

All One Sky Foundation. 2021. "Climate Resilience Express Planning Guide." https://static1.squarespace.com/static/5ed809f05c460126fe7f10e2/t/61f803efb1ad1d2daeda2a3a/1643643897294/AOS_CRE_Planning+Guide_Final-highres.pdf.

Auditor General of Canada. 2022. "Report 1—Federal Support for Sustainable Municipal Infrastructure." https://www.oag-bvg.gc.ca/internet/english/parl_cesd_201605_01_e_41380.html#p61.

Beauchamp, E., M. Hirons, K. Brown, and E. J. Milner-Gulland. 2020. "Twenty Priorities for Future Social-Ecological Research on Climate Resilience." *Environmental Research Letters*, 15(10), 105006. https://iopscience.iop.org/article/10.1088/1748-9326/abb157/pdf.

Bernstein, Joseph, and Andre Reznikov. 2003. "Estimates of Automorphic Functions." arXiv preprint math/0305351.

Bizikova L., T. Neale, and I. Burton. 2008. "Canadian Communities' Guidebook for Adaptation to Climate Change. Including an Approach to Generate Mitigation Co-benefits in the Context of Sustainable Development." First edition. Environment Canada and University of British Columbia, Vancouver. https://publications.gc.ca/collections/collection_2017/eccc/En56-226-2008-eng.pdf.

Blaze Baum, Kathryn. 2021. "Is It Time to Make 'Natural Capital' an Asset Class?" *Globe and Mail.* December 10. https://www.theglobeandmail.com/business/article-is-it-time-to-make-natural-capital-an-asset-class/.

Bowron, Beate, and Gary Davidson. 2011. "Climate Change Adaptation Planning: A Handbook for Small Canadian Communities." Canadian Institute of Planners. https://www.cip-icu.ca/Files/Resources/RURAL-HANDBOOK-FINAL-COPY.

Burke, John, Michael Fenn, Melville McMillan, Robert Taylor, and Wyatt Skovron. 2015. "Examining Municipal Government Models from the Alberta Perspective." Alberta Association of Municipal Districts and Councils. https://rmalberta.com/wp-content/uploads/2020/01/Examining-Municipal-Government-Models-from-the-Alberta-Perspective-FINAL-FOR-WEBSITE.pdf.

Bush, E., and D. S. Lemmen, eds. 2019. "Canada's Changing Climate Report." Government of Canada. https://publications.gc.ca/collections/collection_2019/eccc/En4-368-2019-eng.pdf.

Calgary Metropolitan Region Board. 2022. "Growth Plan." https://www.calgarymetroregion.ca/growth-and-servicing-plan.

Canadian Council of Ministers of the Environment. 2021. "Guidance on Good Practices in Climate Change Risk Assessment." https://ccme.ca/en/res/riskassessmentguidancesecured.pdf.

Canadian Infrastructure. 2019. "Monitoring the State of Canada's Core Public Infrastructure: The Canadian Infrastructure Report Card." http://canadianinfrastructure.ca/downloads/canadian-infrastructure-report-card-2019.pdf.

Canadian Institute of Planners (CIP). 2011. "Climate Change Adaptation Planning: A Handbook for Small Canadian Communities." Natural Resources Canada. https://www.cip-icu.ca/Files/Resources/RURAL-HANDBOOK-FINAL-COPY.

———. 2019. "Perspectives of Climate Change: A Report on the 2019 Benchmarking Survey of Canadian Professional Planners." Natural Resources Canada. https://www.cip-icu.ca/getattachment/Resources/Resources/2019-CIP-Climate-Change-Survey-Final-Report/CIP-FINAL-report.pdf.aspx.

Canadian Public Sector Accounting Standards Board (PSAB). 2022. "PSAB Decision Summary (International Strategy)." https://www.frascanada.ca/en/search-results#q=natural%20assets&sort=relevancy.

Canadian Underwriter. 2020. "How Much These Four Alberta Cats Cost Insurers in 2020." September 10. https://www.canadianunderwriter.ca/catastrophes/how-much-these-four-alberta-cats-cost-insurers-in-2020-1004196753/.

———. 2021. "Severe Drought Expected to Cost Alberta $1 Billion in Insurance Payouts." July 23. https://www.canadianunderwriter.ca/insurance/severe-drought-expected-to-cost-alberta-1-billion-in-insurance-payouts-1004210606/.

