# Adapting to Water Scarcity

## An *Adapt-action* Summary Report

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# Adapting to Water Scarcity

A Summary Report from *Adapt-action* – An Online Tool to Help Alberta Municipalities Become More Climate Resilient

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# Introduction

The *Adapt-action* tool is an on-line resource to help Alberta municipalities adapt to a changing climate regime by taking action to become more resilient communities.

You can visit the tool at: **www.adaptaction.ca**

However, you are not always at an internet-connected computer, and many municipal processes require the support of printed information. This summary report is intended to support municipal personnel in those circumstances.

This report includes all of the information in the *Adapt-action* tool associated with the '**Adapting to Water Scarcity**' module. The information is gathered and presented in such a way that you have a portable PDF summary, but one that you can navigate through easily. This format allows the user to print or extract individual pieces of information (a strategy, implication write-up, or environmental change description).

The goal is to provide usable, sharable, compelling information to support municipalities in their efforts to become more climate resilient.

# The Adapt-action Tool

## What is the *Adapt-action* tool

*Adapt-action* guides users through a series of issue 'narratives' - storylines about climate change issues that might be affecting you. Each one is outlined from the environmental changes you will see, to the implications for your community, through to the strategies you can employ to adapt and become more climate resilient. As you navigate through each issue narrative, you will be able to view and collect information about:

- Predicted climate change impacts and their effects;
- Implications of these impacts to agriculture, health, recreation, infrastructure and biodiversity in your community; and
- What your municipality can do to prepare and adapt to these expected changes.

The *Adapt-action* tool was created by the Miistakis Institute as part of the *Biodiversity Management and Climate Change Adaptation* project, which was led by the Alberta Biodiversity Monitoring Institute (ABMI), conducted in partnership with the University of

Alberta and the University of Saskatchewan, and funded by the Climate Change Emissions and Management Corporation (CCEMC).

## Who is the tool for?

Climate change affects everyone in your community. Everyone is in a unique position to do something to adapt to it, but everyone needs information tailored to their outlook. The *Adapt-action* tool zeros in on municipalities, describing issues from their perspective, and framing strategies in terms of their mandates and capabilities. However, anyone in the community can benefit from this information because municipal staff and councils cannot create climate-resilient communities on their own.

And all approaches to climate change adaptation need to be considered. However, the *Adapt-action* tool emphasizes proactive, ecosystem-based approaches. Though increasing in use around the world, these tactics are often underutilized, despite being cost effective, representing robust risk management, and providing numerous co-benefits. The *Adapt-action* tool will assist municipalities and community members seeking these kinds of approaches.

## Why are we talking about climate change adaptation?

The vast majority of scientists believe humans are interfering with the climate system, which poses risks to both human and natural systems.

Here are some of the risks identified in the Intergovernmental Panel on Climate Change (2014) report:

- In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans.
- In many regions, changes in precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality
- Most terrestrial and freshwater species have shifted their geographic ranges, seasonal activities, migration patterns, abundances and species interactions in response to climate change.

- Based on many studies covering a wide range of regions and crops, negative impacts of climate change on crop yields have been more common than positive impacts.
- Climate related hazards exacerbate other stressors, often with negative outcomes for livelihoods, especially for people living in poverty.

Although these risks are drawn from a global assessment, many of these risks are relevant to southern Alberta.

Communities have adapted to impacts of weather and climate variability for generations through implementation of a range of practices including irrigation, crop diversification, disaster management and water management, but climate change poses a bigger challenge, one outside our range of past experiences.

To manage for expected risks, climate change adaptation strategies are an important consideration for regional and local governments. *"Adaptation infers to the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects"* (IPCC 2014). Governments at all levels world-wide are integrating climate change considerations into planning and policy developments.

More recently, the language of 'climate change adaptation' has been evolving into 'climate resilience.' It sounds like a new batch of jargon, but it is a critical difference. Resilience is the ability of something bounce back or recover quickly; the use of this terms moves the adaptation conversation much more into the realm of 'proactively' creating that ability, rather than 'reactively' adjust to new conditions.

Resource: Intergovernmental Panel on Climate Change (IPCC). 2014. Summary for Policy Makers
http://ipcc-wg2.gov/AR5/images/uploads/WG2AR5_SPM_FINAL.pdf

## How do we deal with scientific uncertainty?

The United Nations Intergovernmental Panel on Climate Change (IPCC) has determined the climate is changing, the average global temperature is warming and that humans have caused the warming by increasing CO2 and other greenhouse gases into the atmosphere through fossil fuel emissions and land use changes. The IPCC indicates there is unequivocal agreement that humans are the cause of climate change, but there

is uncertainty around the severity of future impacts. This is primarily due to the complexity of trying to accurately model the climate, but also because it is largely depends on how we as a species respond to global emission reduction targets. What we do know is it is not too late to avoid the worst; lower emissions will mean reduced climate change and less severe impacts.

To address the uncertainty of future emissions climate scientists have developed emissions scenarios, plausible representations of future releases of greenhouse gases in to the atmosphere. Within the Adapt-action tool we present climate predictions based on two common emission scenarios:

- A2: Greenhouse gas emissions rise continuously, reaching the highest levels of all scenarios by the end of the century.
- B1: Greenhouse gas emissions initially rise faster than in the A2 scenario, with a low mid-century peak and the subsequent decline in emissions is faster.

If change is coming, but we are uncertain of the severity, how does a local community effectively plan to adapt to these changes? It is important to understand that addressing climate change wisely will yield many benefits to the economy and the quality of life, that acting sooner would be less disruptive than acting later, and that local communities can adapt and in many cases are already implementing strategies that promote climate resilience.

## What is an Ecosystem-based Approach to climate change?

There are different ways to approach adaptation, but one approach that is garnering increasing attention is *Ecosystem-based Adaptation* (EbA). EbA sees adaptation as a function of resilience. Hence, a key premise of EbA is to protect the ecosystem that provides life supporting systems (ecosystem services) humans need to survive.

EbA is built on the notion that a healthy functioning ecosystem is more resilient and therefore better able to adapt to ecosystem stress, such as climate change. Restoring or maintaining ecosystem resilience therefore reduces the vulnerability of communities to climate change. Ecosystems provide services that play a role in adaptation to climate change, such as risk reduction of natural disasters (floods, drought), food security, sustainable water management and livelihood diversification.

> *The Convention on Biological Diversity defines EbA as: "Sustainable management, conservation and restoration of ecosystems, as part of an overall adaptation strategy that*

*takes into account the multiple social, economic and cultural co-benefits for local communities." (Convention on Biological Diversity, 2010, Decision X/33)*

One of the main benefits of EbA is its potential to achieve multiple benefits. For example, an EbA strategy to sustainably manage wetlands and floodplains has multiple benefits, such as the maintenance of water flow and water quality, flood control, and water storage, all of which contribute to the reduced risks of drought. However, besides reducing vulnerability to natural disaster, other benefits include improved recreational opportunities (fishing), regulation of water, and enhanced carbon storage. Given the multiple benefits of EbA strategies, they are often termed 'no-regret' strategies. That is, given the uncertainty around the frequency and extent of environmental impacts expected from climate change, EbA actions will still provide benefit to communities even if climate change impacts are less severe than predicted.

## Building Resiliency to Water Scarcity

Alberta, especially the grasslands natural region, frequently experiences periods of low water availability and has a history of multi-year droughts; between 1900 to 2005 Alberta experienced 35 recorded droughts. Many of these droughts have had severe economic impacts on the rural agriculture community, including loss of agriculture production. For example, during the drought of 2001-2002 an approximate $3.6 billion drop in agricultural production occurred accompanied by a shortage of livestock feed.

Agriculture-based communities, in particular, have been susceptible to climate variability and periods of low water availability and to a certain extent are adept at adapting to changing conditions. However, climate change will cause the prairies to get hotter resulting in changes to the hydrological cycle, such as reduced water flow during late summer and increases in evapotranspiration, further reducing moisture levels. These environmental changes have the potential to exacerbate the conditions that lead to drought and an increased frequency of drier years is expected. The Government of Canada climate change report of 2008 stated that increases in water scarcity resulting from climate change presents the greatest risk to the Prairie Provinces, including Alberta.

Re-occurring water deficits (drought) has implications on economy, environment and culture of the prairie communities.

### Building Climate Resiliency


Building climate resiliency in a local community is based on three steps:

- Understanding what the changes to the local environment will be,
- Understanding what the implications of those changes are to the community, and
- Developing strategies that can target those implications.

A community that can effectively navigate those three steps will be in the best position possible to face a changing climate regime with resiliency.

## Environmental Changes/Effects

Water scarcity issues, which are already a concern in southern Alberta, are likely to be exacerbated due to increasing levels of carbon dioxide in the atmosphere. The result will be an increase in ambient air temperature, and changes to the timing of precipitation with a decrease in the spring and late summer. The following table outlines the current climate variables and the predicted changes by 2080 in the grasslands natural region based on two emission scenarios:

- A2: Greenhouse gas emissions rise continuously, reaching the highest levels of all scenarios by the end of the century; and
- B1: Greenhouse gas emissions initially rise faster than in the A2 scenario, with a low mid-century peak and the subsequent decline in emissions is faster.

**Summary Table of Key Climate Variables for Alberta**

| | Current | A2 Scenario | B1 Scenario |
|---|---|---|---|
| **Variable - Average Annual** | | | |
| Temp (°C) | 4.0 °C | + 4.8 °C | + 2.8 °C |
| Precipitation (mm) | 371.6 mm | +21.8 mm | +16.2 mm |
| **Variable - Average Seasonal** | | | |
| Mean Temp Coldest Month (°C) | -11.7 °C | + 4.5 °C | + 3.3 °C |
| Mean Temp Warmest Month (°C) | 17.8 °C | +5.3 °C | +3.1 °C |
| Growing Degree Days | 1,599 days | +54.9 days | +33.9 days |

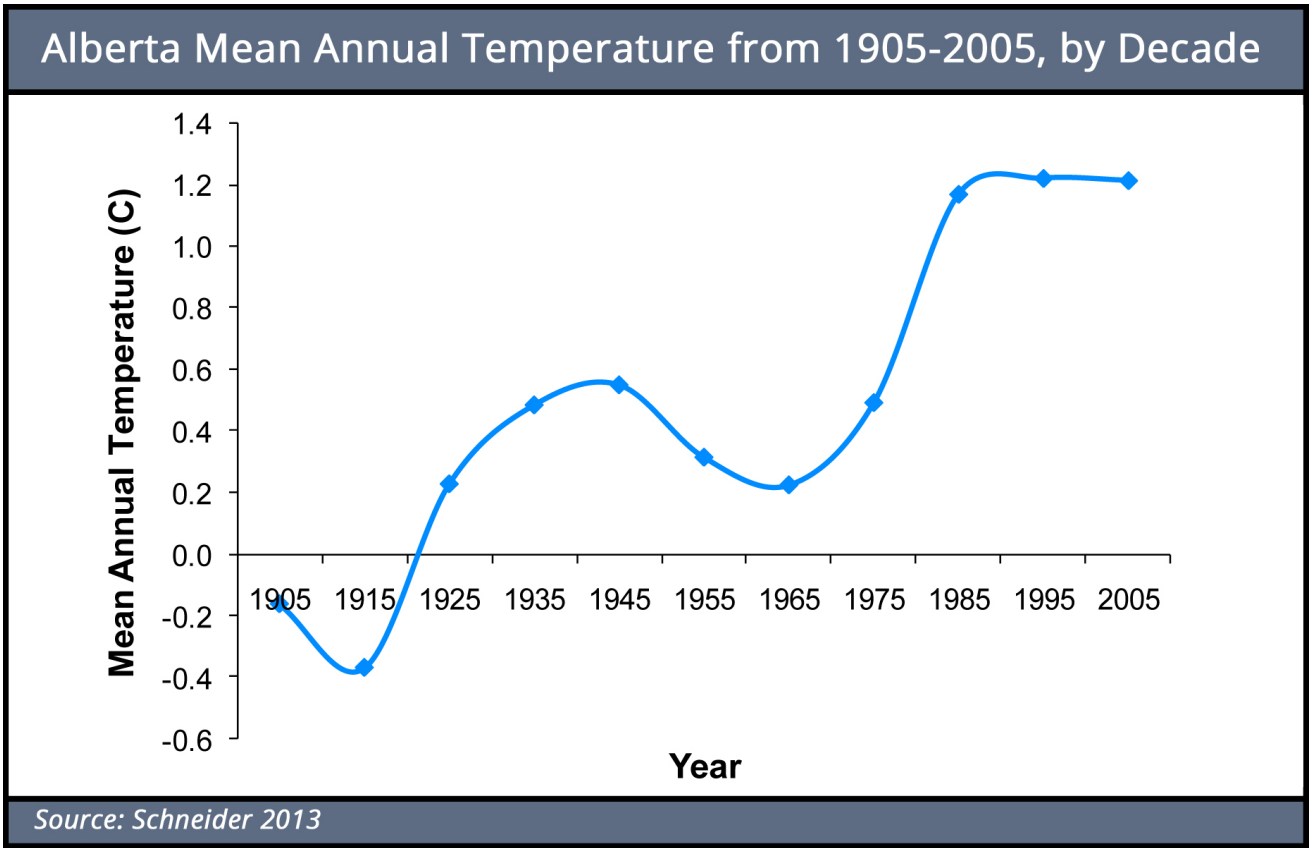
*Source: Schneider 2013*

The resulting predicated changes in temperature and precipitation include a decrease of moisture levels in the soil, increase in growing degree days, decreases in stream flow and changes in stream flow timing. Although decreases in water are expected, there is

uncertainty around the severity of the impacts, to address this modellers use emissions scenarios.

## Temperature

Alberta has experienced an increasing temperature trend, as depicted in the following graph. The mean annual temperature increased by 1.4 °C from 1905 to 2005.




In the Grasslands Natural Region, climate change modeling estimates that there will be a rise of 4.2°C by 2080 under the A2 scenario and 2.8°C under the B1 scenario (Schneider 2013). A recent report in Alberta suggests that an increasing temperature greater than 2°C is inevitable even with reduced emissions targets. Nevertheless, the B1 scenario is more desirable and is dependent on reduced emissions.

A trend of increasing temperature will occur in both the summer and winter, and have a large influence on the number of growing degree days, amount of glacier melt, and changes in stream flow.

The online tool displays maps which show the current temperature, as well as

predictions for 2050 under the A2 scenario. The inset map shows departure from change, indicating where on the landscape there is a greater degree of change expected from current conditions. A slider allows the user to move back and forth between time periods.

*REFERENCES*

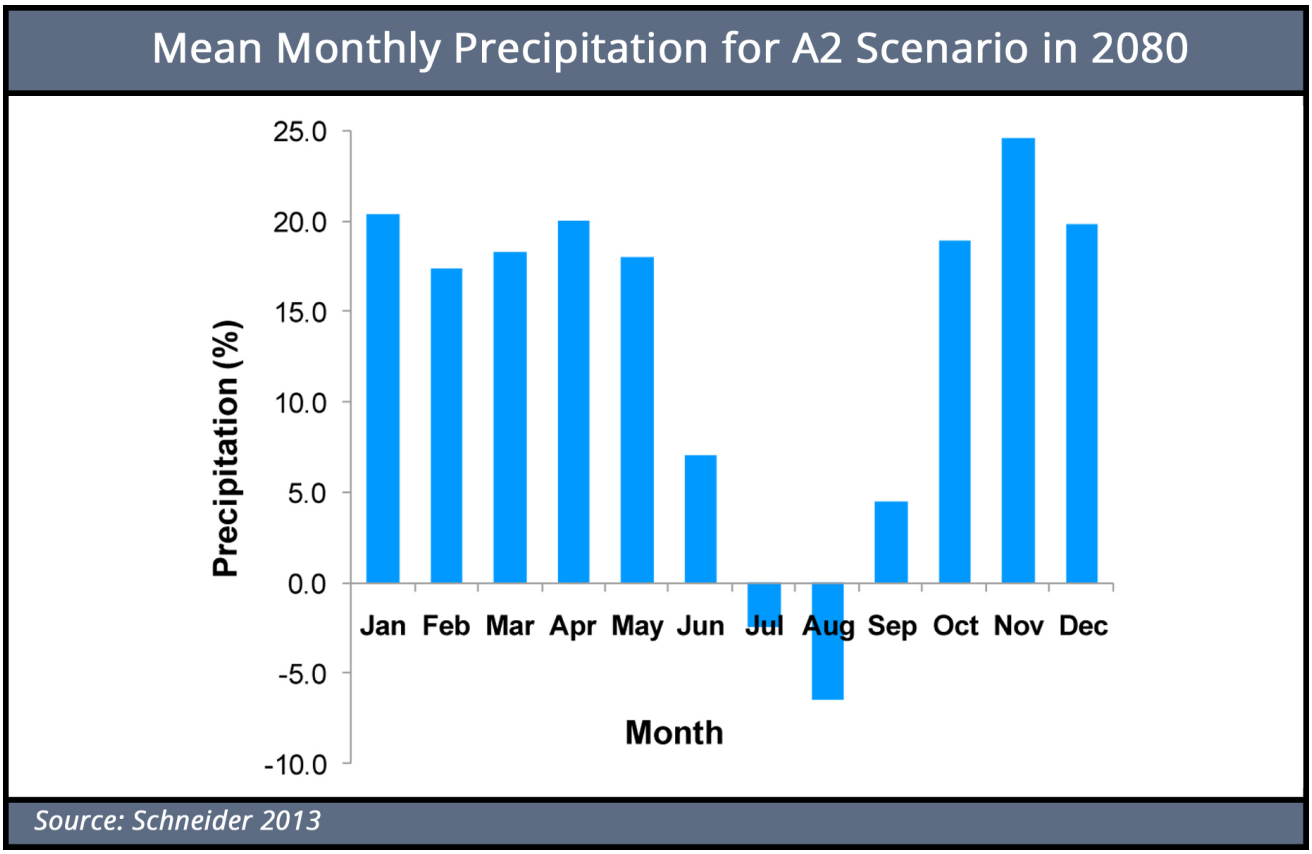
Schneider, Richard. 2013. Alberta Natural Subregions Under a Changing Climate: Past, Present and Future. University of Alberta: Prepared for the Biodiversity Management and Climate Change Adaptation Project.

## Precipitation

Alberta has not experienced a changing trend in precipitation over time; annual rainfall has remained relatively consistent since 1905 in the grasslands region. It is, however, predicted that mean annual precipitation will increase in the future from a historic norm of 371.6 mm, to 393.4 mm under the A2 scenario, a change of 21.8 mm, and 387.8 mm under the B1 scenario, a change of 16.2 mm (Schneider 2013).

Although total precipitation will remain the same or increase, there will be a shift in the timing of precipitation, where there may be a decline in the summer months, and an increase the other months. The A2 scenario suggests a decrease of 6.5% in August, while the B1 scenario suggests a decrease of 2.3%.

The following graph shows the mean monthly precipitation for A2 scenario in 2080.

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Schneider, Richard. 2013. Alberta Natural Subregions Under a Changing Climate: Past, Present and Future. University of Alberta: Prepared for the Biodiversity Management and Climate Change Adaptation Project.

## Available moisture

Although overall precipitation is projected to increase, most climate models predict that the grasslands natural region will become substantially drier in coming decades. Climate Moisture Index (CMI) is used to measure wetness, whereby positive numbers imply wetness and negative numbers imply dryness. By averaging across all models, the grassland natural region mean CMI decreases from -21.8 cm for the historical norm to -42.7 cm under the 2080 warm (A2) scenario and to -34.7 cm under the 2080 cooler (B1) scenario. The main reason for this decline is that warmer temperatures increase the rate of evapotranspiration from vegetation and soils, offsetting any potential increases in precipitation. In addition, although total precipitation is projected to increase, precipitation during midsummer - when moisture stress is greatest - is expected to

decline.

The predicted changes in the timing of precipitation and increases in temperature will impact the number of growing degree days and available moisture.

The online tool includes maps depicting current and future trends of a CMI for the grassland natural region. The larger map depicts current CMI values and changes in CMI predicted for 2080 under the A2 scenario. The user can move the slider back and forth between the two time periods displayed. The smaller map depicts areas where change is greatest, in this case darker red depicts conditions with a greater degree of dryness.