CanLII. 1981. Nova, An Alberta Corporation v. Amoco Canada Petroleum Company Ltd., 1981 CanLII 211 (SCC), [1981] 2 SCR 437. https://canlii.ca/t/1z1gq.

———. 1992. Friends of the Oldman River Society v. Canada (Minister of Transport), CanLII 110 (SCC), [1992] 1 SCR 3. https://canlii.ca/t/1bqn8.

———. 2000a. *Environmental Protection and Enhancement Act*, RSA c E-12. https://canlii.ca/t/5575w.

———. 2000b. *Irrigation Districts Act*, RSA 2000, c I-11. Agriculture, Forestry, and Rural Economic Development. https://canlii.ca/t/5538w.

———. 2016. *Modernized Municipal Government Act*, SA 2016, c 24. https://canlii.ca/t/53l57.

———. 2020a. *Emergency Management Act*, RSA 2000, c E-6.8. https://canlii.ca/t/55pf6.

———. 2020b. *Red Tape Reduction Implementation Act*, 2020, SA 2020, c 25. https://canlii.ca/t/54qd1.

Cannon, Alex J., Dae Il Jeong, Xuebin Zhang, and Francis W. Zwiers. 2020 "Climate-Resilient Buildings and Core Public Infrastructure." Environment and Climate Change Canada. https://publications.gc.ca/collections/collection_2021/eccc/En4-415-2020-eng.pdf.

City of Saskatoon. 2020. "Natural Capital Asset Valuation Pilot Project." https://www.saskatoon.ca/sites/default/files/documents/ncav-report-final.pdf.

Cohen, S., E. Bush, X. Zhang, N. Gillett, B. Bonsal, C. Derksen et al. 2019. "Changes in Canada's Regions in a National and Global Context." Chapter 8 in "Canada's Changing Climate Report." E. Bush and D. S. Lemmen, eds. Government of Canada. 424-443. https://changingclimate.ca/CCCR2019/chapter/8-0/.

Council of Canadian Academies. 2019. "Canada's Top Climate Change Risks. The Expert Panel on Climate Change Risks and Adaptation Potential." https://cca-reports.ca/wp-content/uploads/2019/07/Report-Canada-top-climate-change-risks.pdf.

Diamant, Peter. 1996. "Consolidation and the Small Municipality: A Commentary." RDI Report Series 1996-2. The Rural Development Institute, Brandon University, Brandon, MB.

Edmonton Metropolitan Region Board. 2017. "Re-imagine. Plan. Build." Amended January 15, 2022. https://www.emrb.ca/growth-plan.

Engineers and Geoscientists of British Columbia. 2021. "New Guidelines On Local Government Asset Management." https://www.egbc.ca/app/Practice-Resources/Individual-Practice/Guidelines-Advisories/Document/01525AMWZVWX2LETUSHVF3LMTH6M24ZLTN/Local%20Government%20Asset%20Management.

Engineers Canada and Natural Resources Canada. 2021. "The PIEVC Protocol for Assessing Public Infrastructure Vulnerability to Climate Change Impacts: National and International Application." The Public Infrastructure Engineering Vulnerability Committee (PIEVC). https://pievc.ca/wp-content/uploads/2021/08/PIEVC_Program-May-2021.pdf.

Environment and Climate Change Canada and Prairie Climate Centre. 2019. "Climate Atlas of Canada." Version 2. Using BCCAQv2 climate model data. https://climateatlas.ca/.

Faramarzi, Monireh, Karim C. Abbaspour, Wei Lu, Jon Fennell, Alexander J. B. Zehnder, and Greg G. Goss. 2017. "Uncertainty Based Assessment of Dynamic Freshwater Scarcity in Semi-arid Watersheds of Alberta, Canada." *Journal of Hydrology: Regional Studies,* 9: 48–68. https://www.sciencedirect.com/science/article/pii/S2214581816301859.

Federation of Canadian Municipalities (FMC) and Canadian Institute of Planners (CIP). 2022. "Municipalities for Climate Innovation Program 2017-2022." https://fcm.ca/en/programs/municipalities-climate-innovation-program.

Feltmate, B., and M. Moudrak. 2021. "Climate Change and the Preparedness of 16 Major Canadian Cities to Limit Flood Risk." Intact Centre on Climate Adaptation, University of Waterloo. https://www.intactcentreclimateadaptation.ca/wp-content/uploads/2021/02/16-Cities-Flood-Preparedness-1.pdf.