While the available moisture will be lower overall, the change in precipitation pattern and timing will increase the likelihood and intensity of flood events in the non-summer months.

## Growing degree days

Growth in plants and insects is temperature dependent, therefore growth does not occur unless temperate exceed a lower threshold level (base temp). Growing Degree-Days (GDD) is a measure of the number of days that the temperature is above base temp for a 24 hour period. GDD therefore represent the amount of heat energy available for development. It is important to note that many plants and insects require a specified number of GDD to reach maturity. GDD tend to accumulate in the late spring and summer.

GDD is an important measure for agriculture because it can determine accumulation of heat energy, enabling farmers to predict fruiting and flowering patterns and to predict which crops might be appropriate for the area. GDD can also play an important role in pest control.

As a result of climate change the accumulation of GDD is expected to increase due to an earlier onset of spring. Growing degree days in the grasslands natural region are expected to increase from a mean of 1,599 days for historic norm, to 2,478 days under the A2 scenario, a change of 54.9 more GGDs, and 2,141 days under the B1 scenario, a change of 33.9 more GGDs (Schneider 2013). The development process of plants and insects are largely dependent on ambient air temperature unless there other environmental stressors are present such as lack of moisture. Although the accumulation of GDD is predicted to increase, moisture levels may become the limiting factor to growth.

*References*

Schneider, Richard. 2013. Alberta Natural Subregions Under a Changing Climate: Past, Present and Future. University of Alberta: Prepared for the Biodiversity Management and Climate Change Adaptation Project.

## Stream flow

Southern Alberta is largely dependent on stream flow emerging from the Rocky Mountains for primary water supply. Modeling predicts that climate change will result in changes in the magnitude and timing of stream flow (Rood et al. 2008). An earlier spring snow melt caused by warming temperatures is expected to result in changes to stream flow timing. Earlier snow melt causes an early onset of runoff resulting in drier summer conditions and reduced late season water supply (Larson et al 2011) and increased flooding risk in the non-summer months.

The reduction is stream flow and a shift in stream flow timing is caused by warming temperatures and changes in precipitation, causing a reduction in snow accumulation due to higher rain/snow ratios and shorter accumulation period.

It is estimated that there will be a 15% reduction in summer stream flow and a 5% decrease in overall annual stream flows for the Oldman River and adjacent rivers between 2005 and 2050 (Shepherd et al 2010).

Reduced annual stream flows will result in concerns for water resource managers, creating challenges for irrigators and municipal water supplies, while flow spikes will create challenges for flood impacts on municipal infrastructure.

*References*

Larson, Robert P., James M. Byrne, Dan L. Johnson, Stefan W. Kienzie and Matthew G. Letts. 2011. Modelling Climate Change Impacts on Spring Runoff for the Rocky Mountains of Montana and Alberta II: Runoff Change Projections using Future Scenarios. Canadian Water Resources Journal. Volume 36(1), pages 35-52.

Rood, Stewart B. , Jason Pan, Karen M. Gill, Carmen G. Franks, Glenda M. Samuelson, and Anita Shepherd. 2008. Declining summer flows of Rocky Mountain rivers: Changing

seasonal hydrology and probable impacts on floodplain forests. Journal of Hydrology, 349, pages 397-410.

## Glacier area

Glacier area in Alberta's Eastern Slopes decreased by 20% from 1985 to 2005 and the areal extent of glaciers is expected to continue to decrease due to increases in temperature. Glaciers play an important role in stream flow timing and contribute to water volume. Glaciers, due to their coldness, are responsible for delaying snow melt and run-off to rivers until later in the summer when water scarcity is a concern. As glaciers retreat, it is expected to result in earlier melting and runoff, thus changing the timing of steam flows. In addition, glaciers play an important role in snow accumulation, as they tend to trap snow, impacting snowpack volume and reducing late season run-off.

As glaciers melt there will be more run-off, but once glaciers are gone, total volume of runoff will be reduced, impacting stream flow levels and water levels in the South Saskatchewan River Basin.

## Wetlands

In Alberta, since settlement, 64% of wetland have been lost due to land use changes, industrial development, management practices and policies and population growth. Today it is estimated that Alberta loses 0.3-0.5% of their wetlands annually.

In the prairie ecosystem a decrease of 5% occurred in the grassland region from 1985 to 2001 due to elimination or degradation by artificial drainage. Larson et al (2010) predicted that a 3°C rise in temperature with no change in precipitation would result in a 15% decrease in basins holding water in the grassland region.

Wetland lose will be further exacerbated because of climate change; an increase in temperature results in a shift from permanent to more temporary wetlands. Average water level of wetlands is predicted to decline and the amount of time that seasonal wetlands remain dry will increase. Also reduced run off from wetlands will impact ground water flows (Larson et al 2010).

The implications of a decrease in the number and areas of wetlands include reduced;

- flow of ground water recharge;
- opportunities for flood control;

- potential for water filtration (improved water quality); and
- plant and animal species dependent on wetlands.

Just how serious is a reduction in the number of wetlands, a recent hydrological assessment report from University of Saskatchewan reported drainage of depressional storage is a major factor in increasing prairie streamflows in most years and increasing flooding in wet years. Therefore the elimination of vast numbers of small ponds and wetlands across the Canadian prairie has removed a crucial buffer that can temporarily store water on the landscape during periods of excessive precipitation. The authors found a significant reduction in the number of wetlands due to drainage systems implemented by landowners in the watershed they studied and findings suggest that in their research basin 2011 prairie flooding would have had a 32 percent lower peak if the number of wetlands was the same as in 1958. The researchers also found the same flood would be 78 per cent higher with no wetlands at all, a likely scenario if drainage networks continue to proliferate unchecked.

### *References*

Larson, Robert P., James M. Byrne, Dan L. Johnson, Stefan W. Kienzie and Matthew G. Letts. 2011. Modelling Climate Change Impacts on Spring Runoff for the Rocky Mountains of Montana and Alberta II: Runoff Change Projections using Future Scenarios. Canadian Water Resources Journal. Volume 36(1), pages 35-52.

# Implications

A changing global climate is just that - global. That makes it challenging to understand what those changes mean for a local community.

The first vital step is to know how the changing climate regime will play out in terms of its effects on the environment around us. How will the temperature change? How will precipitation patterns change? What will be the effect on snowpacks, glaciers, and stream flows? Etc.

However, to be prepared -- and to create climate-resilient communities -- we need also to understand the implications of those changes. How will these changes affect our everyday lives?

This section guides you through answers to that question.

The information is divided into five sections: agriculture, infrastructure, human health, biodiversity, and recreation. The choice of these categories was based on research into both the most relevant implications for Alberta communities, as well as feedback from municipal stakeholders as to what is top of mind for them.

## Agriculture

A changing climate regime will have significant implications for agricultural communities and the agricultural industry. Important concerns for agriculture include potential decreases in production of crops and grassland ecosystems, impacting crop yields and livestock stocking rates. Drought conditions may lead to increased frequency and severity of pests and invasive species, further reducing crop productivity. The consequences of increasing water scarcity, such as reduced health and quality of crops, pasture and livestock will have impacts on food production in Southern Alberta.

Ultimately, water scarcity could have severe economic impacts on the livelihoods of many southern Alberta communities.

### *Existing Soil Conservation Practices May no Longer be Adequate*

#### *How does climate change affect soil conservation?*

Soil erosion is greatly influenced by extreme weather events, such as droughts which are projected to increase as a result of climate change. As soils dry out due to higher temperature and drier conditions resulting from a shift in precipitation regimes and shift in stream flow, they become more susceptible to erosion events (Warren 2004; Varallyay 2007). These changes contribute to less vegetation cover and lower humidity in soils and the air, both factors that may increase wind erosion (Ryan et al. 2008). During the drought of 2001-2002 both Saskatchewan and Alberta saw severe wind erosion (Sauchyn & Kulshreshtha 2008).

Underlying Environmental Changes

- Temperature
- Precipitation
- Stream flow

### *Why are we concerned?*

Soil erosion impacts the productivity and sustainability of agriculture, and can affect both stream and air quality in the surrounding area (Ryan et al. 2008). Certain agricultural practices can also exacerbate risk to soil erosion including summerfallow tillage. Alternative practices (such as minimum tillage or chemfallow) can help reduce soil erosion risk (Warren 2004). Practices such as 'cover crops' may also help to reduce susceptibility to erosion while contributing to increased yields in following years (Delgato et al. 2011).

### *What we can we do about it?*

To support these efforts, municipalities can pursue support strategies such as:

- Update Municipal Development Plan
- Create climate-ready land use zones
- Coordinate with Watershed Management Plans
- Raise awareness of agricultural issue/options
- Promote water-moderate products
- Promote less water-intensive agriculture
- Wetland/recharge protection
- Impervious surface reduction
- Retain native riparian vegetation
- Develop State of Watershed

Identify invasive species trajectories
Know ecological infrastructure
Map drought, flood, and recharge areas
Identify valuable water-affected habitat
Identify water quality risks
Promote natural infrastructure

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### *Invasive Species May Flourish*

#### *How does climate change affect invasive species?*

By nature invasive species have broader climatic tolerances than native species (Thorpe 2011), and in the face of a changing climate this means that invasive species may have the upper hand over native (and crop) species. Increases in temperature and changes in stream flow timing, leading to drier conditions in summer months (lower available moisture), may cause both native ecosystems and agricultural systems to become stressed and consequently more vulnerable to invasive species (Burgiel & Muir 2010).

Underlying Environmental Changes

- Temperature
- Available moisture
- Stream flow

### *Why are we concerned?*

The increased presence of invasive species means that desired crop species will have to compete for resources, potentially leading to further stress. In a study done by the Alberta Biodiversity Monitoring Institute, the Grasslands Region of Alberta was found to be most at risk to new invasive species in both the current, and projected future climate (Chai et al. 2014).

### *What we can we do about it?*

Strategies that can be taken to mitigate the effects of invasive species revolve around reducing stress and promoting resiliency for native or crop plant communities. Municipalities' efforts to support these initiatives can include:

- Adapt approvals policies
- Coordinate with Watershed Mgmt Plans
- Raise awareness of ag issue/options
- Wetland/recharge protection
- Retain native riparian vegetation
- Raise awareness of water scarcity
- Identify important wetlands
- Develop State of Watershed
- Identify invasive species trajectories
- Identify valuable water-affected habitat
- Understand projected changes in water

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## *Stocking Rates May Need to Decrease*

### *How does climate change affect stocking rates?*

Based on the predictions for soil moisture deficits combined with effects from temperature increases and precipitation changes, pasture lands are predicted to decrease in quality and quantity.

Underlying Environmental Changes

- Temperature
- Precipitation
- Available moisture

### *Why are we concerned?*

To preserve their land farmers and ranchers may be forced to reduce stocking rates on pasture land. This can be achieved through the sale of some of a herd, or culling of the bottom 5-15% (ARD 2012). During the droughts of 2001-2002 some farmers and ranchers were forced to cull herds for this reason (Warren 2004).

### *What we can we do about it?*

In order to help address the need for decreased stocking rates in the face of water scarcity, municipalities can pursue strategies to help maintain water sources that can sustain livestock herds during droughts, and preserve pasture of adequate quality and quantity. Such strategies may include:

Update Sustainability Plans
Create climate-ready land use zones
Coordinate with Watershed Mgmt Plans
Economic scenario planning
Raise awareness of ag issue/options
Promote water-moderate products
Promote less water-intensive ag
Beaver reintroduction
Wetland/recharge protection
Constructed wetlands
Retain native riparian vegetation
Raise awareness of water scarcity
Identify important wetlands
Develop State of Watershed
Map drought, flood, and recharge areas
Understand projected changes in water
Promote natural infrastructure

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### *Irrigated Agriculture will be Affected*

#### *How does climate change affect irrigation?*

Irrigation is the largest net consumer of water in Canada and 60% of Canada's irrigated cropland is in Alberta. The demand for irrigation is growing and some watersheds in the province have already reached their maximum allocations for agricultural water withdrawals (Environment Canada 2004).

Environmental changes such as warmer temperatures, reduced precipitation during the growing season, and less available moisture will further increase the demand for water resources for agriculture including irrigation (Saychyn and Kulshreshtha 2008). On the other hand, retreating glaciers and reduced stream flow and timing shift will result in less available water for irrigation, since irrigation in Alberta relies predominately on water diverted from rivers (Environment Canada 2004).

Underlying Environmental Changes

- Temperature
- Precipitation
- Available moisture
- Stream flow
- Glacier area

#### *Why are we concerned?*

The results are cyclical; less water means a greater need for irrigation, while increased irrigation further stresses the water supply. Changing irrigation methods, such as storing water in dams and reservoirs may be inefficient due to evaporative losses (Saychyn and Kulshreshtha 2008) while using ground water instead of surface water resources for irrigation will further alter the hydrological cycle (Environment Canada 2004).

#### *What can we do about it?*

Efforts are currently underway in Alberta to improve irrigation efficiency to conserve water resources such as using sprinkler or drip instead of flood irrigation, replacing open canals with pipelines, introducing irrigation limits for individuals, and incenting on farm water saving technologies (Alberta Agriculture and Rural Development 2014; Alberta Irrigation Project Association 2005). These are important actions by irrigators to improve

water efficiency and highlight efforts to prepare for a changing climate. In the future less water intensive agriculture may become more favourable as water resources for irrigation may not be available. Many farmers rely on irrigation when precipitation is scarce. However, during the 2001-2002 droughts many farmers found that irrigation resources were not sufficiently available (Wandel et. al 2009). Converting to less water intensive agriculture, such as planting more drought resistant and water efficient crops may be a more effective way to adapt to water scarcity (AAFC 2009).

Alberta Agriculture and Rural Development as well as the Alberta Irrigation Project Association have developed strategies and set targets for improving irrigation efficiency. Municipalities can play an important role in incorporating these strategies working towards these targets by:

- Create climate-ready land use zones
- Coordinate with Watershed Mgmt Plans
- Raise awareness of ag issue/options
- Promote water-moderate products
- Promote less water-intensive ag
- Wetland/recharge protection
- Raise awareness of water scarcity
- Incent low-water technology
- Develop State of Watershed
- Know ecological infrastructure
- Map drought, flood, and recharge areas
- Understand projected changes in water

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### *Conflicts May Arise Between Agricultural and Other Water Users*

#### *How does climate change affect conflicts between water users?*

In Alberta water is allocated to different users such agricultural, commercial, industrial, municipal, recreational, and the environment. Most surface water in Alberta is allocated to agriculture and irrigation. In some regions of Alberta, such as the South Saskatchewan River basin, irrigation makes up over 70 percent of the surface water allocation, which amounts to 28 percent of the annual river flow (Government of Alberta 2010; Environment Canada 2004).

The demand for water diversion is expected to increases due to higher temperatures, a lack of precipitation during the growing season, and more growing degree days, while the supply of water could decrease due to glacial retreat and shifts in stream flow and timing. These conditions could trigger conflicts between users, especially in watersheds, such as the Oldman, where the annual flow is almost entirely allocated and allocations cannot increase with demand (Saychyn and Kulshreshtha 2008). Water allocations and apportions are based on stream flow and may need to be altered as flow levels change (Government of Alberta 2010).

Underlying Environmental Changes

- Temperature
- Precipitation
- Growing degree days
- Stream flow
- Glacier area

### *Why are we concerned?*

Conflicts could also arise between upstream and downstream users as resources may be exhausted before they reach downstream users (Wittrock et al. 2007). During droughts in Taber there were issues between urban and rural users as both sides believed the other was mis-using water resources (Wittrock et al. 2007). Municipalities can play an important role in preventing or reducing conflict between users. The municipality of Taber imposed water use restrictions during the 2001-2002 droughts which required users to collectively conserve resources (Wittrock et al. 2007). There may also be opportunities for users to share infrastructure and resources, such as using industrial pipelines for irrigation in times of scarcity or reusing wastewater from other industries.

### *What can we do about it?*

Municipalities can prevent and reduce user conflicts by:

- Update Sustainability Plans
- Update Municipal Development Plan
- Create climate-ready land use zones
- Coordinate with Watershed Mgmt Plans
- Recreation scenario planning
- Emergency scenario planning
- Economic scenario planning
- Raise awareness of ag issue/options
- Raise awareness of water scarcity
- Catalyze Climate Smart groups
- Know ecological infrastructure
- Map drought, flood, and recharge areas
- Understand projected changes in water
- Assess at-risk infrastructure
- Low-risk infrastructure siting

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### *Crop failures will increase due to drought*

#### *How does climate change affect drought and crop failure?*

Climate scenarios predict that there will be an increase in extreme events such as droughts in Alberta. Droughts, and associated crop damage or failure, are concerns for the Grasslands Natural Region as up to 85 percent of land is under cultivation (Natural Areas Committee 2006). Overall, Southern Alberta is expected to experience warmer, drier conditions than at present (Barrow and Yu 2005). A warmer temperature will increase the rate of evapotranspiration, reduce the amount of available moisture in the soil for agriculture, and increase the demand for water (EcoResources and ISSD 2010). Although overall precipitation may increase, there may be a decrease in summer precipitation contributing to water shortage and the risk of severe drought (Lemmen and Warren 2004). Warming temperatures and changes in precipitation are also expected to cause a reduction in stream flow and a shift in stream flow timing which could further stress water supply (Larson 2011). These environmental changes are predicted to increase the frequency and severity of droughts leading to crop failures and a reduction in crop production.

Underlying Environmental Changes

- Temperature
- Precipitation
- Available moisture
- Stream flow

#### *Why are we concerned?*

Past droughts, such as in 2001-2002 had major implications on crop production, where the prairies experienced a drop in production of 3.6 billion. In Alberta, crop insurance

payments jumped from $274 million in 2001, to $790 million in 2002 due to crop failure from drought (Government of Canada 2013).

*WHAT CAN WE DO ABOUT IT?*

A municipality can reduce susceptibility to drought by:

- Update Sustainability Plans
- Coordinate with Watershed Mgmt Plans
- Promote less water-intensive ag
- Promote water-moderate products
- Wetland/recharge protection
- Map drought, flood, and recharge areas
- Incent low-water technology
- Raise awareness of ag issue/options

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### *Farm-based Water Storage will be Less Effective*

*How does climate change affect farm-based water storage?*

Farm-based water storage (dugouts) is typically recharged by spring run-off from snow melt. With climate change we can expect a shift in timing of stream flow to earlier in the year, which could mean water shortages later in the growing season. During the 2001-2002 drought, the successive dry years meant that by September 2002 the dug-outs on many farms had run dry (Wandel et al. 2009). The lack of water in dug-outs required farmers to seek out other options such as hauling of water, which can negatively affect farmers' income (Wittrock et al. 2007).

Underlying Environmental Changes

Stream flow

*Why are we concerned?*

To respond to this issue, agricultural producers have refurbished dug-outs for more water retention, or installed pipelines for non-precipitation dugout recharge via rivers or other sources. In Hanna, AB farmers joined with the Electric Power Generating Station for additional water supply in water-scarce years (Wittrock et al. 2007).

*What we can we do about it?*

Municipalities can support these responses in several ways such as:

Update Sustainability Plans
Create climate-ready land use zones
Coordinate with Watershed Mgmt Plans
Raise awareness of ag issue/options
Promote water-moderate products
Promote less water-intensive ag
Beaver reintroduction
Wetland/recharge protection
Constructed wetlands
Promote stormwater capture
Retain native riparian vegetation
Raise awareness of water scarcity
Identify important wetlands
Map drought, flood, and recharge areas

Understand projected changes in water
Adapt infrastructure for climate change
Promote natural infrastructure

*REFERENCES*

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### *May be a Decrease in Livestock Feed*

*HOW DOES CLIMATE CHANGE AFFECT LIVESTOCK FEED?*

Pastures and forage crops are complex plant ecosystems and the impacts of climate change on the quantity and quality of pastures and crops that support livestock will be difficult to predict and be locally specific. However, in times of water scarcity the production and quality of crops, including feed crops and pasture, may decrease. This is due to less available moisture caused by a shift in precipitation and stream flow timing leading to drier summer months. Drier conditions have been shown to have a direct impact on yearly production in the prairie grasslands (Thorpe 2011). Crops during drought years are also more susceptible to higher toxicity levels (ARD 2012).