Feltmate, Blair, and Jason Thistlethwaite. 2012. "Climate Change Adaptation: A Priorities Plan for Canada." Climate Change Adaptation Project (Canada). https://www.intactcentre.ca/wpcontent/uploads/docs/Climate%20Change%20Adaptation%20-%20A%20Priorities%20Plan%20for%20Canada%20(2012).pdf.

Finn, Jean-Guy. 2008. "Building Stronger Local Governments and Regions." Report of the Commissioner on the Future of Local Governance. https://www2.gnb.ca/content/dam/gnb/Departments/lg-gl/pdf/BuildingStrongerLocalGovernmentsAndRegions.pdf.

Global Risk Institute. 2022. "Treading Water: Impact of Catastrophic Flooding on Canada's Housing Market." February 15. https://globalriskinstitute.org/publications/treading-water-impact-of-catastrophic-flooding-on-canadas-housing-market/.

Government of Alberta. 2005. "Alberta Environment Water for Life: Aquatic Ecosystems Review of Issues and Monitoring Techniques." Alberta Environment (ABENV). https://open.alberta.ca/publications/0778543935#summary.

———. 2014. "Water Act Administrative Guideline for Transfer of Water Allocations (and Agreements to Assign Water, and Licence Amendments)." Environment and Parks. Volume 2.0. Revised November. https://open.alberta.ca/dataset/07741435-0383-4d0b-ad56-826cabd0d4cd/resource/1023192b-d2f3-42bb-a634-d8daecc17864/download/2014-guidelinetransferwaterallocation-nov2014.pdf\.

———. 2017. "Amendments to the Municipal Government Act, 2015–2017: Implementation Fact Sheets." Municipal Affairs. https://open.alberta.ca/publications/mga-implementation-fact-sheets.

———. 2020. "Intermunicipal Collaboration Framework Workbook: Resource Guide for Municipalities." Alberta Municipal Affairs. https://www.abmunis.ca/sites/default/files/Advocacy/Programs_Initiatives/MGA_Change_Mgt_Resources/icf_workbook_update_2020_final.pdf.

———. 2021. "2021 Municipal Codes." Alberta Municipal Affairs. https://open.alberta.ca/dataset/7b81986c-b05a-4b72-8f12-aec3a22970ae/resource/6fdc7bf0-ac2f-400e-b74a-4a9d37437f65/download/2022-lgcode.pdf.

———. 2022a. "Government Emergency Plans." https://www.alberta.ca/government-emergency-plans.aspx.

———. 2022b. “Alberta Broadband Strategy: Connecting Albertans, Growing the Economy.” Service Alberta. https://www.alberta.ca/alberta-broadband-strategy.aspx.

———. 2023. “Government Emergency Plans.” https://www.alberta.ca/government-emergency-plans.aspx.

Guyadeen, Dave, Jason Thistlethwaite, and Daniel Henstra. 2019. “Evaluating the Quality of Municipal Climate Change Plans in Canada.” *Climatic Change,* 152(1): 121–143. https://link.springer.com/article/10.1007/s10584-018-2312-1.

Hadwen, Trevor, and Grace Schaan. 2021. “The 2017 Drought in the Canadian Prairies.” Special Report on Drought. United Nations Office for Disaster Risk Reduction. https://www.preventionweb.net/files/78461_cs4.gar2017canadianprairiesdroughtc.pdf.

Hayhoe, Katharine, and Anne Stoner. 2019. “Alberta’s Climate Future.” Final Report. ATMOS Research & Consulting. https://open.alberta.ca/dataset/89a69583-a11b-4e31-a857-b311ab6563cc/resource/17ce2d24-ba7b-466c-acd9-33a2cf6beb69/download/aep-alberta-climate-report-arc.pdf.

Hebdon, Robert, and Patrice Jalette. 2008. “The Restructuring of Municipal Services: A Canada – United States Comparison.” *Environment and Planning C: Government Policy,* vol. 26: 144–158.

Honegger, Caspar, and Christoph Oehy. 2016. “The Road to Flood Resilience in Canada.” Swiss Reinsurance Company Ltd. https://www.swissre.com/Library/the-road-to-flood-resilience-in-canada.html.

Infrastructure Canada and National Research Council. 2022. “Climate-Resilient Buildings and Core Public Infrastructure Initiative.” https://www.infrastructure.gc.ca/plan/crbcpi-irccipb-eng.html.

Insurance Bureau of Canada. 2021. “Calgary hailstorm causes $247 million in insured damages”. Online reports http://www.ibc.ca/ab/resources/media-centre/media-releases/calgary-hailstorm-causes-247-million-in-insured-damage

Insurance Bureau of Canada. 2022a. “Nature Based Solutions.” Online reports. http://www.ibc.ca/pe/disaster/nature-based-solutions.

———. 2022b. “Severe Weather in 2021 Caused $2.1 Billion in Insured Damage.” http://www.ibc.ca/on/resources/media-centre/media-releases/severe-weather-in-2021-caused-2-1-billion-in-insured-damage.

Intergovernmental Panel on Climate Change (IPCC). 1990. “IPCC First Assessment Report.” IPCC Secretariat, World Meteorological Organization. https://www.ipcc.ch/site/assets/uploads/2018/03/ipcc_far_wg_I_full_report.pdf

———. 1992. *Climate Change 1992: The Supplementary Report to the IPCC Scientific Assessment.* Cambridge: Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2020/02/ipcc_wg_I_1992_suppl_report_full_report.pdf.

———. 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.* Cambridge: Cambridge University Press. https://www.ipcc.ch/report/managing-the-risks-of-extreme-events-and-disasters-to-advance-climate-change-adaptation/.

International Public Sector Accounting Standards Board (IPSASB). 2022. "Consultation Paper, Natural Resources." May 16. https://www.ipsasb.org/publications/consultation-paper-natural-resources.

Jones, Lindsey, Natasha Grist, Eva Ludi, and Elizabeth Carabine. 2014. "Planning for an Uncertain Future: Promoting Adaptation to Climate Change Through Flexible and Forward-looking Decision Making." A report for the Africa Climate Change Resilience Alliance. https://oxfamilibrary.openrepository.com/bitstream/handle/10546/316675/rr-odi-planning-for-uncertainity-summary-260314-en.pdf?sequence=1.

Latimer, Keith. 2019. "Nova Scotia Restructuring Offers New Models for Consolidation." *Municipal Worl*d. September 22. https://coxandpalmerlaw.com/publication/nova-scotia-restructuring-offers-new-model-for-consolidation/.

Lavell, A., M. Oppenheimer, C. Diop, J. Hess, R. Lempert, J. Li et al. 2012. "Climate Change: New Dimensions in Disaster Risk, Exposure, Vulnerability, and Resilience." In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation,* C. B. Field, V. Barros et al., eds. Cambridge: Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap1_FINAL-1.pdf.

Le Treut, H., R. Somerville, U. Cubasch, Y. Ding, C. Mauritzen, A. Mokssit et al. 2007. "Historical Overview of Climate Change." In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* S. Solomon, D. Qin et al., eds. Cambridge: Cambridge University Press. https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/ch1.html.

Locky, David A. 2011. "Wetlands, Land Use and Policy: Alberta's Keystone Ecosystem at a Crossroads." Green paper presented at Alberta Institute of Agrologists. March 16.

Marois, Thomas. 2022. "A Public Bank for the Public Interest." Canadian Union of Public Employees. https://cupe.ca/sites/default/files/cupe_cib_marois_report_2022_e.pdf.

McClearn, Matthew, and Justine Hunter. 2021. "Were B.C.'s Dikes Ever Up to the Job of Stopping Floods Like These?" *Globe and Mail*. December 2. https://www.theglobeandmail.com/canada/article-were-bcs-dikes-ever-up-to-the-job-of-stopping-floods-like-these/.

.

Municipal Climate Change Action Centre (MCCAC) 2022. "Climate Resilience Capacity Building ProgramGuidebook".https://mccac.ca/app/uploads/Climate-Resilience-Capacity-Building-Program-Guidebook.pdf.

Municipal Climate Services Collaborative (MCSC). 2020. "Talking it Through: A Discussion Guide for Local Government Staff on Climate Change Adaptation." Environment and Climate Change Canada, Cat. No.: En4-409/2020E-PDF. https://publications.gc.ca/site/eng/9.891148/publication.html.

Municipal Natural Asset Initiative (MNAI). 2022. "Developing Levels of Service for Natural Assets: A Guidebook for Local Governments." https://mnai.ca/resources-and-reports/.

North American Regional Climate Change Assessment Program (NARCCAP). n.d. Accessed July 9, 2022. https://toolkit.climate.gov/tool/north-american-regional-climate-change-assessment-program-narccap.