Underlying Environmental Changes

Precipitation
Available moisture
Stream flow

*WHY ARE WE CONCERNED?*

During times of water scarcity farmers may be required to seek out alternative feed sources, including purchase of feed, or consider using drought-stressed crops whose yields and/or quality are poor. In latter cases the quality should be tested to monitor toxicity levels (ARD 2012). Alternatively, decrease in crop quality may result in food

grown for human consumption being used instead to feed livestock.

Case studies from the 2001-2002 drought in Alberta indicate that farmers had to truck in feed for their livestock from other provinces due to low quantities, and poor quality, of forage and feed crops (Wittrock et al. 2007).

### *What we can we do about it?*

In order to avoid issues around decreased feed availability, municipalities can:

- Coordinate with Watershed Mgmt Plans
- Economic scenario planning
- Raise awareness of ag issue/options
- Promote water-moderate products
- Promote less water-intensive ag
- Retain native riparian vegetation
- Raise awareness of water scarcity
- Develop State of Watershed
- Identify invasive species trajectories
- Know ecological infrastructure
- Map drought, flood, and recharge areas

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### *Salinization Will Increase*

#### *How does climate change affect salinization?*

As the available moisture in soil decreases (due to temperature increases and precipitation pattern changes) soil salinization, or presence of salts in the soil, may also increase. With higher temperatures comes increased evaporation, and as Alberta has ground water full of salts dissolved from our bedrock (AAFRD 2000), when ground water evaporates out of the soil, salts are left behind leaving soil with higher salt concentrations or salinization (Varallyay 2007).

Underlying Environmental Changes

- Temperature
- Precipitation
- Available moisture

#### *Why are we concerned?*

An increase in soil salinization can cause land loss due to saline seeps, which render land unusable in an agricultural context. Soil salinization can also lead to crop damage and yield reductions, as salt presence limits plant growth (MacMillan & Marciak 2001). Salinity is already a concern for many Alberta municipalities, for example past efforts to map areas experiencing salinity included 1.6 million acres of land in southern Alberta, showing an average crop yield reduction of 25% on these acres (Alberta Agriculture 1991).

#### *What we can we do about it?*

In order to mitigate these impacts, municipalities can:

- Coordinate with Watershed Mgmt Plans
- Economic scenario planning
- Raise awareness of ag issue/options
- Promote water-moderate products
- Promote less water-intensive ag
- Beaver reintroduction
- Wetland/recharge protection
- Constructed wetlands

Retain native riparian vegetation
Raise awareness of water scarcity
Identify important wetlands
Map drought, flood, and recharge areas
Understand projected changes in water

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### *Canal Systems will Experience Greater Water Losses due to Evaporation*

#### *How does climate change affect canals?*

Canals play an important role in distributing water for agriculture. Networks of canals carry water from rivers, reservoirs, and internal storage dams to farms for uses such as irrigation and livestock watering. Many farmers rely on this supply of water on a daily basis or during times of drought. Inevitably, some of the water in these open air canals is lost to evaporation and does not reach the consumer (IWMSC 2002). The amount of water in reservoirs and canals lost to evaporation is expected to grow as temperatures rise and rates of evaporation increase (Environment Canada 2004). At the same time, water scarcity or drought conditions could increase the demand for irrigation.

Underlying Environmental Changes

Temperature
Precipitation
Glacier area

### *Why are we concerned?*

Another challenge for the canal system will be availability of water for distribution. Most of the water distributed by canals is diverted from surface sources such as rivers. As glaciers retreat and precipitation becomes more variable there will be less water available for irrigation (Environment Canada 2004). This may create a need for different methods of water distribution such as farm-based water storage or less water intensive agricultural practices such as planting drought resistant crops.

### *What can we do about it?*

Efforts are currently underway in Alberta to improve water distribution efficiency. Many irrigations districts have replaced canals with pipelines and upgraded existing canal infrastructure by lining canals to prevent seepage. These improvements saved an estimated 50 million cubic meters of water from canal leakage and evaporation during the period from 1999 to 2012 (Alberta Agriculture and Rural Development 2014; Alberta Irrigation Project Association 2005).

Municipalities can work towards irrigation targets set by Alberta Agriculture and Rural Development and the Alberta Irrigation Project Association by:

Coordinate with Watershed Mgmt Plans
Economic scenario planning
Raise awareness of ag issue/options
Promote water-moderate products
Promote less water-intensive ag
Wetland/recharge protection
Raise awareness of water scarcity
Incent low-water technology
Map drought, flood, and recharge areas
Understand projected changes in water
Assess at-risk infrastructure
Built infrastructure scenarios
Abandon marginal infrastructure

Promote natural infrastructure

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## *Crop Disease Rates May Increase*

### *How does climate change affect crop disease?*

A changing climate will have a variety of impacts on crop production in Alberta. A particular concern is the potential for an increase in crop disease and subsequent crop failure or reduced crop quality. Climate change is expected to influence the relationship between host plants and pathogens, although the interactions between climatic changes and disease rates are complex.

### *Why are we concerned?*

Warmer winter temperatures could result in higher survival rates for plant viruses and an increased severity of disease infestations (Lemmen and Warren 2004). A longer growing season and more growing degree days could mean more time and favourable conditions for pathogen development (Jarvis et al. 2010). In addition, warmer temperatures will alter the geographic distribution of diseases, which could result in the introduction of new diseases or strains that crops are not resistant to (Lemmen and Warren 2004). Extreme events, such as droughts, may make crops more vulnerable to diseases. Research has also suggested that increased levels of CO2 may affect pathogen

development and alter some plant's disease resistance (Chakraborty et al. 1999).

In terms of disease control, a warming temperature, changing precipitation regime, and increased frequency of extreme events may alter the effectiveness of pesticides and herbicides. Some pesticides and herbicides function less efficiently under warmer temperatures, while some pesticides function more effectively when rain occurs after application, which could be an issue during times of low rainfall (Lemmen and Warren 2004; Chakraborty et al. 1999). On the other hand, extreme events such as heavy rainfall could wash away chemical controls (Chakraborty et al. 1999).

Underlying Environmental Changes

- Temperature
- Precipitation
- Growing degree days

### *What can we do about it?*

The interactions between climate change and disease rates will vary between crops and in many cases impacts on crop disease are uncertain. Crop disease monitoring and inspection are important measures to prevent and contain outbreaks and develop and understanding of disease interactions under a changing climate. Municipalities can prepare for changes in crop disease rates by:

- Economic scenario planning
- Raise awareness of ag issue/options
- Identify invasive species trajectories
- Map drought, flood, and recharge areas

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### *Lack of natural moisture may decrease amount of arable land*

#### *How does climate change affect arable land?*

Arable land is land that is under temporary agriculture crops, pasture, or is fallow (UN Food and Agriculture Organization 2013). In other words, it is the amount of land that is used to support crops or grazing. Arable land is critical to the economy and wellbeing of the Grasslands Natural Region since crops and pasture make up the dominant land uses (Natural Areas Committee, 2006).

Under some scenarios, due to warmer temperatures and greater overall precipitation, the amount of arable land is predicted to increase in North America (Zhang and Cai 2011). However, in Alberta warmer temperatures will increase the rate of evaporation. More evaporation means less available moisture for certain crops which makes land less suitable for agriculture (Lemmen and Warren 2004). Although overall precipitation may increase, there will likely be a reduction in precipitation during the summer resulting in a lack of soil moisture during the growing season (Barrow and Yu 2005; EcoResources and ISSD 2010).

Underlying Environmental Changes

- Temperature
- Precipitation
- Available moisture

#### *Why are we concerned?*

Other implications of water scarcity such as salinization and soil erosion will also reduce the suitability of land for agriculture. Together, these factors could lead to an overall reduction in arable land in areas of Alberta and a greater need for irrigation (Zhang and Cai 2011; Environment Canada 2004). For example, the soil erosion that resulted from the 2001 and 2002 droughts has had a long term detrimental impact on arable land in Canada (Government of Canada 2013).

#### *What can we do about it?*

A municipality can adapt to changes in natural moisture and maintain arable land by:

- Update Sustainability Plans
- Coordinate with Watershed Mgmt Plans
- Raise awareness of ag issue/options
- Promote water-moderate products
- Wetland/recharge protection
- Promote less water-intensive ag
- Map drought, flood, and recharge areas
- Incent low-water technology

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## Human health

Climatic conditions affect human well-being both directly, through the physical effects of climatic extremes, and indirectly through influences on the levels of pollution in the air, on the freshwater systems that provide food and water, and on the vectors and pathogens that cause infectious diseases (see Climate Change and Human Health, World Health Organization).

### *Air Pollution Related Health Effects*

#### *How does climate change affect air pollution?*

Air pollution and climate change are intimately connected. Air pollution, in addition to causing the greenhouse effect and subsequently climate change, can also have direct effects on human health. In fact nearly all climate altering pollutants, except carbon dioxide, can have direct or indirect health effects (IPCC 2014). At a local level, climate change can alter weather conditions and affect sources, and persistence, of air pollution. Temperature increases can cause the formation of pollutants such as ground-level ozone, which is produced through a chemical reaction when there is stagnant air and high temperatures (Bernard et al. 2001; Anderson et al. 2013). Reduced soil moisture and altered precipitation can cause an increase in natural and human-caused particulate matter (PM). Arid conditions and wind can stir up dust and other PM, as well as promote natural emissions from fires and soils (Bernard et al. 2011; IPCC 2014).

Underlying Environmental Changes

Temperature
Available moisture

#### *Why are we concerned?*

The increased presence of air pollution will have implications for respiratory illnesses, especially in vulnerable populations that include children, seniors and those with existing conditions such as asthma (Lamy & Bouchet 2008). Typically air pollution is also of greater concern for populations in urban areas (WHO 2003). The presence of ozone even for short durations can cause respiratory infections and long term pulmonary issues (Anderson et al. 2013). Particulate matter (PM) can affect health through both the respiratory and cardiovascular systems (Anderson et al. 2013). Of particular concern in arid conditions are aeroallergens, airborne pollen and spores, which can exacerbate

respiratory illnesses like asthma and increase risk for acute respiratory infections such as bronchitis (CDC 2010; Bernard et al. 2001).

### *What we can we do about it?*

As a municipality some strategies to help mitigate air-pollution related health effects of climate change are to:

- Update Sustainability Plans
- Update Municipal Development Plan
- Emergency scenario planning
- Retain native riparian vegetation
- Low-risk infrastructure siting
- Adapt infrastructure for climate change
- Promote natural infrastructure

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### *Increased Water and Food-borne Contamination*

#### *How does climate change affect food and water contamination?*

During times of water scarcity, contamination of water and food sources may occur. This can put populations at risk should they ingest contaminated food or water, or if contaminated water comes into direct contact with eyes, ears, or open wounds (IPCC 2014). Bacteria and pathogens already exist in water and lower water levels create an increase in their concentration (WHO 2003). Additionally, changes in climate variables such as an increase in temperature can lengthen the seasonality or alter the range of waterborne diseases (WHO 2003). Decreased stream flow and altered timing, and retreating glaciers causing longer, drier summers encourage growth and survival of pathogens and bacteria in certain foods and water sources (IPCC 2014, CDC 2010; Lamy and Bouchet 2008).

Underlying Environmental Changes

- Temperature
- Stream flow
- Glacier area

#### *Why are we concerned?*

Water-borne contaminants can occur in surface and groundwater. This has implications for drinking water, especially from private wells, and for crops that can become contaminated through improperly treated irrigation water and inadvertently through contaminated surface run off (CDC 2010). Food-borne contamination can come from

contaminated crops or from foods that are improperly stored or prepared (Lamy and Bouchet 2008). Water and food-borne viruses, bacteria and pathogens can lead to infectious disease, with the most common examples in Canada being E. Coli, Salmonella and Giardia (Lamy and Bouchet, 2008). Increases in diarrhea due to Salmonella show a distinct seasonality with increased temperatures (IPCC 2014). Secondary implications in cases of contaminated water include sanitation and hygiene issues due to a perceived lack of water and water restrictions, which can contribute to further spread of diseases (CDC 2010).

### *What we can we do about it?*

Strategies should aim to look at mapping the fate and trajectory of contaminants and monitoring of weather and environmental impacts on the contaminants. The protection of watersheds through responsible land use can also impact water quality (WHO 2003). Strategies that municipalities can employ include:

Update Sustainability Plans
Update Municipal Development Plan
Adapt approvals policies
Coordinate with Watershed Mgmt Plans
Recreation scenario planning
Emergency scenario planning
Economic scenario planning
Raise awareness of ag issue/options
Wetland/recharge protection
Develop State of Watershed
Know ecological infrastructure

Map drought, flood, and recharge areas

Identify water quality risks
Understand projected changes in water
Promote natural infrastructure

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## *Vulnerable Populations in Rural and Urban Communities*

### *How does climate change affect population vulnerability?*

Certain groups of people will be more greatly affected by the health impacts of climate change. Vulnerable populations include seniors, children, those with pre-existing health conditions, remote communities, and those with lower income. These groups of people may have less ability to adapt to environmental changes or cope with health issues. Higher incidences of illnesses, psychosocial issues, including stress and anxiety, and death may occur within these populations as a result of climate change. This will increase the demand on health care services and facilities within communities.

Underlying Environmental Changes

- Temperature
- Precipitation

### *Why are we concerned?*

Vulnerable populations could be more susceptible to the health impacts of air pollution. Warmer temperatures will increase the concentration of air pollutants such as ozone, which could cause issues for those with respiratory issues such as asthma. Reduced precipitation will increase the incidence of events such as forest fires and droughts. Seniors, those with cardiovascular issues, and those with respiratory issues such as emphysema will be particularly sensitive to particulate matter in the air, including dust

and smoke, from these events.

Vulnerable populations will also be impacted by increased incidences of vector and zoonotic diseases as well as water and food borne illnesses. The majority of deaths from outbreaks of West Nile virus and e coli in Canada were seniors, children, and those with pre-existing health issues.

Extreme events will also impact the health of vulnerable populations. Heat waves could cause complications or death for seniors and those with cardiovascular issues, especially in urban areas. Extreme events could also interrupt the health care services that vulnerable populations rely on. Rural and remote communities could also be disproportionately impacted by the health impacts of climate change, since it may be more difficult to access health care facilities and services.

### *What can we do about it?*

Municipalities can reduce negative health impacts for vulnerable populations. Warning systems such as the Air Health Quality Index have been introduced in some communities and should be accessible to vulnerable populations. Municipalities can increase awareness about the health risks of climate change among vulnerable populations, their caregivers, as well as health care providers. Health emergency plans should include special provisions for vulnerable populations. Municipalities can also:

Update Municipal Development Plan
Adapt approvals policies
Coordinate with Watershed Mgmt Plans
Emergency scenario planning
Raise awareness of water scarcity
Catalyze Climate Smart groups
Know ecological infrastructure
Map drought, flood, and recharge areas
Understand projected changes in water
Assess at-risk infrastructure
Built infrastructure scenarios
Low-risk infrastructure siting
Adapt infrastructure for climate change

Promote natural infrastructure

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### *Increased Vector-borne and Zoonotic Diseases*

#### *How does climate change affect disease vectors?*

Diseases that are transmitted through insect and animal vectors are at risk of increasing with a changing climate. The main drivers of this increased risk are an increase in temperature and precipitation variability, which may alter the range and seasonality of disease transmission (WHO 2003; Greer et al. 2008). Vector-borne and zoonotic diseases rely on a host for incubation prior to transmission to humans. Common examples of vector-borne diseases are mosquito-transmitted West Nile Virus and tick-transmitted Lyme disease and Rocky Mountain Fever. Increases in temperature could speed up life cycles of vectors, such as mosquitos and ticks, and increase vector populations. Higher temperatures could also potentially accelerate the development rate of pathogens and viruses (Lamy & Bouchet 2008). Diseases could establish vector populations in Alberta during longer summer seasons with higher temperatures, and in turn cause an increase in incidents (Greer et al, 2008). Decreased precipitation in summer months could also cause lower water levels in water bodies making them stagnant and prime breeding grounds for mosquito (CDC 2010). Climate change could also encourage the importation of vectors to new regions and expose previously not at risk regions to diseases such as malaria or dengue fever (Greer et al. 2008).

Underlying Environmental Changes

Temperature
Precipitation

### *Why are we concerned?*

Depending on the disease and the particular case, the impacts on human health are mild and in rare cases severe. Using West Nile as an example, most cases have mild flu-like symptoms or no symptoms at all (Lamy & Bouchet 2008). In the 2007 West Nile Virus outbreak in Alberta of the 320 reported cases, only 2 were fatal. However, during this Alberta wide outbreak 77% of West Nile cases occurred in Southern Alberta due to vector populations extending their range north from the US, making Southern areas of Alberta more vulnerable.

### *What we can we do about it?*

As a municipality the strategies could include:

Adapt approvals policies
Coordinate with Watershed Mgmt Plans
Emergency scenario planning
Economic scenario planning
Retain native riparian vegetation
Raise awareness of water scarcity
Catalyze Climate Smart groups
Identify important wetlands
Identify invasive species trajectories
Know ecological infrastructure
Map drought, flood, and recharge areas
Identify valuable water-affected habitat
Identify water quality risks
Understand projected changes in water

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### *Health Effects of Extreme Weather Events*

#### *How does climate change affect extreme weather events and health?*

The frequency and intensity of extreme events, such as heat waves, drought, heavy rainfall and floods, are expected to increase with climate change and water scarcity. These events could have negative impacts on both human health and health care provision including injury, death, illnesses, psychosocial issues, damages to health care infrastructure, and increased demand on the health care system. These impacts will disproportionately affect vulnerable populations, such as the elderly, children, those with illnesses, those with low income, and the homeless as they tend to have less means and ability to adapt to extremes.

Underlying Environmental Changes

- Temperature
- Precipitation
- Available moisture

#### *Why are we concerned?*

Warmer temperatures will increase the risk of extreme heat and heat waves, particularly in urban areas. Heat waves can contribute to heat fatigue, heat exhaustion, dehydration, heat rash and aggravate pre-existing circulatory or respiratory issues. Heat waves are particularly detrimental when they occur early in the spring or summer before people have acclimatized. On the other hand, warmer winter temperatures could have positive

impacts on human health due to reduced cold related deaths, injuries, and illnesses.

Droughts are a major concern for the prairies due to warmer temperatures, decreasing overall precipitation, and less available moisture. Droughts could cause stress and anxiety for farmers, increase the risk of pathogens and toxins in stagnant water, and enhance respiratory issues due to dust. Other extreme events such as wildfires could occur in conjunction with droughts and cause respiratory issues from smoke, displacement, injury, death, and damage to health care facilities.

Although overall precipitation is expected to decrease on the prairies, more extreme rainfall events and potential flooding will occur. Heavy rainfall could result in runoff of sewage, waste, bacteria, and toxins and impact drinking water quality. Flooding could cause displacement and damage to health care facilities.

Extreme events and disasters also have psychosocial implications such as mental illness, depression, stress, anxiety, and trauma. The health care system and community programs will need to be capable of providing appropriate services to address these psychosocial issues. Health Care facilities could be placed under stress due to increased demand, potential damage to infrastructure, and the interruption of services during extreme weather events.

### *What can we do about it?*

Effective emergency planning and preparedness can increase disaster resilience within municipalities. Developing business continuity plans, understanding risks, and introducing adaptive measures such as early warning systems are some important components of emergency preparedness.

Adaptive measures that municipalities can undertake to reduce the risks and impacts of extreme events include:

- Update Sustainability Plans
- Update Municipal Development Plan
- Adapt approvals policies
- Coordinate with Watershed Mgmt Plans
- Recreation scenario planning
- Emergency scenario planning
- Economic scenario planning
- Raise awareness of ag issue/options

Beaver reintroduction
Wetland/recharge protection
Constructed wetlands
Promote stormwater capture
Impervious surface reduction
Retain native riparian vegetation
Catalyze Climate Smart groups
Identify important wetlands
Know ecological infrastructure
Map drought, flood, and recharge areas
Identify water quality risks
Understand projected changes in water
Assess at-risk infrastructure
Built infrastructure scenarios
Low-risk infrastructure siting
Adapt infrastructure for climate change
Promote natural infrastructure

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### *Socio-Economic Impacts on Community Health and Well Being*

*HOW DOES CLIMATE CHANGE AFFECT COMMUNITY HEALTH AND WELL BEING?*

Health and well being of individuals and communities is largely determined by socio-

economic factors such as income, employment, and access to health care services. Climate change and water scarcity will indirectly affect health through socio-economic impacts such as (Lemmen and Warren 2004):

- Loss of income and productivity
- Social disruption
- Diminished quality of life
- Increased costs to health care
- Lack of institutional capacity to deal with disasters

For example, droughts on the prairies, caused by increased temperatures, reduced precipitation, and retreating glaciers, would result in economic losses for agriculture. This could lead to health concerns for farmers such as stress and anxiety, and less income to pay for health services or healthy, nutritious food.

Underlying Environmental Changes

Temperature
Precipitation
Glacier area

*WHY ARE WE CONCERNED?*

More severe and frequent weather events such as wildfires and floods could damage property, damage infrastructure such as electricity, cause unemployment, and cause displacement of people. A lack of reliable income, infrastructure, and shelter could influence the overall health of communities. Extreme events will also impact the psychosocial well being of individuals through stress, anxiety and trauma.

Health care service provision may also be impacted by climate change as extreme events could interrupt services and damage infrastructure. Other health impacts, such as air pollution and water borne diseases could place additional demand on the health care system.

*WHAT CAN WE DO ABOUT IT?*

Municipalities can reduce negative socio-economic impacts of climate change and enhance community resilience by:

## Update Sustainability Plans

Update Municipal Development Plan
Recreation scenario planning
Emergency scenario planning
Economic scenario planning
Raise awareness of ag issue/options
Promote water-moderate products
Catalyze Climate Smart groups
Map drought, flood, and recharge areas
Identify water quality risks
Understand projected changes in water
Assess at-risk infrastructure
Low-risk infrastructure siting

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## Recreation

In Alberta, a great deal of recreation happens outside, making use of the abundant recreational resources and opportunities the province offers. That makes these activities acutely vulnerable to variations in climate and weather.

As a changing climate regime affects moisture availability, wildlife habitat, water quality, the implications trickle down to recreational activities. Changes in these areas have direct implications on recreational spaces, especially those based on lakes and rivers, or irrigated spaces. In particular boating, swimming, hunting and fishing are impacted, but so too are golfing, camping and even picnicking.

Those effects, especially those that limit these recreation activities, have ramifications for the economy, human health, and people's quality of life in general.

### *Impacts to Kayaking and Rafting Due to Decreased Run-off and Volume of Water from the Mountains*

#### *How does climate change affect kayaking and rafting?*

Kayaking and white water rafting rely on run off from the mountains for safe, navigable waters. As glaciers retreat and stream flow decreases in volume and shifts in timing, this threatens the amount and consistency of water in rivers, and the opportunity for kayaking and rafting. In particular, variability in stream flow affects these activities as it can result in unsafe conditions during times of high flow and/or lack of opportunity during times of low flow. This has consequences for recreation based tourism operators, and recreational users.

#### Underlying Environmental Changes

Stream flow
Glacier area

#### *Why are we concerned?*

During the 2002 drought in Colorado, rafting tour operators noticed that with the decreased stream flow there was a decrease in customers and correspondingly a decrease in revenues. Although some operators were able to capitalize on sections of the river that were traditionally too hard, many operators were forced to suspend

business earlier in the season.

#### *What we can we do about it?*

Strategies for municipalities could include:

- Coordinate with Watershed Mgmt Plans
- Recreation scenario planning
- Wetland/recharge protection
- Promote stormwater capture
- Raise awareness of water scarcity
- Incent low-water technology
- Develop State of Watershed
- Know ecological infrastructure
- Catalyze Climate Smart groups

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### *Increased Algae Blooms & Plant Growth Impacting Fish Species*

#### *How does climate change affect algae blooms and fish species?*

In water scarce years fish habitat, such as lakes, rivers and wetlands, may be impacted by increases in temperature and decreased stream flow leading to lower water levels. Resulting warmer water and more growing degree days, creates ideal habitat and conditions for algal blooms and plant growth, especially cyanobacteria, a kind of algae.

After algae blooms, it dies and consumes oxygen as it decays. Algae, and cyanobacteria in particular, are known for causing anoxic, or oxygen poor zones, that are deadly for fish species (IISD 1997). In addition to warm water conditions, nutrient rich run-off in lakes also encourage these blooms. This kind of phosphorous rich run-off typically occurs from agricultural and municipal sources holding fertilizer remnants used for crops and grass.

Underlying Environmental Changes

- Temperature
- Growing degree days
- Stream flow

*WHY ARE WE CONCERNED?*

With poor habitat conditions, persistence of fish populations may decrease. With less fish in lakes and rivers this will have negative impacts for fishing activities. Cold water fish may become particularly stressed with these habitat changes. Populations may suffer and where possible species may move northwards, impacting traditional fishing areas. This also means that new species may migrate northwards into fishing areas in the Grasslands.

*WHAT WE CAN WE DO ABOUT IT?*

Strategies to help fish populations and maintain recreational fishing activities must revolved around protecting fish habitat.

- Update Sustainability Plans
- Coordinate with Watershed Mgmt Plans
- Recreation scenario planning
- Economic scenario planning
- Raise awareness of ag issue/options
- Beaver reintroduction
- Constructed wetlands
- Wetland/recharge protection
- Retain native riparian vegetation
- Raise awareness of water scarcity
- Catalyze Climate Smart groups
- Identify important wetlands

Develop State of Watershed
Identify invasive species trajectories
Map drought, flood, and recharge areas
Identify water quality risks
Understand projected changes in water

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### *Shift in Birding & Hunting Activities as Species Move North*

#### *How does climate change affect birding and hunting?*

Hunting and birding relies on bird and game populations. As climate changes causing an increase in temperature and a reduction in number of wetlands this could have negative impacts for habitat and game species populations. Habitat changes can lead to changes in distribution and population of big game, waterfowl and upland game species.

Wetlands play an important role for breeding of ducks and waterfowl and as a stop for migratory species such as geese. As wetlands dry up in water scarce years this could impact reproduction and populations. The Southern region of Alberta is predicted to see the sharpest decline in migratory birds due to changes in water availability (Pembina 2012). A decrease in pothole wetlands in the prairies could mean a drastic decrease in duck productivity, up to a loss of 22% (Sauchyn & Kulshreshtha 2008).

Underlying Environmental Changes

- Temperature
- Wetlands

*WHY ARE WE CONCERNED?*

Changes in habitat due to high temperatures and dry conditions, may cause species to adapt by changing their distribution and traditional hunting and birding areas may no longer be plentiful. With warmer temperatures larger game species such as moose and deer may move northward. In Alberta's mountain parks warming has already pushed some species up to higher elevations, which will only be accelerated with future warming (Sauchyn & Kulshreshtha 2008). This will have implications for hunting outfitters and recreational hunters.

*WHAT WE CAN WE DO ABOUT IT?*

Strategies municipalities can take to help preserve hunting and birding practices revolve around habitat protection:

- Update Sustainability Plans
- Update Municipal Development Plan
- Coordinate with Watershed Mgmt Plans
- Recreation scenario planning
- Beaver reintroduction
- Constructed wetlands
- Wetland/recharge protection
- Retain native riparian vegetation
- Raise awareness of water scarcity
- Identify important wetlands
- Develop State of Watershed
- Identify valuable water-affected habitat

Understand projected changes in water
Promote natural infrastructure

### *References*

Brown, S. and L. Hunt. 2007. Climate Change and Nature-based Tourism, Outdoor Recreation and Forestry in Ontario: Potential Effects and Adaptation Strategies. Ontario Ministry of Natural Resources. Ontario, Canada.

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## *Decreased water quantity in lakes & rivers impacting water sports (swimming, boating and sailing)*

### *How does climate change affect swimming and boating?*

The impact of climate change on water sports will manifest through the impacts on the resources, such as lakes and rivers, required for swimming, boating and sailing. Water quality and quantity in these bodies stands to be impacted by rising temperatures, altered stream flow & timing, shift in precipitation patterns and retreating glaciers resulting in less summer time river flow from the mountains. Less influx of water from streams and precipitation combined with higher temperatures, causing higher rates of evapotranspiration, can lead to lower, warmer, water levels in lakes, rivers and wetlands.

Underlying Environmental Changes

- Temperature
- Precipitation
- Stream flow
- Glacier area

### *Why are we concerned?*

Lower water levels can create navigational hazards and reduced access for boats, limiting boating areas and correspondingly limiting the number of boats that can safely be present on a water body. In extreme cases boats can become land locked when water is low enough that docks become stranded above the water line.

Higher temperatures and lower water levels create an increased risk of pathogen and bacteria, which can be harmful to human health (such as water-borne illnesses). As an example, swimmers itch is typically more prevalent in shallower, warmer water and results in unpleasant rashes for bathers and, if concentrations exceed a certain threshold, beach closures (Health Canada, 2012).

### *What we can we do about it?*

Implications are largely reduced recreational opportunity and some health and safety risks. Strategies should aim to preserve water resources and increase awareness of risks.

- Recreation scenario planning
- Wetland/recharge protection
- Retain native riparian vegetation
- Raise awareness of water scarcity
- Develop State of Watershed
- Identify water quality risks
- Understand projected changes in water
- Know ecological infrastructure

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### *Increased Need to Water Golf Courses, Campgrounds & Picnic Sites*

#### *How does climate change affect managed landscapes?*

With higher temperatures, lower available moisture, and more growing degree days there may be an increased need for irrigation of recreational resources such as golf courses and campgrounds in water scarce years. These conditions, leading to longer, drier summers may create the need for supplemental water above average annual irrigation levels.

Underlying Environmental Changes

- Temperature
- Available moisture
- Growing degree days

#### *Why are we concerned?*

This extra demand can have negative impacts on water systems. During water scarce

years water systems may already be stressed due to low water levels and high demand for water. The cumulative impact of increased demand and low water levels may cause high stress on the water system.

For recreational resources, their 'performance' is measured by the experience of the user and thus is relative to their expectations. Expectations typically include aesthetic appearance, utility (shading, ground cover) and recreation. Being that this impact on users is relative, impacts can be harder to quantify but there can be implications for profits and user enjoyment of golf courses, campgrounds and picnic sites.

### *What we can we do about it?*

Strategies revolve around managing the amount of irrigation to prevent excess irrigation and maximize the efficiency of water being used. Other strategies revolve around managing expectations of users, especially during water scarce years.

- Update Sustainability Plans
- Update Municipal Development Plan
- Create climate-ready land use zones
- Adapt approvals policies
- Coordinate with Watershed Mgmt Plans
- Recreation scenario planning
- Economic scenario planning
- Promote stormwater capture
- Impervious surface reduction
- Retain native riparian vegetation
- Raise awareness of water scarcity
- Incent low-water technology
- Catalyze Climate Smart groups
- Develop State of Watershed
- Know ecological infrastructure
- Map drought, flood, and recharge areas
- Understand projected changes in water
- Assess at-risk infrastructure

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## Infrastructure

Climate changes that will impact infrastructure include changes to the freeze thaw cycle in winter months, hotter drier summers, milder winters and increased frequency of flooding events.

According to the Canadian-based International Institute for Sustainable Development's report, Climate Change Adaptation and Canadian Infrastructure:

> *"Climate change has the potential to substantially affect the effectiveness and lifespan of infrastructure in Canada, particularly in transportation, buildings and water management infrastructure. The exposure and vulnerability of these different types of infrastructure varies greatly. Collectively, though, substantial economic costs have already been attributed to the impact of climate hazards on such infrastructure, and these costs are only expected to increase in the future."*

### *Accelerated deterioration in the function and longevity of bridge infrastructure*

#### *How does climate change affect bridges?*

Bridges are critical infrastructure for the Canadian transportation industry, and economic and social activity that relies on movement of goods and people. Climate change predictions of higher temperatures, shifts in precipitation patterns, and decreased stream flow resulting in longer, drier summers could have impacts on the life cycle and deterioration rate of bridge infrastructure.

A higher frequency of hot, dry days and prolonged temperature increases can impact bridge surfaces by causing an increase in incidents and severity of pavement softening and rutting. More extreme high temperature can cause stress on expansion joints in bridges, leading to cracking. When higher average temperatures mix with overnight freezing this creates freeze thaw weathering that can cause cracking in bridge surfaces and in worst-case scenarios, could compromise stability. Older bridges are predicted to be more susceptible to impacts, due to previous weathering, composition and design.

Underlying Environmental Changes

- Temperature
- Precipitation

### Stream flow

#### *Why are we concerned?*

Bridges are built to last multiple decades, without major upgrades or reconstruction before a period of 50-100 years (Infrastructure Canada 2006). Premature deterioration due to hotter, drier conditions can affect the lifecycle of bridges and increase the need for earlier maintenance. This additional stress increased temperatures puts on bridges can be exacerbated by heavy truck traffic and thus maximum loads may be forced to decrease to mitigate further damage. Maintenance costs may increase, especially in older bridges and service disruption for activities dependent on bridges may also occur.

#### *What can we do about it?*

Strategies for mitigating the impacts to bridges should focus on design of future bridges as well as assessing existing infrastructure and its maintenance needs. Specific strategies include:

- Update Sustainability Plans
- Adapt approvals policies
- Raise awareness of water scarcity
- Map drought, flood, and recharge areas
- Assess at-risk infrastructure
- Built infrastructure scenarios
- Low-risk infrastructure siting
- Adapt infrastructure for climate change
- Abandon marginal infrastructure

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### *Decreased water storage, management, and transportation capability*

#### *How does climate change affect water management?*

Water storage and management infrastructure has traditionally used historic climate records as a design reference (Infrastructure Canada 2006). Compared to historical records, years of water scarcity caused by climate change may results in lower water levels and reduced water supply for human consumption. Changes in stream flow, shifts in precipitations, high temperatures, lower available moisture and reduced wetlands will cause lower water levels and hotter, drier summers. Such scenarios of water paucity typically also create an increase in demand for water. This mismatch can put additional stress on water storage, drainage and transportation infrastructure.

Lower water levels and high temperatures can cause water quality and quantity problems. High temperatures can create high rates of evaporation from reservoirs, exacerbating existing water supply problems and increasing need for more water storage infrastructure. Low water levels can also create stagnant water and decrease water quality. This puts pressure on treatment facilities and reduces their capacity during drought (NCCARF 2010). Post-consumption waste and storm water infrastructure may also be impacted. Dry soil makes pipes more vulnerable to failure, such as in Texas in 2011 when water mains were cracked and buckled from the dry conditions (Combs S. 2012).

Times of water scarcity may also make infrastructure more susceptible to damage from more sporadic precipitation events. Lower absorptive capacity of soils creates an increased possibility for overland flooding after droughts and infrastructure, such as dams, may suffer from failures (Boyle, Cunningham and Dekens 2013).

Underlying Environmental Changes

- Temperature
- Precipitation
- Available moisture
- Stream flow
- Glacier area

### *Why are we concerned?*

Lower water levels means less supply for consumptive uses such as agriculture and residential use. Existing water storage infrastructure may not be sufficient to meet demands, creating the need for additional dams, reservoirs and diversions. Low water supplies may also create apportionment conflicts between different users.

Water scarcity could mean loss of potable water, inconsistency in water supply or unpredictability of water services. The effectiveness of municipal water infrastructure may be compromised and services may suffer in the interim or long term. Lifespan of infrastructure may be shortened and costs of maintenance, repair and replacement could increase. This includes compromised service of irrigation canals, reservoirs, and waste water systems.

### *What can we do about it?*

Effective mitigation strategies to prevent impacts on water storage, management and transportation include technological, behavioural and management changes from the planning stage onwards. Demand management during times of water scarcity is also important to prevent stress on water systems. Specific strategies include:

- Update Sustainability Plans
- Update Municipal Development Plan
- Create climate-ready land use zones
- Adapt approvals policies
- Coordinate with Watershed Mgmt Plans

Emergency scenario planning
Economic scenario planning
Beaver reintroduction
Wetland/recharge protection
Constructed wetlands
Promote stormwater capture
Impervious surface reduction
Retain native riparian vegetation
Raise awareness of water scarcity
Incent low-water technology
Catalyze Climate Smart groups
Identify important wetlands
Develop State of Watershed
Know ecological infrastructure
Map drought, flood, and recharge areas
Identify water quality risks
Understand projected changes in water
Assess at-risk infrastructure
Built infrastructure scenarios
Low-risk infrastructure siting
Adapt infrastructure for climate change
Abandon marginal infrastructure
Promote natural infrastructure

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### *Increased risks to residential, commercial and industrial buildings*

#### *How does climate change affect buildings?*

During times of water scarcity resulting climatic conditions create dry, hot conditions that can be risky and harmful to buildings. High temperatures, shifts in precipitation, and low available moisture, especially in combination, result in higher risks of fire and potential for premature weathering. Dry soils, from low moisture and high evaporation, can cause cracking in building foundations from the shrinking and swelling of the ground (Freeman & Warner 2001). Dried out soils and high temperatures create dry surrounding that puts buildings at an increased risk of damage or destruction from wildfires. Buildings also rely on supporting infrastructure, such as water management for storm and wastewater, which can also be impacted in water scarce years.

Underlying Environmental Changes

- Temperature
- Precipitation
- Available moisture

#### *Why are we concerned?*

Costs associated with service delivery, building maintenance, repair and maintenance of supporting infrastructure may increase. The added risk to buildings from fires poses a threat to homes, workplaces and communities. In 2003 British Columbia experienced higher than average summer temperatures, accompanied with low stream flows and dry soil conditions; This combination of climatic conditions created an environment that allowed wildfires to thrive, destroying 334 homes and causing about $250 million in

property losses (Environment Canada 2013).

### *What can we do about it?*

In order to mitigate the impacts to homes, businesses and other buildings, municipalities can:

- Update Sustainability Plans
- Update Municipal Development Plan
- Adapt approvals policies
- Economic scenario planning
- Impervious surface reduction
- Raise awareness of water scarcity
- Incent low-water technology
- Develop State of Watershed
- Map drought, flood, and recharge areas
- Understand projected changes in water
- Built infrastructure scenarios
- Low-risk infrastructure siting
- Adapt infrastructure for climate change

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### *Premature deterioration of roadways due to thermal cracking, rutting, frost heave and thaw weakening*

#### *How does climate change affect roadway deterioration?*

Traditionally, the design of roadways has been based on historical climate data and generally assumed that climate will remain relatively static (Canadian Council of Engineers 2008). With projections of climate conditions outside historical norms, this could result in the premature deterioration of roadways. Higher temperatures in addition to drier conditions created by decreased available moisture and shifts in precipitation, can have implications for the lifespan, maintenance and quality of roadways.

Roads designed based on historical records may have an inadequate number of expansion joints for projected future temperatures. If there isn't enough expansion joints roads can buckle in higher temperatures. Higher temperature extremes also create the potential for pavement rutting and deformation. If high temperatures are prolonged this can make pavement more brittle and prone to cracking. Lastly if increasing temperatures mix with freezing temperatures this can create freeze thaw weathering, a detrimental impact on roads, which results in weakening and cracking of roadways.

Underlying Environmental Changes

- Temperature
- Precipitation

Available moisture

### *Why are we concerned?*

Roads are central to both social and economic activity in Canada, therefore any impacts on our ability to use roads may manifest as social and economic impacts. If roads are to see increased damage from water scarcity and associated climatic conditions this could result in disruption of service for economic and social activity. Deterioration may also translate into higher maintenance costs, more frequent maintenance and decreased load weight that roads can sustain.