Pacific Climate. n.d. https://www.pacificclimate.org/data/statistically-downscaled-climatescenarios.

Parry, Jo-Ellen, and Prairies Regional Adaptation Collaborative. 2022. "Preparing for Climate Change in the Prairie Provinces: Regional Survey Outcomes on the Climate Adaptation Priorities and Progress of Communities." ClimateWest. https://climatewest.ca/publications/preparing-for-climate-change-in-the-prairie-provinces-regional-survey-outcomes-on-the-climate-adaptation-priorities-and-progress-of-communities/.

Province of British Columbia. 2003. *Flood Hazard Statutes Amendment Act.* Ministry of Water, Land and Air Protection. https://www.bclaws.gov.bc.ca/civix/document/id/lc/billsprevious/4th37th:gov56-3.

———. 2006. "A Primer on Regional Districts in British Columbia." Ministry of Community Services. https://prrd.bc.ca/wp-content/uploads/page/regional-district-primer/2006-Primer-BC-RDs.pdf.

Public Infrastructure Engineering Vulnerability Committee. 2021. "The PIEVC Protocol for Assessing Public Infrastructure Vulnerability to Climate Change Impacts: National and International Application." Delivered at Annual Conference Inspired by Nature. May 26–29. https://pievc.ca/wp-content/uploads/2021/08/PIEVC_Program-May-2021.pdf.

Public Safety Canada. 2019. "Emergency Strategy for Canada: Toward 2050." https://www.publicsafety.gc.ca/cnt/rsrcs/pblctns/mrgncy-mngmnt-strtgy/index-en.aspx.

———. 2023. https://www.publicsafety.gc.ca/index-en.aspx.

Rural Municipalities of Alberta (RMA). 2022. "Municipal Structures an Alternative Dialogue for Municipalities in Alberta." October. https://rmalberta.com/wp-content/uploads/2022/10/Municipal-Structures-An-Alternative-Dialogue-FULL.pdf.

Sauchyn, D., D. Davidson, and M. Johnston. 2020. "Prairie Provinces." Chapter 4 in *Canada in a Changing Climate: Regional Perspectives Report,* F. J. Warren, N. Lulham, and D. S. Lemmen, eds. Ottawa: Government of Canada.

Sauchyn, D., J. Vanstone, J. St-Jacques, and R. Sauchyn. 2015. "Dendrohydrology in Canada's Western Interior and Applications to Water Resource Management." *Journal of Hydrology*, vol. 529: 548-558. https://doi.org/10.1016/j.jhydrol.2014.11.049.

Saxe, Dianne, and Meredith James. 2014. "Do Municipalities Have a Duty to Adapt to Climate Change?" *Municipal World* 124 (7): 41–42.

Shank, C. C., and A. Nixon. 2014. "Climate ChZZZange Vulnerability of Alberta's Biodiversity: A Preliminary Assessment." Biodiversity Management and Climate Change Adaptation Project. https://www.natureserve.org/sites/default/files/shankandnixon_2014_climatechangevulnerabilityofalbertasterrestrialbiodiversity_abmi.pdf.

Sheppard, S. R. 2012. *Visualizing Climate Change: A Guide to Visual Communication of Climate Change and Developing Local Solutions*. Oxfordshire: Routledge.

Statistics Canada. 2017. "Infographic: Fort McMurray 2016 Wildfire – Economic Impact." https://www150.statcan.gc.ca/n1/pub/11-627-m/11-627-m2017007-eng.htm.

———. 2022. "Population and Dwelling Counts: Canada and Designated Places." Table 98-10-0012-01. https://doi.org/10.25318/9810001201-eng.

Tang, Zhenghong, Samuel D. Brody, Courtney Quinn, Liang Chang, and Ting Wei. 2010. "Moving from Agenda to Action: Evaluating Local Climate Change Action Plans." *Journal of Environmental Planning and Management,* vol. 53(1): 41–62. https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1005&context=arch_crp_facultyschol.

United States Geological Survey. n.d. "What Is the Difference Between Weather and Climate Change?" Accessed April 2022. https://www.usgs.gov/faqs/what-difference-between-weather-and-climate-change.

Warren, F. J., and D. S. Lemmen, eds. 2014. *Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation*. Ottawa: Government of Canada. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Full-Report_Eng.pdf.

Warren, F., and N. Lulham, eds. 2021. *Canada in a Changing Climate: National Issues Report*. Ottawa: Government of Canada. https://publications.gc.ca/collections/collection_2021/rncan-nrcan/M174-24-2021-eng.pdf.