### *What can we do about it?*

The primary strategies to help adapt to the deterioration of road infrastructure involve changing the approach to the design and planning process. Infrastructure Canada (2006) advocates for "no-regrets" measures when designing future infrastructure to account for changes in climate, whether or not we are certain they will occur. More specific strategies include:

Update Sustainability Plans
Emergency scenario planning
Economic scenario planning
Raise awareness of water scarcity
Incent low-water technology
Map drought, flood, and recharge areas
Understand projected changes in water
Assess at-risk infrastructure
Built infrastructure scenarios
Low-risk infrastructure siting
Adapt infrastructure for climate change
Abandon marginal infrastructure

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### *Deterioration of managed landscapes, such as golf courses, parks, and lawns*

#### *How does climate change affect managed landscapes?*

With increased temperatures, more growing degree days and more variable precipitation, managed landscapes may require additional water to compensate for

drier conditions. Without water 'substitutes' from additional irrigation, managed landscapes such as golf courses, parks and lawns, may dry out and deteriorate. With less available water and higher demand for human uses, additional influxes of water may not be available.

Underlying Environmental Changes

- Temperature
- Precipitation
- Growing degree days

### *Why are we concerned?*

The deterioration of managed landscapes means that the aesthetic appeal and utility of these recreational resources may be compromised. Water scarcity could mean less foliage on trees and therefore less shade in parks. Similarly, lawns may also dry out and have less ground cover. This increased demand for water may additional stress on the water system as well as causing an increase in maintenance costs of managed landscapes.

### *What can we do about it?*

Changing traditional practices and managing expectations may help to reduce the demand for additional water for irrigation of managed landscapes during times of water scarcity.

Specific strategies may include:

- Update Sustainability Plans
- Update Municipal Development Plan
- Create climate-ready land use zones
- Adapt approvals policies
- Recreation scenario planning
- Promote stormwater capture
- Impervious surface reduction
- Retain native riparian vegetation
- Raise awareness of water scarcity
- Incent low-water technology
- Catalyze Climate Smart groups

Understand projected changes in water
Assess at-risk infrastructure
Built infrastructure scenarios
Adapt infrastructure for climate change
Abandon marginal infrastructure

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## Biodiversity

A changing climate has a direct impact on the plant and animal species that exist in an area. In southern Alberta, we will see drier conditions, changes in stream flows and moisture regimes, and greater extremes in weather. The natural regions of Alberta will migrate northward (Schneider 2013), leading to simplification of the natural region diversity in the area. Species in the region will need to adapt, and can do so by moving northward or to higher elevations. Those that are better-suited to drier conditions, including invasive species, will adapt better.

The change in habitats will have effects in particular on wetland species, migratory birds and waterfowl, as well as for aquatic species in lakes and rivers. The diverse array of species and their ecological niches are the source of much human well-being, from intrinsic values of nature, to our sense of place and cultural identity, to utilitarian needs like hunting, recreation, pharmaceuticals and scenic values.

### *Loss of aquatic corridors*

#### *How does climate change affect aquatic corridors?*

Grassland aquatic ecosystems are made of networks of rivers, lakes, wetlands and small watercourses. Some of these water bodies and watercourses are permanent, while others are seasonal or intermittent. These ecosystems provide highly productive habitat for aquatic species such as fish, invertebrates, and amphibians (Thorpe 2011). Aquatic species use corridors to move, reproduce, and survive. Aquatic habitats on the prairies are currently fragmented by barriers such as dams, roadways, and wetland drainage. Fragmentation is expected to worsen with climate change as aquatic habitats decrease or are eliminated due to water scarcity (James 2001). Surface water sources, including streams, rivers, lakes and wetlands, will be reduced due to changes in the precipitation regime, warmer temperatures, and increased evapotranspiration. Stream flow is also predicted to decrease due to retreating glaciers and changes in stream flow timing. Increased pressure on water resources for human use, such as agriculture, will further exacerbate water availability. Due to water level changes some watercourses and wetlands may dry up or become impassible for aquatic species.

Underlying Environmental Changes

Temperature
Precipitation

Stream flow
Glacier area

### *Why are we concerned?*

Aquatic species could be threatened by a loss of aquatic corridors and may be at risk of extirpation (James 2001). Many aquatic species are highly sensitive to changes in water temperature, turbidity, salinity, and oxygen levels. As the climate changes, slight changes within waterbodies could make these habitats inhabitable for some species (Saychyn and Kulshreshtha 2008). If waterbodies and watercourses become impassible or inhospitable aquatic species, such as fish, may not be able to access appropriate spawning areas, while migratory species may not be able to access seasonal refuges(Lemmen and Warren 2004). The Pembina Institute (2012) estimates that there will be a 47% reduction in suitable trout habitat due to aquatic fragmentation.

### *What can we do about it?*

Water resources are in high demand within the grasslands natural region and municipalities can play a role in ensuring that there is enough water available for economic, community, and ecological needs. Promoting water conservation in one area, such as improving irrigation efficiency, will also conserve water for aquatic habitats and species. Municipalities can promote protection of aquatic corridors through water resource conservation and ecological conservation such as:

Update Sustainability Plans
Update Municipal Development Plan
Create climate-ready land use zones
Adapt approvals policies
Coordinate with Watershed Mgmt Plans
Promote water-moderate products
Promote less water-intensive ag
Beaver reintroduction
Wetland/recharge protection
Constructed wetlands
Impervious surface reduction
Retain native riparian vegetation
Identify important wetlands
Develop State of Watershed
Identify invasive species trajectories

Know ecological infrastructure
Map drought, flood, and recharge areas
Identify valuable water-affected habitat
Understand projected changes in water
Promote natural infrastructure

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### *Degradation of wetland habitats*

#### *How does climate change affect wetlands?*

Wetlands make up a small proportion of the grasslands area. However, they support high levels of biodiversity and provide many ecosystem services. Wetlands are characterized by high water tables, aquatic plants and include bogs, fens, swamps, marshes, and shallow water (van der Kamp and Marsh 2004).

Wetlands are currently threatened by drainage, development, and some agricultural practices, and are expected to decline further due to climate change (Thorpe 2011). Wetlands on the prairies undergo seasonal changes in water level and rely heavily on springtime runoff, snowmelt, as well as trapped drifting snow (van der Kamp and Marsh 2004). Warmer summer and winter temperatures, reduced snowpack, higher levels of evapotranspiration, decreased summer precipitation and reduced stream flows could cause wetlands to decrease in size, experience earlier seasonal drying, or disappear completely. Changing precipitation regimes, peak flow timing and more frequent extreme events will also cause greater water level fluctuations within wetlands.

Underlying Environmental Changes

- Temperature
- Precipitation
- Available moisture
- Stream flow
- Glacier area

### *Why are we concerned?*

Wetlands provide essential habitat for fish, invertebrates, amphibians, and wildlife including waterfowl and migratory birds. Other benefits of wetlands include carbon storage as well as recreation such as bird watching and hunting of waterfowl (van der Kamp and Marsh 2004). A decline in the number of wetlands, earlier seasonal drying, and greater water level fluctuations will threaten these important habitats and functions. Declining and degraded wetlands will correspond to a decline in the species that rely on them, which could lead to species extinction or extirpation. Lower water tables may also reduce the ability of wetlands to filter contaminants (Lemmen and Warren 2004).

A report by the Pembina Institute (2001) predicted that the loss of Alberta's wetlands and the services they provide, including species habitat, cost approximately 7.7 billion dollars cumulatively in 1999. Given that wetlands continue to decline this cost is likely rising. The same report valued Albertan wetlands at approximately five billion dollars in 1999 (Wilson et al. 2001).

### *What can we do about it?*

Climate change threatens wetlands and the species that rely on them. However, healthy functioning wetlands can help to reduce some impacts of climate change such as

drought and flooding (van der Kamp and Marsh, 2004). Preserving existing wetlands, restoring former wetlands, and creating new wetlands can help to maintain biodiversity as well as the services that these ecosystems provide. Many wetlands are located on private, agricultural land so municipalities will need to work with landowners. Wetlands can also be restored within urban areas to provide water storage and filtering. Municipalities can preserve wetlands and encourage restoration through:

- Update Sustainability Plans
- Update Municipal Development Plan
- Create climate-ready land use zones
- Adapt approvals policies
- Coordinate with Watershed Mgmt Plans
- Recreation scenario planning
- Raise awareness of ag issue/options
- Beaver reintroduction
- Wetland/recharge protection
- Constructed wetlands
- Retain native riparian vegetation
- Raise awareness of water scarcity
- Identify important wetlands
- Develop State of Watershed
- Identify valuable water-affected habitat
- Understand projected changes in water

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### *Changes in migratory bird and waterfowl behaviour*

#### *How does climate change affect migratory birds and waterfowl?*

Wetlands provide essential breeding habitat and refuges for waterfowl and migratory birds. Wetlands are expected to decline as the climate changes, which will negatively impact the bird species that rely on them for survival. Surface water sources, including wetlands, will decrease due to reduced precipitation, warmer temperatures, as well as increased evapotranspiration (Thorpe, 2011). Decreased snowpack coupled with earlier spring runoff will also alter the amount of water in wetlands (Pembina Institute 2012). Increased pressure on water resources for human use, such as agriculture, will further exacerbate water availability. As a result, wetlands may dry up or may undergo fluctuations in water level that do not correspond with migratory bird and waterfowl behaviour (Thorpe 2011).

Underlying Environmental Changes

- Temperature
- Precipitation
- Available moisture
- Stream flow
- Glacier area
- Wetlands

#### *Why are we concerned?*

The Prairie Pothole Region, which includes parts of the Canadian Prairie Provinces, makes up ten percent of North America's waterfowl breeding habitat and is particularly important for duck breeding. Migratory birds also rely on this area for refuge while migrating, but this area is threatened by climate change (Ducks Unlimited 2014). A study conducted in 1995 (Larson) found that a three degree temperature increase could result in a 15 percent decrease in basins holding water within the Pothole region. Studies have shown that duck populations and reproduction rates are lower during drought years since conditions are not ideal (Thorpe, 2011). Ducks may choose a different area for breeding during droughts. However, under water scarce conditions birds may not have other habitat options.

Other studies predict that wetlands will experience more extreme fluctuations in water levels including drying out, overflowing and a greater ratio of dry land to open water

(Johnson et al 2005). Equal proportions of water to cover within wetlands are the most ideal conditions for waterfowl and extreme fluctuations may make habitats unsuitable for breeding (Thorpe 2011). These changes may require birds to alter their breeding behaviour, or could result in bird population declines.

Changes in bird behaviour related to climate have been documented. Many birds arrive at the Delta Marsh in Manitoba earlier in the season than previously (Thorpe 2011). While these behavioural changes indicate that birds can adapt to some climatic changes, they may not be able to successfully adapt to all rapid changes. Additionally, when one species alters its behaviour it will have impacts on the behaviour of species, such as predators, that rely on them.

If waterfowl and migratory bird populations decline it will also have a negative impact on hunting and other recreational activities, such as bird watching (Ducks Unlimited 2014).

### *What can we do about it?*

Municipalities can help to protect critical migratory bird and waterfowl habitat and conserve water resources by:

- Coordinate with Watershed Mgmt Plans
- Recreation scenario planning
- Beaver reintroduction
- Wetland/recharge protection
- Constructed wetlands
- Promote stormwater capture
- Retain native riparian vegetation
- Identify important wetlands
- Develop State of Watershed
- Identify valuable water-affected habitat
- Understand projected changes in water
- Promote natural infrastructure

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### *Degraded riverine and lake Habitats*

#### *How does climate change affect riverine and lake habitats?*

Drier conditions on the prairies will alter rivers, lakes and the species that depend on them. Water levels in lakes and rivers are expected to decrease. Peak stream flows will occur earlier in the year resulting in less water flow in the summer when water demands are greatest (Hendersen and Sauchyn 2008). Reduced precipitation, glacial retreat, as well as greater evaporation will also contribute to declining water levels. Human demands for water, such as irrigation, will further stress water availability (Schertzer et al. 2004). Less frequent, but greater intensity precipitation events will bring more runoff including sediments, nutrients, and contaminants into waterbodies.

Water quality in rivers and lakes may be compromised due to these warmer water temperatures, lower water levels, as well as higher levels of nutrients and sediments (Saychyn and Kulshreshtha 2008). Under these conditions lakes will be more susceptible to algal blooms, salinization, and oxygen deficiencies. Smaller or seasonal lakes may dry up completely (Schertzer et al. 2004).

Underlying Environmental Changes

Precipitation
Glacier area

### *Why are we concerned?*

Aquatic species and fish may be negatively impacted by altered water conditions. Many fish species are highly sensitive to changes in temperature, turbidity, salinity, and oxygen levels and may not be able to survive (Saychyn and Kulshreshtha 2008). Species at risk, such as the Western silvery minnow are particularly susceptible to extirpation. This fish species may not be able to survive if water temperatures increase and drought conditions worsen (Pembina 2012).

Seasonal drying of lakes and water quality issues will also negatively impact waterfowl and migratory birds (Thorpe 2011).

### *What can we do about it?*

Ensuring that sufficient water resources are available for ecological needs will help to protect aquatic biodiversity. Water efficient practices in other areas, such as agriculture, will also benefit biodiversity. Municipalities can maintain aquatic biodiversity by:

- Update Sustainability Plans
- Update Municipal Development Plan
- Create climate-ready land use zones
- Adapt approvals policies
- Coordinate with Watershed Mgmt Plans
- Recreation scenario planning
- Raise awareness of ag issue/options
- Promote water-moderate products
- Promote less water-intensive ag
- Beaver reintroduction
- Wetland/recharge protection
- Constructed wetlands
- Promote stormwater capture
- Impervious surface reduction
- Retain native riparian vegetation
- Catalyze Climate Smart groups
- Identify important wetlands
- Develop State of Watershed
- Identify invasive species trajectories
- Know ecological infrastructure

Map drought, flood, and recharge areas
Identify valuable water-affected habitat
Understand projected changes in water
Promote natural infrastructure

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### *Degradation of riparian habitats*

#### *How does climate change affect riparian habitats?*

Riparian areas exist on the fringes of waterbodies at the interface between water and land. Shifting stream flows could contribute to damage and degradation of riparian areas. Warming temperatures will cause the snowpack to melt earlier, resulting in less stream flow in the summer when water demands are highest (Hendersen and Sauchyn 2008). Summer precipitation is expected to decrease. However, more frequent storm events are also expected. Extreme weather events such as storms, flooding, and runoff could damage sensitive riparian areas through erosion and sedimentation. Drought conditions could also degrade riparian habitats as some types of vegetation may not survive with low levels of water (Staudinger 2012).

Underlying Environmental Changes

- Temperature
- Precipitation
- Available moisture
- Stream flow

### *Why are we concerned?*

Riparian areas are highly biodiverse as often support sensitive and unique vegetation and provide ideal habitat for wildlife and breeding. Riparian areas are also important because they: maintain water quality by filtering out sediments; contaminants, and nutrients; prevent downstream flooding through water storage; provide bank and shoreline stabilization; and provide recreational areas (ESRD 2012). Riparian areas will play a role in reducing impacts of climate change through flood prevention, water filtration, and water storage. However, degraded riparian habitats cannot effectively provide these ecosystem services. Riparian habitats are currently threatened by development, agriculture, and infrastructure and the impacts of climate change could contribute to further deterioration of riparian areas (Alberta Riparian Habitat Management Society 2014).

### *What can we do about it?*

Maintaining, preserving, and restoring riparian areas will help to prevent negative impacts of climate change such as flooding and drought, and will also reduce further riparian area degradation. Some municipalities in Alberta have introduced larger setback widths near waterbodies in order to preserve riparian areas (ESRD 2012). Other ways to maintain riparian areas and prevent further degradation include:

- Update Sustainability Plans
- Create climate-ready land use zones
- Adapt approvals policies
- Coordinate with Watershed Mgmt Plans
- Recreation scenario planning
- Beaver reintroduction
- Wetland/recharge protection
- Constructed wetlands
- Retain native riparian vegetation
- Raise awareness of water scarcity
- Identify important wetlands
- Develop State of Watershed

Know ecological infrastructure
Map drought, flood, and recharge areas
Identify valuable water-affected habitat
Understand projected changes in water
Low-risk infrastructure siting
Promote natural infrastructure

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### *Shifts and changes in species' habitats*

#### *How does climate change affect habitat shifts?*

Climatic changes will alter the composition and distribution of grassland habitats and favour some habitat types over others. Warmer and drier conditions are expected on the prairies due to warming temperatures, less summer precipitation, as well as reduced soil moisture (Sauchyn and Kulshreshtha 2008). The number of growing degree days is also expected to increase, although water scarcity may negatively influence overall plant growth (Thorpe 2011). Due to these conditions, habitats, and the species that they support, are generally shifting northwards in latitude and upwards in elevation

(Schneider 2013). When climatic conditions change dramatically species can either migrate to more favourable conditions, or adapt in place, such as flowering earlier in the season. If species do not migrate or adapt they will be at risk of population declines or extinction (Thorpe 2011). Consequently, there will be an expansion in the ranges of species that are better adapted to these warmer, drier conditions and a range reduction for species that favour cooler, moister conditions (Thorpe 2011).

Habitat shifts occur over long periods of time and there is often a lag between climatic changes and species migrations. A number of overall habitat trends are predicted. There will be a reduction in isolated forested and woody areas within grasslands due to reduced soil moisture. These areas are expected to be overtaken by grasslands (Thorpe 2011). Grassland habitats are generally expected to shift northwards. The warmer the temperature, the greater the predicted habitat shift (Schneider 2013). The structure of grasslands is expected to shift to shortgrass over midgrass, while the composition will shift to mixedgrass species that can better adapt to climatic changes (Thorpe 2011). Conditions will favour warm, dry grassland species, which are generally found further south over cool, wet grassland species (Schneider 2013). It is difficult to predict exact species compositions that will arise. However, it is likely that new species assemblages will occur as species adapt and migrate at different rates (Thorpe 2011).

Underlying Environmental Changes

Temperature
Precipitation
Available moisture
Growing degree days

*WHY ARE WE CONCERNED?*

Habitat shifts will influence biodiversity in terms of those species that thrive and those that decline. Generalist species that can survive in a variety of habitats will adapt more easily, as will species with large ranges. Specialist species that have specific habitat requirements and small ranges are expected to decline (Pembina 2012). For example, amphibian species could be at risk since they cannot easily migrate (Thorpe 2011). Species that rely on forested areas within grasslands will likely decline along with their habitat (Pembina 2012). Species that are currently at risk are particularly vulnerable to changes and could become extinct (Pembina 2012). Grasslands that thrive with cooler, moister conditions, such as the Northern Fescue subregion, are expected to decline and be overtaken by more adaptable mixed grasslands.

Habitat shifts could result in an overall reduction of biodiversity due to this decline in specialist species, species at risk, cool weather species, and species that cannot migrate or adapt quickly enough. These changes will have implications for humans including: a potential reduction in suitable grazing areas due to lack of appropriate forage; altered hunting and fishing due to wildlife population declines and habitat changes; and the potential for drought loving invasive species to thrive (Sauchyn and Kulshreshtha 2008; Thorpe 2011). Habitat shifts will be influenced by the rate at which species can adapt and migrate. Species migrations may not be able to keep up with the rate of climate change (Schneider 2013).

### *What can we do about it?*

Ensuring that sufficient water resources are available for ecological needs as well as protecting habitats at risk will help to maintain grassland biodiversity. Reducing other habitat stressors, such as fragmentation and habitat loss will help to reduce the negative impacts of habitat shifts. Municipalities can maintain grassland biodiversity by:

- Update Sustainability Plans
- Update Municipal Development Plan
- Create climate-ready land use zones
- Coordinate with Watershed Mgmt Plans
- Recreation scenario planning
- Raise awareness of ag issue/options
- Beaver reintroduction
- Wetland/recharge protection
- Constructed wetlands
- Retain native riparian vegetation
- Raise awareness of water scarcity
- Identify important wetlands
- Develop State of Watershed
- Identify invasive species trajectories
- Identify valuable water-affected habitat
- Understand projected changes in water
- Promote natural infrastructure

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### *Increase in drought-tolerant invasive species*

#### *How does climate change affect invasive species?*

The occurrence of invasive species is expected to increase due to climate change which could pose a significant threat to biodiversity within the grasslands natural region. Invasive species are plants, animals, or insects that can grow rapidly, spread quickly, and take over habitat of other native plants. Invasive species may be native or exotic to an area. Warmer, drier conditions due to warming temperatures and less summer precipitation could favour invasives (Thorpe 2011). Reduced soil moisture and the occurrence of drought may encourage the growth of drought-tolerant invasive or exotic plant species (Thorpe 2011).

Invasive species also have many traits that allow them to adapt to climatic changes including short generation times, rapid dispersal and growth, as well as tolerance for a wide variety of habitats (Chai et al. 2014). As habitats shift northwards invasive species that thrive in warmer, drier conditions may take over (Thorpe 2011). Additionally, during drought conditions native species may be more susceptible to invasion. Warmer winter temperatures may increase the occurrence of invasive weeds that are controlled by cold winter temperatures. The occurrence of current invasive species as well as new invasive species is expected to increase within the grasslands natural region (Chai et al. 2014). Figure 1 (Chai et al., 2014) provides a visual representation of Municipalities and Counties that have a high risk of new invasive species under current (a) and future (b) climate conditions. The Grasslands Natural region, which includes most of the shaded areas in southern Alberta, is particularly susceptible.

Underlying Environmental Changes

Temperature
Precipitation
Available moisture

### *Why are we concerned?*

Invasive and exotic species could push out native plants leading to population declines and the risk of extinction. Species that are currently at risk will be particularly vulnerable. As a result, overall biodiversity will decrease. Invasive species could have implications for grazing since they may not provide suitable forage for livestock. Drought conditions will also make crops more vulnerable to invasions. During the 2001 and 2002 droughts on the prairies grasshopper invasions exacerbated crop failure. Grasshoppers are native to the prairies, occur periodically, and tend to be preceded by warm, dry conditions. An increase in the frequency of drought events could also increase the frequency of grasshopper outbreaks (Wittrock et al. 2007). Invasive species can have significant economic implications such as management and control costs, as well as the cost of crop failure, or rangeland degradation (McClay et al. 2004). These economic losses are expected to increase with the presence of more invasive species.

### *What can we do about it?*

Some methods to control the spread of invasive species include protecting ecosystems, reducing habitat disturbances that may encourage the spread of invasives, as well as management of activities, such as grazing, that may spread invasives. Other ways that municipalities can manage invasive species include:

Adapt approvals policies
Coordinate with Watershed Mgmt Plans
Recreation scenario planning
Raise awareness of ag issue/options
Promote less water-intensive ag
Retain native riparian vegetation
Raise awareness of water scarcity
Develop State of Watershed
Identify invasive species trajectories
Know ecological infrastructure
Map drought, flood, and recharge areas
Identify valuable water-affected habitat
Understand projected changes in water

Promote natural infrastructure

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## Strategies and Actions

The climate is warming, resulting in global scale change to our natural environment and impacting our economic and social systems. To address these changes, local governments in Canada and around the world are developing climate change adaptation plans, strategies, and actions.

Adaptation is characterized as coping with or exploiting changes, through action of some sort. There are different ways to approach adaptation, but one approach that is recently garnering attention is ecosystem based approaches to adaptation (EbA). EbA is characterized by a focus on adaptation as a function of resilience. EbA is built on the notion that a healthy functioning ecosystem is more resilient (greater flexibility) and therefore better able to adapt to ecosystem stress, such as climate change. Restoring or maintaining ecosystem resilience therefore reduces the vulnerability of communities to climate change.

Water scarcity concerns increase the importance of a municipality working to protect existing water resources, conserving water and improving water storage opportunities. Ensuring access to adequate and healthy water is important for the agricultural, recreational, health, infrastructure, and biodiversity components of a vital community.

### Climate-proof municipal plans

Although some municipalities have chosen to develop separate climate change adaptation action plans, for some it is more desirable to build climate based considerations into existing planning documents. Municipalities have multiple planning documents, regulations and policies that guide different aspects of municipal affairs. Considering municipal planning documents, land use zones, policies and guidelines, etc. in relation to building climate resiliency will help a municipality achieve and support efforts to address water scarcity.

#### *Update Sustainability Plans to reflect climate change*

Many Alberta municipalities have created Sustainability Plans (Environmental Plans, Environmental Master Plans), all of which have environmental sustainability as a pillar or central consideration. One need/challenge in these plans is to identify specific strategies, and then link these to other municipal plans or strategies. Climate resiliency strategies identified in the *Adapt-action* tool are well-suited to this need; their inclusion leads to

more climate-resilient Sustainability Plans.

In some cases municipalities do undertake a separate climate change action plan (which may be called a climate risk management plan, readiness plan, action plan, or any number of other terms). One characteristic of successful plans is their ability to link to other plans or policies, other decisions that are already being made by the municipality. See the Policy Resource (below) to see how southern Alberta municipalities can make these links.

*RESOURCES*

- Alberta Urban Municipalities Association (AUMA) sustainability plan template and guide
- Alberta Municipal Districts and Counties Association (AAMDC) sustainability plan tool kit
- Climate change adaptation action planning resources
- Alberta municipal climate resilience policy resource
- Natural Step Integrated Community Sustainability Planning Guide
- County of Lethbridge Integrated Community Sustainability Plan
- Lacombe County Environmental Management Plan
- City of Prince George, BC
- District of Saanich, BC

### *Create climate-resilient land use zones*

Every municipality's Land Use Bylaw allows them to designate zones, and prescribe the intended function of lands within that zone. As well as describing the intent, the land use zone will lay out the permitted uses and discretionary uses, each list intended to support the zones primary function. Additionally, municipal land use bylaws can use overlays to add a provisional or voluntary layer to the zone, catalyzing more inventive activity in support of the goal.

For example, municipalities can ensure the ability of landscapes within the community to function as groundwater re-charge areas by creatively zoning for them. Groundwater Recharge zones or overlays can be designated within the Land Use Bylaw, with associated permitted uses that do not impede the ability of surface water to permeate and refill sub-surface aquifers.

Similarly, land use zones and overlays can be used to explicitly identify, plan for and

develop in support of:

- Areas where critical infrastructure (hospitals, water services, etc.) would need to be located in a climate-change-influenced landscape
- Landscape connectivity needed for species habitat changes due to climate change

*RESOURCES*

- Boston Groundwater Conservation Overlay District
- Portage County, WI, Groundwater Protection Overlay District
- California Water Plan Update, Recharge Areas Protection
- Groundwater Protection Through Local Land-use Controls
- Transfer of Development Credits (TDCs) in Alberta

### *Coordinate with regional Integrated Watershed Management Plans*

Each Watershed Planning and Advisory Council (WPAC) in Alberta is tasked by the provincial government with leading the development of an Integrated Watershed Management Plan (IWMP), and promoting the adoption of the plans's recommendations. Developed in collaboration with all levels of government and other stakeholders, these plans identify issues and examine the best course of action to address them, and consider water, land use, and information needs. A key feature of several of these plans is the source water protection needs for downstream communities, which are complicated by climate change.

Integrating municipal policies and plans with the local IWMP creates tremendous opportunities to draw on the information and resources gathered there for local application, and to promote strategies that must occur at a regional level. All WPACs in the Grasslands region are currently involved in developing these plans.

*RESOURCES*

- Toward a Resilient Watershed: Addressing Climate Change Planning in Watershed Assessments
- Bow River Basin Council (BRBC) Bow Basin Watershed Management Plan
- South East Alberta Watershed Alliance (SEAWA), Integrated Watershed Management Plan
- Oldman Watershed Council, Integrated Watershed Management Plan
- Milk River Watershed Council, Integrated Watershed Management Plan

### *Undertake scenario planning for emergency response*

Understanding the impact a changing climate will have for emergency services has two components, both which would benefit immensely from scenario planning. First is the potential increased need for emergency services. This involves understanding the potential community need (and associated capacity) of services in the case of increased flooding, water shortages, extreme heat events, wildfire, or disease outbreaks, especially for remote or vulnerable populations.

The second is the potential impact on the services infrastructure. This includes planning to react (e.g., ensuring back-up power exists for water infrastructure, or identifying which sub-plans or strategies have a climate change vulnerability), and planning so there is no need to react (e.g., risk-informed placement of hospitals, roads, utilities, emergency service centres, and water treatment and supply). Each of these should be addressed in scenario planning in the context of planning, provision, and possible retrofit.

*RESOURCES*

- Missoula County Climate Change Planning (Wildfire)
- Enhancing Health Care Resilience for a Changing Climate (Infrastructure placement)

### *Update Municipal Development Plans to reflect climate change*

Because the Municipal Development Plan is the highest-level, cross-municipal planning document, virtually every potential climate change adaptation strategy could be referenced and affected by the MDP (including watershed planning, infrastructure planning, environmental significant areas, water services, and agriculture). As well as addressing specific land use needs, the MDP sets the tone, allowing climate resilience planning to be reflected through stated development principles, proposed integration of land uses, financing, and general development constraints. The MDP can express climate change as an issue and climate resiliency as an adaptation approach. The MDP also lays out how municipal planning will integrate with the applicable regional plan, and gives the community - through the public hearing process - an opportunity to be educated and informed about climate resiliency challenges and opportunities.

Common themes included in MDPs which could speak to climate change adaptation activity include protection of agricultural operations, recreation, environmental

conservation, parks and protected areas, emergency services, transportation, economic development and utilities.

*Resources*

- Alberta municipal climate resilience policy resource

### *Adapt development approvals guidelines and policies to climate change*

Municipalities wield tremendous influence to promote climate resiliency through the approvals and permitting process. All development requires a variety of approvals at the municipal level, which presents several opportunities.

Municipalities can prescribe that developments avoid damage to community features that support climate resiliency. These measures include avoiding high quality habitats, erosion-prone banks and slopes, wildland urban interface, groundwater recharge areas, and wetlands. Collectively, approvals can ensure development activity is bound by projected (climate-adjusted) water availability, extreme weather, and biodiversity change, from the building design to the land use level. Finally, the approval process can put the onus on the proponent to indicate how the proposed development will support ecological infrastructure, including promoting grassy areas, and reduction of heat island effects.

Tactics can include disincentives (e.g., designated levies) for developing in these areas, incentives (e.g., Transfer of Development Credits), prescriptions in growth management strategies and plans, and/or requiring that building designers use predictive climate models in proposed designs.

*Resources*

- Climate Change Adaptation Planning: A Handbook for Small Canadian Communities
- City of Leduc Weather and Climate Readiness Plan
- Resilient Design Principles (Resilient Design Institute)

### *Undertake scenario planning for recreation and tourism infrastructure*

For many people, Alberta is a recreational paradise owing to the province's abundance of nature-based recreational opportunities. Much of the local economy in many of

Alberta's communities is based on the revenues from these well-established support industry. Impacts of increasing water scarcity, flooding and extreme weather will be significant for many slices of the recreation sector, directly affecting the economic development needs and activities of municipalities.

How, and the degree to which, these impacts will be felt is unclear for most communities. Scenario development for recreation and the associated infrastructure can help local communities identify risks, changes, and ultimately opportunities. Scenario development in southern Alberta could focus on water-based recreation infrastructure (lakes, rivers); impacts on swimming, fishing, boating due to lower water levels (especially in low water years); public safety due to varied water levels; increased potential for disease outbreaks; changes in habitat for recreational species.

### *Undertake scenario planning for economic development*

The economic impacts for a community of NOT adapting to climate change are likely far more severe than those associated with adaptation, but will be particular to each community. Scenario planning led by the economic development staff can help understand - and address - these dynamics.

Scenario development can look at the potential changes in sectors (tourism, recreation, agriculture, forestry, construction, etc.) as a result of climate change, and assess the likely changes to the community's job force, demand for skills, technology needs, re-training, etc.

#### *Resources*

- Adapting to Climate Change: Is Canada Ready? (Conference Board of Canada)

## Improve water retention capability

A critical part of becoming more resilient to water scarcity is increasing or restoring the ability of the natural landscapes to retain water. As water supplies decrease or become increasingly erratic, municipalities can implement programs and create/revise policies which support or augment the ability of those local landscapes to naturally retain greater amounts of the water that does come into the system.

### *Promote beaver reintroduction and retention*

Long thought of as a peril to land management, beavers are now coming to be seen as cost-effective agents of adaptation. With increased water scarcity, increased flood event intensity, and decreases in biodiversity, the importance of naturally-occurring (and naturally-maintained) water bodies increases.

Additionally, large-scale water storage structures are coming to be seen as costly and inflexible risk management investments; a mosaic of smaller water storage options is becoming increasingly important. Beavers' dam and pond-building creates natural infrastructure for storing, controlling and filtering water, as well as creating important habitat patches. As the need for flood abatement, groundwater re-charge, habitat maintenance, and recreation provision increase, beaver-created wetlands could become an important municipal water management strategy.

Thoughtful re-introduction of beavers can ensure community landscapes receive these ecosystem services. Municipalities can promote retention and reintroduction of beavers through direct acquisition of vital landscapes, outreach to landowners, collaboration with conservation groups, and supportive zoning and management.

*RESOURCES*

- Beaver, Climate Change and Resilience; Seventh Generation Institute
- The Beaver Solution; The Lands Council
- Methow Valley Beaver Project; Methow Conservancy
- Agricultural Decision Matrix Tool for Beaver Management
- Leave it to Beavers; Miistakis Institute
- Beaver and Climate Change Adaptation in North America: A Simple, Cost-Effective Strategy

### *Construct and restore wetlands*

Although protecting the natural system of wetlands is a more effective approach to climate resiliency, municipalities can also promote the development of constructed or engineered wetlands in cases where wetlands have been drained or degraded, or in cases where specific functions of a wetland system can viably be created in a new location. In the face of climate change, these power will become more important.

In these cases, the municipality identifies where an increase in flood abatement, water filtration, groundwater re-charge, or water storage service that wetlands normally provide is needed. There is an extensive practice in the field now, and many municipalities have undertaken these activities.

Municipalities now also have the ability to apply to be a Wetland Restoration Agent in Alberta (under the Water Act), receiving a mitigation payment from a development that is impacting a wetland, and using those dollars to restore associated wetland function in the system.

#### *Resources*

- Provincial Wetland Restoration Guide
- Riparia Ltd (Calgary-based landscape architecture firm)

### *Reduce impervious surfaces*

Human habitation means increasing impervious surfaces - hard surfaces (roads, parking lots, roofs) and their associated drainage infrastructure that prevent precipitation for being absorbed. Reducing this effect of impervious surfaces is increasingly vital both to flood management and groundwater recharge in developed areas.

There are two dynamics that municipalities can address. First, in Alberta groundwater is relied on by many people for their drinking water and for the water table that supports our surrounding vegetation. Impervious surfaces confound the ability of water to percolate into the ground and recharge the aquifers that support these services. Second, the associated drainage system is engineered to straight and smooth, effectively increasing the speed with which water is redirected into our water bodies, dramatically increasing the volume, force, and erosive power of the water, especially in high-precipitation events.

To address these issues, municipalities can do four things. First, they can measure and understand the degree to which their impervious surfaces are contributing to these issues. Second, they develop new standards for necessarily impervious surfaces such as roads, to reduce their impact. Third, they can promote new technologies which capture, slow and facilitate percolation of precipitation. This would include outreach to community members on the problems, and connect them to these solutions. Fourth, municipalities can retain green and grassy areas, through park areas, dry ponds, boulevards, and other pervious land uses in an effort to reduce overall impediments to percolation.

*RESOURCES*

- Reduce Impervious Surfaces - Vermont Green Infrastructure Initiative
- Reduce Impervious Surfaces (CRD)
- Green Infrastructure in Calgary's Mobility Corridors
- Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide
- Adaptive Approaches in Stormwater Management Plan (City of Ottawa)
- Innovative Stormwater Management Practices
- California Water Plan Update, Recharge Areas Protection
- Resilient Design Principles (Resilient Design Institute)
- Public Infrastructure Engineering Vulnerability Committee - PIEVC (Engineers Canada)
- Climate Change and Infrastructure, Urban Systems, and Vulnerabilities: Technical Report for the US Department of Energy in Support of the National Climate Assessment
- Comprehensive Stormwater Management Master Plan Guidelines:

### *Protect wetlands and other recharge areas*

Naturally occurring wetlands or areas with natural ability to support infiltration (and thus groundwater re-charge) exist across municipal landscapes. These areas play an increasingly important role in helping communities be climate resilient through their capacity for flood abatement, groundwater re-charge, nature-based recreation, and biodiversity maintenance.

Although zoning is the most obvious tools at a municipality's disposal (and an important one), municipalities have significant powers for protecting private lands. These include the ability to hold conservation easements, purchase critical landscapes, acquire

environmental reserve easements, and require environmental reserves. In these ways, they can act very much like a land trust, and though these powers have traditionally been used mostly for acquiring parkland, they can be used for protecting wetlands and other landscape features important for climate resiliency.

Under the Alberta Land Stewardship Act, municipalities are qualified to hold conservation easements; under the Municipal Government Act, municipalities can acquire environmental reserve easements instead of taking environmental reserve. Both of these tools leave the land in the hands of the landowner, but apply a set of restrictions used to protect the agreed-upon conservation (or climate resilience) values.

*RESOURCES*

- Alberta Land Stewardship Act (conservation easements, Sec 28)
- Conservation Easements in Alberta (online guide)
- Municipal Government Act

### *Promote local stormwater capture*

In many cases, the climate-affected issue around water is one of inconsistency. In southern Alberta, summer droughts are projected to routinely follow springs marked by significant flooding. Adaptation in these cases, seeks mechanisms to smooth these variations.

As well as larger, regional water storage such as wetlands, beaver ponds, and dams, 'micro-storage' is likely to become a critical component of a comprehensive municipal climate-resilience strategy. At the base of micro-storage is numerous, small-scale initiatives to capture, store and use stormwater in times of high or normal-flow for use later.

These can take the scale of local and regional irrigation projects down to household-based efforts. The technologies range from green (vegetated) and blue (stormwater capture) roofs, bio-swales, to rain barrels.

There are three critical roles for municipalities. First is providing information on the different technologies and their potential uses locally. Second, is the pressure for regulatory evolution, as there are currently provincial barriers to the expanded use of captured rainwater for non-potable uses. Third, is the active promotion of the use of these technologies, which many municipalities currently do through such activities as

subsidized rain barrel sales.

### *Retain native vegetation, especially in riparian areas*

We have tended to put our homes along the waterways of the province, putting our built infrastructure in our riparian areas, and dramatically altering the vegetative and soil structure of those areas. These areas serve numerous important purposes, purposes which will become more important in the face of a changing climate.

Properly functioning riparian areas can provide significant flood mitigation if the soil and vegetation are robust enough to accommodate the water flow. They are critical habitat areas, and will be more so as they serve as evolutionary migration routes for climate-affected species. And they can filter and reduce pathogens, especially if mature vegetation can keep the water bodies cooler.

Municipalities can play a critical roll in maintaining the climate-resilience function of riparian areas by activities such as protecting important riparian areas from development, replanting or re-grading degraded areas, setting and enforcing buffers and development setbacks. In some areas, local communities are making the protection and promotion of these areas central to a landscape-level flood mitigation program.

#### *Resources*

- Alberta Flood ReLeaf (available to Alberta municipalities)
- Alberta Riparian Habitat Management Society (Cows and Fish)
- Communities Adapting to Climate Change Initiative (Columbia Basin Trust)
- Adaptive Land use for Flood Alleviation (EU)
- Room for the River (Netherlands)
- Riparian Area in Calgary (City of Calgary)
- Riparian Land Conservation and Management (Rocky View County)

## Understand hydrological system

Adapting to the effects and implications of climate change will require municipalities to better understand the system within which they operate, and upon which they rely. The hydrological system - the operating system behind the watershed - is perhaps one of the most important systems for a climate-resilient municipality to understand. Comprehending that system includes understanding wetlands, re-charge dynamics, flood risks, ecological infrastructure, invasive risks, and associated habitats. That understanding will need to include current information as well as future projections, and be undertaken in partnership with existing groups and initiatives.

Numerous more specific strategies will be dependent on this understanding.

### *Identify wetland complexes of importance*

Wetlands are critical landscape features for municipalities as their existence and placement factor into development approvals, drainage planning, flood control, water recharge, conservation planning - all critical components of both municipal service planning, and becoming a more climate-resilient community. These efforts are challenged when the municipality is unclear where the wetlands, especially those of particular importance are located.