Webb, Bob, Lisa Petheram, and Peter Weiske. 2014. "Climate Adaptation Decision Support Strategies: Developing a National Agenda." LAPS 2 Final Report, June 5. Australian National University. https://www.researchgate.net/publication/319165028_Climate_Adaptation_Decision_Support_Strategies_Developing_a_National_Agenda_LAPS_2_Final_Report_-_5_June_2014/link/599694b5aca27283b120f1f4/download.

Woodruff, S. C., S. Meerow, M. Stults, and C. Wilkins. 2022. "Adaptation to Resilience Planning: Alternative Pathways to Prepare for Climate Change." *Journal of Planning Education and Research*, 42(1): 64–75.103.

World Meteorological Organization (WMO). 2022. "State of the Global Climate Report 2021." https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate.

Wu, J., and T. Wu. 2013. "Ecological Resilience as a Foundation for Urban Design and Sustainability." In *The Ecological Design and Planning Reader*. Berlin: Springer. https://link.springer.com/chapter/10.1007/978-94-007-5341-9_10.

Zhang, X., G. Flato, M. Kirchmeier-Young, L. Vincent, H. Wan, X. Wang et al. 2019. "Changes in Temperature and Precipitation Across Canada." Chapter 4 in *Canada's Changing Climate Report*, E. Bush and D.S. Lemmen, eds. Ottawa: Government of Canada. 112–19. https://publications.gc.ca/collections/collection_2019/eccc/En4-368-2019-eng.pdf.

ABOUT THE AUTHOR

Dr. Mary-Ellen Tyler has interdisciplinary graduate degrees in environmental science, design, and planning and is currently full professor of Planning and Landscape Architecture at the University of Calgary, in Calgary, Alberta. She has extensive professional practice experience in regional planning, community development, and applied environmental science in Canada and internationally. She has worked in both the public and private sector in land use planning, water management, natural resource management, intergovernmental relations, policy analysis, and local government service delivery. Her academic and professional research involves integrating water management and land use planning and climate change adaptation.

ABOUT THE SCHOOL OF PUBLIC POLICY

The School of Public Policy has become the flagship school of its kind in Canada by providing a practical, global and focused perspective on public policy analysis and practice in areas of energy and environmental policy, international policy and economic and social policy that is unique in Canada.

The mission of The School of Public Policy is to strengthen Canada's public service, institutions and economic performance for the betterment of our families, communities and country. We do this by:

- *Building capacity in Government through* the formal training of public servants in degree and non-degree programs, giving the people charged with making public policy work for Canada the hands-on expertise to represent our vital interests both here and abroad;
- *Improving Public Policy Discourse outside Government* through executive and strategic assessment programs, building a stronger understanding of what makes public policy work for those outside of the public sector and helps everyday Canadians make informed decisions on the politics that will shape their futures;
- *Providing a Global Perspective on Public Policy Research* through international collaborations, education, and community outreach programs, bringing global best practices to bear on Canadian public policy, resulting in decisions that benefit all people for the long term, not a few people for the short term.

The School of Public Policy relies on industry experts and practitioners, as well as academics, to conduct research in their areas of expertise. Using experts and practitioners is what makes our research especially relevant and applicable. Authors may produce research in an area which they have a personal or professional stake. That is why The School subjects all Research Papers to a double anonymous peer review. Then, once reviewers comments have been reflected, the work is reviewed again by one of our Scientific Directors to ensure the accuracy and validity of analysis and data.

The School of Public Policy
University of Calgary, Downtown Campus
906 8th Avenue S.W., 5th Floor
Calgary, Alberta T2P 1H9
Phone: 403 210 3802

DISCLAIMER

EDITORIAL PRACTICES STATEMENT

This manuscript is a double-blind peer-reviewed contribution to the policy conversation that has been assessed by at least two reviewers external to the authorial team.

COPYRIGHT

ISSN

ISSN 2560-8312
The School of Public Policy Publications (Print)
ISSN 2560-8320
The School of Public Policy Publications (Online)

DATE OF ISSUE

March 2023

MEDIA INQUIRIES AND INFORMATION

For media inquiries, please contact Dana Fenech at 403-210-6508.

Our web site, **www.policyschool.ca**, contains more information about The School's events, publications, and staff.

DISTRIBUTION

For a full list of publications from The School of Public Policy, please visit www.policyschool.ca/publications