There are a number of ways a municipality can approach developing a locally-applicable sense of where the wetlands of importance are. Some municipalities have stepped out and undertake the effort of mapping their community's wetlands directly themselves, especially as part of drainage mapping efforts. Others have worked with the province, using their resources for groundwater mapping and wetland mapping, or simply clarifying jurisdictional responsibilities. Other potential partners and sources include Ducks Unlimited Canada, the local Watershed Planning and Advisory council (WPAC), the local regional parthership (e.g., the Calgary Regional Partnership), area regional services commissions, or adhoc multi-municipality partnerships.

One of the critical needs after this information has been gathered is to make it available to the community, specially in the context of explaining the local and regional importance of the mapped wetlands.

#### *Resources*

- Canadian Wetland Inventory (Ducks Unlimited Canada)

### *Identify local invasive species trajectories*

Invasive plant species are already a significant concern, and area of focus, for municipalities, with Alberta's Agricultural Fieldmen being the front line for much of this issue, and the Alberta noxious weed list being the primary guidance for risk assessment.

However, a changing climate regime will affect invasive plant species, their prevalence and their trajectories. Climate change will shift the natural regions and the ranges of specific invasive species, allowing invasives from south of the border to move into southern Alberta. This means that the weeds that were of most concern yesterday, may not be the ones we should be concerned about today.

Municipalities can take advantage of research conducted to identify which invasive species they should likely be concerned about in the near, climate-adjusted, future. As well as consulting the research, municipalities can establish relationships with weed specialists in adjacent natural regions who are currently dealing with the weeds of tomorrow, and learn management techniques from them.

#### *Resources*

- Predicting New Invasive Plant Threats to Alberta
- Alberta's Natural Subregions under a Changing Climate (ABMI)

### *Map drought, flood and re-charge zones*

Since the floods of 2013 in southern Alberta, municipalities have been acutely aware of the need to understand the locations of the flood risk, but also the natural water infrastructure broadly. The disasters of tomorrow are projected to be as much about water scarcity as flood. Changes in climate are projected to make both floods and droughts more severe, and the need for associated stormwater storage and re-charge areas ever more critical if we are to manage these resources in a climate-resilient way.

Municipalities can help be more climate resilient by mapping flood risk zones, drought risk zones, and re-charge areas that are critical for managing both issues. Flood hazard mapping is available, as are drought projections at the provincial level. Mapping (and an understanding) of groundwater storage, flow and re-charge are less common. In all three cases, the work can be done in partnership with other municipalities, regional partnerships and commissions, and/or the Government of Alberta. However,

municipalities can do much at the local level, where 'ground truthing' is often required. Simpler hydrological models can identify potential re-charge zones, and development proponents can be required to incorporate assessments of re-charge areas as well.

*RESOURCES*

- Flood Hazard Identification / Mapping / Studies (Alberta Environment and Sustainable Resource Development)
- Alberta Climate and Atlas Maps (AgroClimatic Information Service - ACIS)
- Alberta Water Well Information Database
- Provincial Groundwater Inventory Program (Alberta Geological Survey)

### *Identify water quality risks*

Municipalities already play a large role in managing water systems to minimize the risks associated with low water quality. This can be built on to enhance their climate resilience, given the nature of water quality risks is likely to change significantly under a different climate regime. Exacerbated risks to water quality are likely to be a result of lower flows, flood events, and warmer water temperatures.

A vital step for municipalities is to maintain their water quality monitoring or their participation in (and vigilance over) other water monitoring efforts, but to seek opportunities to do so in a way that considers the changing climate. As always, there are several potential partners in this role including Alberta Health Services public health staff, water quality specialists at Alberta universities, regional services commissions, and regional partnerships. As regional plans role out, they will likely include surface water quality guidelines and management frameworks, and municipalities can play a key role in ensuring these are based on climate-adjusted projections of the risk.

*RESOURCES*

- Agricultural Land Resource Atlas of Alberta - Surface Water Quality Risk for the Agricultural Area of Alberta
- Guidelines for Canadian Recreational Water Quality
- Alberta Surface Water Quality Data

### *Work with WPACS on State of Watershed analyses*

Watershed Planning and Advisory Councils (WPACs) are non-profit organizations

designated by Alberta Environment and Sustainable Resource Development to assess the condition of their watershed and prepare plans to address watershed issues. Each one has developed a State of the Watershed report, which they are bound to update on a regular basis. For climate resilience-planning, these are invaluable resources, and municipalities should both use them, and participate in their development with an eye to how the information gathered can support climate-resilience strategies.

Some key areas for which municipalities should utilize State of the Watershed Reports include projections of stream flows, assessments of flood risks, identification of valuable habitat (and projected changes), and water quality changes.

*RESOURCES*

- Bow River Basin Council (BRBC), State of the Watershed
- South East Alberta Watershed Alliance (SEAWA), State of the Watershed
- Oldman Watershed Council (OWC), State of the Watershed
- Milk River Watershed Council, State of the Watershed

### *Catalogue local ecological infrastructure existence and vulnerability*

Ecological infrastructure is the system of structural and functional terrestrial and aquatic landscape features, interrelationships and processes that produce ecological services (such as water purification, pollination, water regulation, disease regulation, etc.). Planning for resilience-based adaptation requires understanding these elements, at least to some degree, at a various scales.

Cataloguing a community's ecological infrastructure is no small undertaking, but it can happen at several scales, and with partners. A municipality seeking to detail their ecological infrastructure can approach that task in several ways. A regional, multi-facet assessment (usually in conjunction with multiple partners) can provide the larger landscape context - and the complex modeling - that is often needed. Assessments can also be function-by-function (water percolation, stormwater capture, etc.). Finally, they can be issue- and site-specific (e.g., wetland services impaired by development)

*RESOURCES*

- Ecological Infrastructure in the Calgary Region: What We Now Know
- Greenfield Tool Box: Ecological Infrastructure Modeling

- Ecosystem Services Approach Pilot on Wetlands: Integrated Assessment Report

### *Identify high value habitats based on anticipated climate changes*

Municipal efforts to safeguard natural spaces and associated wildlife habitat will be made much more difficult as the climate continues to change and vegetation (and habitats) adapt to those changes. Habitat conservation efforts today may be misplaced or inadequate, confounding the climate-resilience strategies based on planning and development siting, protected areas and private land securement, nature-based tourism and recreation, and agricultural support services.

The Biodiversity Management and Climate Change Adaptation project led by the Alberta Biodiversity Monitoring Institute has been working to identify these shifts in habitats, and much of that work is applicable for municipalities. As well, conservation advocacy groups, university academics, and local land trusts can all provide information on wildlife habitat evolution, and be partners in responding. As well, the soon-to-be-released Alberta Biodiversity Management Framework is slated to contain climate-change-adjusted management information.

#### *Resources*

- Climate Change Vulnerability of Alberta's Terrestrial Biodiversity: A Preliminary Assessment (ABMI)
- Rare Grasslands Birds and Extreme Weather
- Biodiversity Management and Climate Change Adaptation Project (ABMI)
- Alberta's Natural Subregions under a Changing Climate (ABMI)

### *Understand projected changes in local water flow and storage*

Whether communities will have to face increased water flows (flooding events) or water scarcity (low flows and droughts) is really more a question of time than anything - the same location may in the same year experience early season flooding and late season drought. The probability and the intensity of both will vary from place to place. To manage for this, and ultimately become more climate resilient as these effects intensify, involves gathering and understanding the right information.

Municipalities should acquire information that is specific to their location, and work with infrastructure, environment, agriculture and other staff to understand what the

implications are for the local community and the municipal corporation. Gathering and representing this data over time will give municipalities a better basis for useful projections.

This understanding will inform many climate-resilience strategies related to scenario planning, water storage infrastructure development, species and habitat needs, flood abatement needs, and others.

*RESOURCES*

- Alberta Water Portal - Maps
- Alberta River Basin Maps and Data Summaries
- Computerized Tool for the Development of Intensity-Duration-Frequency-Curves under Climate Change

## Promote water-moderate agricultural

Municipalities do not have a mandate to manage agricultural lands, but they do have a role to play in supporting the agricultural operations in their community. This role can include identifying and promoting those agricultural practices which may be less water-dependent than more traditional practices. This has benefits for promoting economic stability in the community, reducing water consumption at the community and regional level, and promoting rural sustainability.

### *Raise local awareness of issues and options facing agriculture*

Rural municipalities can play a central role in making their local agriculture community aware of the projected changes, likely risks, and opportunities for changes in choices and practices that ensure producers are more resilient to climate impacts such as water scarcity, variable precipitation, and associated changes in growing conditions.

The Agricultural Services Board and the Agricultural Fieldman connected to a municipality have a tremendous capacity to support adoption of climate-resilient agricultural practices through outreach and extension. By convening meetings or information sessions, they can help increase local producers' awareness of new management practice information associated with Climate Smart Agriculture.

This can cover topics such as new information on drought-tolerant crops, field management techniques, livestock watering, conservation tillage, soil erosion, field shelter belts, direct seeding, reduced summerfallow, increase crop residue cover, avoidance of overgrazing, improved irrigation methods, reduced herbicide/pesticide use and others. They can also provide information on the climate-resilience benefits of riparian management, wetland maintenance, grassy zones, flood management, and other ecosystem-based adaptation approaches. Discussions around these topics can help draw connections such as those between deep-rooted plants and salinization reduction, the use of seasonal climate predictions to plan growing season, and reductions in phosphorus-rich fertilizer to mitigate low water years/seasons.

#### *Resources*

- Analysis of EG&S Policy Options Fostering Adaptation of Canadian Farmers to Climate Change and Development of a Decision-making Tool.
- Climate-Smart Agriculture (CSA)
- Large-scale implementation of adaptation and mitigation actions in agriculture

- Conservation Agriculture
- Soil Erosion Risk for the Agricultural Area of Alberta

### *Promote conversions to less water-intensive agriculture*

It can be controversial to suggest a movement away from the extensive irrigated agriculture which takes place in southern Alberta, but water availability projections suggest those operations will be less viable in the future. To support local business and community development, municipalities can play a role helping agricultural operators and the local community understand the projections of water availability and the options for less water-intensive agricultural industry.

Practices and opportunities can range from industry-wide large scale to producer-specific smaller scales. Possibilities could include managing long-term reductions in stocking rates, conversion to drought-tolerant crops, promotion of non-irrigated agricultural products, movement away from extensive irrigated agriculture to greenhouses, in-barn improvements of livestock watering devices, improved irrigation management (increase water use efficiency and nutrient use efficiency of plants, improved infiltration, improved irrigation equipment), improved water storage facilities, ponds for agricultural water supply management, and retention of grassy zones to improve water retention by soils.

### *Promote water-moderate food products and businesses*

Many southern Alberta municipalities play a role in promoting agricultural operations and products created in their area, including local food fairs, involvement in farmers markets, and print material advertising these. A new facet of these activities can be promoting local 'water-moderate' businesses and food products.

The agricultural services and economic development staff of municipalities often cooperate on promoting local agri-businesses, working to ensure local and regional consumers are aware of food produced in the community, usually with a particular theme. Water-moderate food products and producers can be profiled at a municipally-hosted local food event, through a water-moderate local food map, or awards for businesses which maintain or reduce water use.

#### *Resources*

- Organizing Local Food Events (Alberta Agriculture and Rural Development)

## Promote water conservation

As water scarcity increases, a critical part of adapting will be to use less water. This is something that needs to be embraced at the individual, company, industry, and community levels. Municipalities can play a significant role in helping this happen through a variety of incentive and disincentive based approaches, as well as by providing awareness-raising information. It is also clear that municipalities cannot accomplish water conservation goals by themselves, but they can play a role in supporting other groups that can take lead roles.

### *Raise awareness of projected water insufficiencies*

Many of the strategies for a community to become more climate resilient are dependent on the community members knowing the projected changes in water supply, flow and quality due to climate change. As the primary delivery agent for water to people in the region, Municipalities are very well-placed to provide this information. The key messages revolve around the overall decrease in water availability, the projected variations in stream flow by season, and the incompatibility between that and the projected regional population.

It is important that community members understand the projected impacts and implications both as individuals as well as a community as a whole. The information contained in the Adapt-action tool provides a solid basis for this information, and explains changes and implications in terms of infrastructure, biodiversity, recreation, agriculture, and human health.

### *Catalyze creation of Climate Smart groups*

Every community is different, so every community's resiliency issues and solutions are different. However, one common factor is that plans and strategies are more effective when the community members are engaged. Many communities have found success in local citizen-led groups that focus on enduring sustainability issues, and innovative approaches to addressing them. In Alberta, there have been Fire Smart, Bear Smart, Wild Smart and other groups of a similar style. The model lends itself well to community-based climate adaptation groups, or 'Climate Smart' groups.

Local groups that focus exclusively on how the community can be more climate resilient provide a valuable mechanism for tailoring information and strategies, engaging the local citizenry, and bolstering the municipality's ability to become climate resilient. In the

same way Alberta municipalities have catalyzed and supported other community 'Smart' groups, they can catalyze the creation of local community-based 'Climate Smart' programs.

Climate Smart programs have been created in regional municipalities in Nova Scotia, and others have been created focused exclusively on businesses.

*RESOURCES*

- Halifax Regional Municipality, Climate Smart
- Climate Smart Business
- Alberta Fire Smart
- Wild Smart

### *Incent low-water-use technology*

There are an increasing number of technologies and techniques that community members, businesses and industries can use to decrease the amount of water they use on an on-going basis.

Municipalities can promote and incent low-water-use technology in several ways. First, they provide education and outreach (and many do), regarding the most common risks for overuse, the benefits of conservation, and the technologies locally available. Second, they can promote water capture techniques (rain barrels and cisterns) that gather water in high-flow times for use later. Third, they can provide incentives to builders to use low-water-use (xeriscaping) technologies in their building and landscape designs. Fourth, they can provide options directly to individuals such as low-flow toilet rebates and subsidized rain barrels. Fifth, they can install residential water meters, and set targets for water use, drawing the community into challenges for low water use. Sixth, in agricultural communities, they can provide information on water-moderate agricultural technologies and practices. Finally, they can lead by example, using all of these technologies and techniques in their municipal operations and facilities.

*RESOURCES*

- City of Calgary Water Efficiency Plan

## Promote climate-resilient infrastructure

Climate-related risk assessments for infrastructure are unanimous in that municipalities face increased challenges of maintenance, longevity and function. Infrastructure elements commonly identified as at risk are those associated with water, sewer, roads, bridges, housing, and managed landscapes. Risk and cost assessments are critical to planning for climate-resilient infrastructure. As well as physical modification of assets, many adaptation opportunities exist in planning, practices, and protection.

### *Conduct assessment of at-risk infrastructure*

An important first step in building climate resiliency in a municipality's infrastructure is to assess the types and degrees of risk exposure facing each infrastructure category. These can be done formally or informally. Often the heads of departments each department can assess a significant portion of the risk by answering questions like, "What would the increased risk and associated response be to [infrastructure] if temperatures were to increase by [X] or storm water was to change by a factor of [Y]". More formal vulnerability assessment methodologies exist, an increasing number of which specifically assess climate-related increases in risk.

As well, inspection schedules of at-risk infrastructure should be reviewed, being vigilant for damage to water systems, roads, or bridges, or blockages of culverts and water intakes.

#### *Resources*

- Public Infrastructure Engineering Vulnerability Committee - PIEVC (Engineers Canada)
- How Will Climate Change Affect Civil Infrastructure
- What Will Adaptation Cost? An Economic Framework for Community Planners

### *Place critical infrastructure in less climate-affected areas*

Addressing infrastructure risk due to a changing climate is often more about prevention than cure. With an understanding of how landscapes are either vulnerable because of climate change or valuable for their adaptive capacity, transportation and other infrastructure can be sited to avoid the risk. For example, municipalities can encourage siting of roadways away from areas that face increased risk due to flooding, erosion or heat effect, or avoid approving residential development in fire-prone areas.

*Resources*

- EPA - Climate Change Adaptation - Transportation
- The People, Economy, Land, and Resources of Missoula County and Potential Vulnerabilities to Climate Change

### *Abandon infrastructure too expensive to fix or maintain*

In some cases, infrastructure was created or maintained prior to a full-cost assessment of the resources required to do so in a climate-change-influenced landscape. Subsequent to an at-risk infrastructure assessment, municipalities can seek to relinquish infrastructure that is overly expensive to maintain or retrofit to a sufficient level of resiliency. For example, at-risk component of road systems may be redundant at a community level. Prioritization should consider other factors such as reducing impacts on natural infrastructure and potential efficiencies from infrastructure reductions that might have lower long-term costs.

*Resources*

- Public Infrastructure Engineering Vulnerability Committee - PIEVC (Engineers Canada)
- Managing Municipal Infrastructure in a Changing Climate

### *Undertake scenario planning for built infrastructure*

It is impossible to predict the future. However, it is possible to calculate plausible future scenarios that can help municipal managers identify the scale of potential impact and scope of potential response. Municipalities can conduct structured or informal scenario planning by 1) understanding the climate-adjusted change in those factors affecting future load on infrastructure (e.g., population increase, water supply decrease), 2) projected impacts on infrastructure (see Implications), and 3) contribution of natural infrastructure (water recharge areas, natural drainage ways, diverse riparian areas, habitat migration corridors). A number of resources and models exist to help municipalities develop these scenarios.

*Resources*

- Public Infrastructure Engineering Vulnerability Committee - PIEVC (Engineers

Canada)
- Natural Resources Canada's (NRCan) Adaptation Platform
- EPA - Climate Change Adaptation - Transportation
- Managing Municipal Infrastructure in a Changing Climate
- Adaptation to the Impacts of Climate Change on Transportation (National Academy of Engineering)
- Climate Change and Infrastructure, Urban Systems, and Vulnerabilities: Technical Report for the US Department of Energy in Support of the National Climate Assessment

### *Adapt infrastructure to be more climate resilient*

In many cases, physically adapting or retrofitting infrastructure can seem beyond the capacity or a small municipality. However, some approaches can be incorporated into new developments or planned upgrades, including larger culverts, low-dust road surfaces, more heat-resilient road materials. Infrastructure adaptation can also include seeking efficiencies such as incorporating natural drainage and water storage capabilities into new development. As well, risk-based cost assessments may show savings over the longer term.

*Resources*

- Public Infrastructure Engineering Vulnerability Committee - PIEVC (Engineers Canada)
- Natural Resources Canada's (NRCan) Adaptation Platform
- EPA - Climate Change Adaptation - Transportation
- Managing Municipal Infrastructure in a Changing Climate
- Adaptation to the Impacts of Climate Change on Transportation (National Academy of Engineering)
- Climate Change and Infrastructure, Urban Systems, and Vulnerabilities: Technical Report for the US Department of Energy in Support of the National Climate Assessment
- Preparing for a Changing Climate: Washington State's Integrated Climate response Strategy

### *Promote protection of natural infrastructure*

Maintenance of natural or ecological infrastructure allows municipalities to draw on the capabilities of natural systems to provide ecosystem-based services that built

infrastructure is often developed to deliver. Water storage, water purification, storm water retention, recreation opportunities, water cooling, and shade protection are all examples of naturally-provided climate-resiliency. Municipalities can maintain these functions and benefits by protecting (e.g., bylaw or deed-restricted restrictions), incorporating (e.g., using natural drainage ways in new developments), constructing (e.g., engineered wetlands), or avoiding (e.g., incenting built development in areas of poor water recharge) ecological infrastructure.

Many naturally-occurring infrastructure systems exist in and around municipalities which play a critical role in maintaining water on the landscape in times of increasing water scarcity. These include beaver ponds, natural wetlands, sloughs, and natural depressions. There is a little or no 'capital' investment required, and once identified, policies and planning guidelines can be adjusted so as to protect their water capture an storage functions. These include policies at the MDP level for maintaining natural infrastructure, development regulations that protect against their removal, and coordination with the Government of Alberta in protecting municipally-important provincial wetlands.

*RESOURCES*

- ICLEI Canada's Municipal Biodiversity Program
- Preparing for a Changing Climate: Washington State's Integrated Climate response Strategy
- Climate Change and Biodiversity (IPCC)
- Draft Principles and Guidelines for Integrating Ecosystem-based Approaches to Adaptation in Project and Policy Design
- Ecosystem-based Adaptation: A natural response to climate change
- Exploring Climate Change Adaptation and Biodiversity (ICLEI)
- Riparian Land Conservation and Management (Rocky View County)
- Riparian Area in Calgary (City of Calgary)
- Source of Opportunity: A Blueprint for Securing Source Water in Southern Alberta
- Stepping Back from the Water: A Beneficial Management Practices Guide for New Development Near Water Bodies in Alberta's Settled Region
- Toward a Resilient Watershed: Addressing Climate Change Planning in Watershed Assessments
- Beaver, Climate Change and Resilience; Seventh Generation Institute
- Provincial Wetland Restoration Guide
- Ecological Infrastructure in the Calgary Region: What We Now Know
- Ecosystem Services Approach Pilot on Wetlands: Integrated Assessment Report

- Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide
- Beaver As a Climate Change Adaptation Tool: Concepts and Priority Sites in New Mexico
- Green Infrastructure in Calgary's Mobility Corridors

# Resources

Throughout the *Adapt-action* tool, there are resources and references associated with various components. These resources have a range, applying implications and strategies, implementation, science and data, and other aspects of climate resiliency.

Resources are annotated, with a brief description of each, and include the associated URL where appropriate. *Adapt-action*'s resources are reproduced here, and gathered under the following headings:

- Comprehensive Adaptation Resources
- Community Planning
- Policy
- Science and Data
- Ecosystem-based Adaptation
- Biodiversity
- Human Health
- Flood Mitigation
- Agriculture
- Infrastructure
- Cases

## Comprehensive Adaptation Resources

**Adapting to Climate Change: An Introduction for Canadian Municipalities**
http://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/reports/municipalities/10079

An introductory resource for municipalities in Canada beginning the process of becoming climate resilient, put in the context of municipal decision making, and with a number of Canadian case examples.

**Cities Impact and Adaptation Tool (CIAT)**
http://graham-maps.miserver.it.umich.edu/ciat/

Primarily a tool for cities around the Great Lakes to explore climate 'peers' in the region, but also contains an extensive (500+) library of municipal climate change adaptation strategies (pretend you are a Great Lakes area city and navigate through the tool).

**Climate Adaptation Knowledge Exchange (CAKE)**
http://www.cakex.org/

A practical and easily-navigated resource for climate adaptation at all levels. Includes case studies, tools, and a virtual library, all searchable.

**Climate Change Adaptation Community of Practice (CCACoP)**
https://www.ccadaptation.ca/

An interactive online community dedicated to advancing knowledge and action in the area of climate change adaptation. The CCACoP is used by researchers, experts, policy-makers and practitioners from across Canada to share knowledge, and communicate with others working in the field of climate change adaptation. Numerous presentations and resources focus on adaptation at the municipal level.

**Climate Change Impacts and Adaptation: A Canadian Perspective**
http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/perspective/pdf/report_e.pdf

A solid resource on the effects of climate change at a national level for water resources, agriculture, forestry, fisheries, coastal zones, transportation and human health and well-being.

**Communities Adapting to Climate Change Initiative (Columbia Basin Trust)**
http://www.cbt.org/Initiatives/Climate_Change/?Adapting_to_Climate_Change

A broad program from the Columbia Basin Trust aimed at informing and supporting local communities to become more climate resilient. The web site contains several awareness and application resources, and information on the participating communities. Includes the Adaptation Resource Kit (http://adaptationresourcekit.squarespace.com) which includes extensive information, case descriptions, and implementation resources usable by Alberta municipalities.

**Natural Resources Canada's (NRCan) Adaptation Platform**
http://www.nrcan.gc.ca/environment/impacts-adaptation

NRCan's climate change adaptation landing page, which redirects to several applicable resources, including the newly-updated synthesis report, "Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation"

**Natural Resources Canada (NRCan) Climate Change Publications**
http://www.nrcan.gc.ca/environment/resources/publications/10766

NRCan has developed several climate change adaptation resources, including several targeted at municipalities, all available from this web site.

**Resilient Communities Project (All One Sky Foundation)**
http://allonesky.ca/resilient-communities-project/

Web site of the All One Sky Foundation's Resilient Communities Project which describes their Alberta-based process for helping municipalities become climate resilient; includes cases, links to resources, and contact information for their adaptation experts.

**ReTooling for Climate Change**
http://www.retooling.ca

A BC-based tool from the Fraser Basin Council that includes numerous adaptation planning resources applicable at the municipal, including several community profiles.

## Community Planning

**Adapting to Climate Change: An Introduction for Canadian Municipalities**
http://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/reports/municipalities/10079

An introductory resource for municipalities in Canada beginning the process of becoming climate resilient, put in the context of municipal decision making, and with a number of Canadian case examples.

**Building Adaptive and Resilient Communities – BARC (ICLEI)**
http://www.icleicanada.org/adaptationtool

ICLEI (Local Governments for Sustainability) Canada has an online adaptation action planning process which many municipalities in Canada (and Alberta) have used. It guides

the user through the stages of initiating, researching, planning, implementing, and monitoring a climate change adaptation action plan.

**Canadian Communities' Guidebook for Adaptation to Climate Change**
http://www.fcm.ca/Documents/tools/PCP/canadian_communities_guidebook_for_adaptation_to_climate_change_EN.pdf

A specific process created to assist municipalities in planning for climate change, but with many practical examples that are applicable to municipalities whether they use the prescribed process or not.

**City of Calgary Water Efficiency Plan**
https://www.calgary.ca/UEP/Water/Documents/Water-Documents/water_efficiency_plan.pdf

A report on the City of Calgary's efforts to foster wise water use, including its case for conservation, water efficiency measures, and implementation plan.

**Climate Change Adaptation Discovery Tool (Columbia Basin Trust)**
http://adaptationresourcekit.squarespace.com/storage/Adaptation%20Discovery%20Tool_Draft%20First%20Edition_June2011.pdf

Excellent document/tool that guides a community through the various aspect of climate resiliency planning from using modeling, structuring decision making, and implications for various municipal departments and services.

**Climate Change Adaptation Planning: A Handbook for Small Canadian Communities**
http://www.fcm.ca/Documents/tools/PCP/climate_change_adaptation_planning_handbook_for_small_canadian_communities_EN.pdf

A project of Natural Resources Canada and the Canadian Institute of Planners specifically aimed at municipalities with limited in-house capacity.

**Climate Change Adaptation through Land Use Planning (Manitoba)**
http://www.gov.mb.ca/ia/plups/pdf/cca.pdf

A simple summary guide created by Manitoba Local Government to seed ideas for municipalities in how they could pursue climate change adaptation efforts.

**Changing Climate, Changing Communities: Guide and workbook for Municipal Climate Change Adaptation (ICLEI)**
http://www.icleicanada.org/resources/item/3-changing-climate-changing-communities

A workbook-based document to guide participant communities through the ICLEI 5-step process for climate change adaptation planning.

**Groundwater Protection Through Local Land-use Controls**
http://wi.water.usgs.gov/gwcomp/integrate/reports/WGNHSSpecialReport11.pdf

A review of practical regulatory approaches to groundwater protection at the state and local level.

**A Guide for Incorporating Adaptation to Climate Change into Land-use Planning**
http://www.cefconsultants.ns.ca/CCGuideLandUseNov05.pdf

A short practical guide for incorporating adaptation considerations into the municipal land-use planning process, including a practical list of potential impacts, and a method for evaluating how 'climate-proof' a plan is.

**Identifying Adaptation Options (UKCIP)**
http://www.ukcip.org.uk/wordpress/wp-content/PDFs/ID_Adapt_options.pdf

A guide from the well-respected UK Climate Impacts Programme (UKCIP) to help local communities identify what climate change adaptation might be available to them, and how to assess their value to the community versus other options .

**The People, Economy, Land, and Resources of Missoula County and Potential Vulnerabilities to Climate Change**
http://headwaterseconomics.org/wphw/wp-content/uploads/Missoula_SocioEconomic_Impacts.pdf

A terrific summary of the climate-related vulnerabilities and impacts for a rural county in the inter-mountain west, including social, economic, and resource implications.

**What Will Adaptation Cost? An Economic Framework for Community Planners**
http://seagrant.noaa.gov/Portals/0/Documents/what_we_do/climate/NOAA_What_Will_Adaptation_Cost_Report.pdf

A straightforward methodology for conducting a local community-based fiscal assessment of the costs of adaptation.

**Wild Smart**
http://www.wildsmart.ca/aboutus.htm

The website of the WildSmart program in Canmore, Alberta, which is based on the successful FireSmart programs, and provides an inspirational model for a potential Climate Smart organization.

## Policy

**Alberta Land Stewardship Act (conservation easements, Sec 28)**
http://www.qp.alberta.ca/documents/Acts/A26P8.pdf

The legislation that enables several conservation and stewardship tools, including 'conservation easements' (Sec. 28) and Transfer of Development Credits (Sec. 48).

**AAMDC sustainability plan tool kit**
http://www.aamdc.com/toolkits-initiatives-2/209-integrated-community-sustainability-plan-icsp-toolkit

The Alberta Association of Municipal Districts and Counties' (AAMDC) toolkit and guide to creating a municipal sustainability plan.

**AUMA sustainability plan template and guide**
http://www.auma.ca/live/AUMA/Toolkits+%26+Initiatives/Integrated+Community+Sustainability+Plan+Template

The Alberta Urban Municipalities Association's (AUMA) template for and guide to creating a municipal sustainability plan.

**Bow River Basin Council (BRBC) Bow Basin Watershed Management Plan**
http://www.brbc.ab.ca/index.php/about-us/core-activities/bbwmp-2012

The Integrated Watershed Management Plan created by the Bow River Basin Council.

**Bow River Basin Council (BRBC), State of the Watershed**
http://wsow.brbc.ab.ca/

The State of the Watershed report created by the Bow River Basin Council.

**Conservation Easements in Alberta (online guide)**
http://www.ce-alberta.ca/

An online guide to understanding and applying conservation easements in Alberta, including specific direction for municipalities.

**Milk River Watershed Council, Integrated Watershed Management Plan**
http://www.mrwcc.ca/index.php/iwmp/

The Milk River Watershed Council's Integrated Watershed Management Plan.

**Milk River Watershed Council, State of the Watershed**
http://www.mrwcc.ca/index.php/projects/state-watershed-report/

The Milk River Watershed Council's State of the Watershed report.

**Municipal Government Act**
http://www.qp.alberta.ca/documents/acts/m26.pdf

The guiding legislation of Alberta's local governments, which contains the Environmental Reserve set back guidelines (Sec. 664).

**Natural Step Integrated Community Sustainability Planning Guide**
http://www.thenaturalstep.org/en/canada/toolkits#ICSP

The Natural Step has created a Community Sustainability Planning Guide (note: sign up is required to be able to download it).

**Oldman Watershed Council (OWC), State of the Watershed**
http://oldmanbasin.org/teams-and-projects/state-of-the-watershed-report/

The Oldman Watershed Council's State of the Watershed report.

**Oldman Watershed Council, Integrated Watershed Management Plan**
http://oldmanbasin.org/teams-and-projects/visioning-for-integrated-watershed-management-plan-team/

The Oldman Watershed Council's Integrated Watershed Management Plan.

**Paying for Urban Infrastructure Adaptation in Canada: An Analysis of Existing and Potential Economic Instruments for Local Governments**
http://act-adapt.org/paying-for-urban-infrastructure-adaptation-in-canada-an-analysis-of-existing-and-potential-economic-instruments-for-local-gove/

A comprehensive but practical report by ACT (the Adaptation to Climate Change Team at Simon Fraser University) looking at local government considerations for financing adaptation including making the economic case for adaptation, conventional and innovative funding and financing, P3s, incentives, and insurance.

**Riparian Land Conservation and Management (Rocky View County)**
http://www.rockyview.ca/Portals/0/Files/Government/Policies/Infrastructure/Policy-419.pdf

Rocky View County's Riparian Land Conservation and Management Policy was created to conserve and manage riparian lands for biodiversity, water quality and quantity, erosion and flood control, and recreational, education, and economic opportunities.

**Source of Opportunity: A Blueprint for Securing Source Water in Southern Alberta**
http://www.water-matters.org/docs/source-of-opportunity.pdf

An analysis of the needs and policy options for conserving headwaters, with a recommended 'blueprint' for source water protection.

**Source Water Protection Plan: Edmonton's Drinking Water System (EPCOR)**
http://corp.epcor.com/watersolutions/operations/Documents/EPCOR-source-water-protection-plan.pdf

A plan by Edmonton's drinking water utility compiling information on the North Saskatchewan River watershed, and using it to identify hazards, assess risks to source waters and make recommendations on how to manage these risks.

**South East Alberta Watershed Alliance (SEAWA), Integrated Watershed Management Plan**
http://www.seawa.ca/state-of-the-watershed/iwmp/

The South East Alberta Watershed Alliance's (SEAWA) Integrated Watershed Management Plan.

**South East Alberta Watershed Alliance (SEAWA), State of the Watershed**
http://www.seawa.ca/?option=com_seawa&Itemid=110

The South East Alberta Watershed Alliance's (SEAWA) State of the Watershed report.

**Transfer of Development Credits (TDCs) in Alberta**
http://www.tdc-alberta.ca/

A comprehensive web guide for municipalities that both explains the concept and provides application guidance for the Transfer of Development Credits, a mechanism to incent conservation and appropriate development.

## Science and Data

**Alberta Climate and Atlas Maps (AgroClimatic Information Service - ACIS)**
http://agriculture.alberta.ca/acis/climate-maps.jsp

Easy-to-operate, interactive map that allows users to see temperature, precipitation, soil, drought, and fire data at a provincial level, both current and historical.

**Alberta Flow Quantity Index**
http://esrd.alberta.ca/focus/state-of-the-environment/water/surface-water/condition-indicators/alberta-river-flow-quantity-index.aspx

The River Flow Quantity Index indicator illustrates the difference between a natural flow regime for the river and the actual flows that were recorded during the year. Flow regimes are examined on a two-season basis: summer (open water considered as one season) and late fall to early spring (the remaining seven months).

**Alberta River Basin Maps and Data Summaries**
http://www.environment.alberta.ca/forecasting/reports/index.html

Current data on precipitation, snow course, runoff forecasts, and reservoir storage summaries provided at a provincial level.

**Alberta Surface Water Quality Data**
http://esrd.alberta.ca/water/reports-data/surface-water-quality-data/default.aspx

A Government of Alberta site that allows users to produce water quality data reports for various monitoring locations around Alberta.

**Alberta Water Portal - Maps**
http://albertawater.com/water-maps

Map an data resources related to water from Alberta Environment and Sustainable Resource Development, Alberta Agriculture and Rural Development, and Agriculture and AgriFood Canada.

**Alberta Water Well Information Database**
http://esrd.alberta.ca/water/reports-data/alberta-water-well-information-database/default.aspx

Database of approximately 500,000 records about individual water well drilling reports, chemical analysis reports, springs, flowing shot holes, test holes, and pump tests; uses an easy-to-use map interface.

**Alberta Wildfire Maps and Data (AESRD)**
http://wildfire.alberta.ca/wildfire-maps/default.aspx

Maps and data, current and forecast, for drought and wildfire.

**Atlas of Alberta Lakes – Water Quality**
http://sunsite.ualberta.ca/Projects/Alberta-Lakes/characteristics3.php

A comprehensive data atlas of the major lakes and reservoirs of Alberta, providing information on several characteristics of water quality.

**Alberta Water Portal – What is Drought?**
http://albertawater.com/what-is-drought

A brief but comprehensive description of what the various kinds of droughts are, as well as a history of droughts in Alberta in the 19th, 20th and 21st centuries.

**Canadian Climate Data and Scenarios (Environment Canada)**
http://ccds-dscc.ec.gc.ca/

An online scenario-building tool that allows users to download data or generate graphs of various climate change parameters (historical, current and projected), based on user-selected criteria, for various weather stations around Canada

**Canadian Wetland Inventory (Ducks Unlimited Canada)**
http://www.ducks.ca/what-we-do/cwi/

The website of the Canadian Wetland Inventory partnership, established in 2002 to provide an accessible, national wetland inventory, which includes an interactive wetland inventory status map to show where a CWI is in progress or complete.

**Climate Data for Alberta**
http://www.rr.ualberta.ca/en/Research/ClimateChange/ClimateDataforAlberta.aspx

Provides data and a download tool that gives users access to climate data that can be used to estimate more than 50 monthly, seasonal, and annual variables for any point location in Alberta.

**Climate Projections for Southern Alberta (All One Sky Foundation)**
http://allonesky.ca/wp-content/uploads/2013/10/Climate-projections-Southern-Alberta_slides-only.pdf

PDF of a slide show by Dr. Mel Reasoner delivered at AOSF's municipal climate resilience workshop in southern Alberta showing climate change projections in science-based but clear visual terms.

**Computerized Tool for the Development of Intensity-Duration-Frequency-Curves under Climate Change**
http://www.idf-cc-uwo.ca

Online tool that helps municipalities explore plausible future rainfall scenarios under a changing climate regime.

**From Impacts to Adaptation: Canada in a Changing Climate**
http://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/reports/assessments/2008/10253

A comprehensive consideration of the vulnerabilities, risks, opportunities, and adaptive capacity in Canada, divided by major region (the Prairies section covers most of Alberta).

**Guidelines for Canadian Recreational Water Quality**
http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/guide_water-2012-guide_eau/index-eng.php

Health Canada's guidelines for recreational water quality, including management practices, public awareness, and pathogenic concerns.

**Prairie Adaptation Research Collaborative (PARC)**
http://www.parc.ca

A multi-government research collaborative based at the University of Regina pursuing climate change impacts and adaptation research in the prairies. Activities and available resources include climate scenario modeling, vulnerability of grasslands research, and an academic research library. Their *Climate Change and Water in the South Saskatchewan River Basin* project is assessing current and future sensitivity of regional socio-economic systems to changes in water supply in the Basin (SSRB).

**Pacific Climate Impacts Consortium – PCIC (University of Victoria)**
http://www.pacificclimate.org

Web site of BC-based climate research institute, featuring numerous data and analysis tools. Includes the Plan2Adapt tool which creates summary outputs of various climate projection scenarios, available for a number of regional breakdowns, providing broadly-applicable descriptions of anticipated climate change impacts.

**Prairies Regional Adaptation Collaborative**
http://www.parc.ca/rac/

A tri-provincial collaborative of Alberta, Saskatchewan and Manitoba government agencies seeking to inform better climate-resilient decision making. Most information is at a regional scale versus local community scale, but still several valuable context-setting resources.

**Provincial Groundwater Inventory Program (Alberta Geological Survey)**
http://www.ags.gov.ab.ca/groundwater/groundwater-inventory.html

Web site of the slow-moving province-wide effort to map groundwater resources to support land use decision making.

**Real time hydrometric data**
http://wateroffice.ec.gc.ca/index_e.html

Website providing public access to Environment Canada's real-time hydrometric data collected at over 1800 locations and access to historical data collected at over 7600 stations (active and discontinued) in Canada.

**Soil Erosion Risk for the Agricultural Area of Alberta**
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex10340#Potential

Agricultural Land Resource Atlas' (Alberta Agriculture and Rural Development) soil erosion risk map and methodology.

**Toward a Resilient Watershed: Addressing Climate Change Planning in Watershed Assessments**
http://www.theresourceinnovationgroup.org/storage/watershed-guide/Watershed%20Guidebook%20final%20LR.pdf

A practical, but technical guide to incorporating climate change considerations into watershed monitoring and assessment.

**Vulnerability of Prairie Grasslands to Climate Change**
http://www.parc.ca/rac/fileManagement/upload/12855-2E11%20Vulnerability%20of%20Grasslands%20to%20climate%20change.pdf

A technical, but thorough consideration of the impacts of climate change on the prairies, particularly with reference to grassland production, drought, biodiversity, rangelands and croplands.

## Ecosystem-based Adaptation

**Draft Principles and Guidelines for Integrating Ecosystem-based Approaches to Adaptation in Project and Policy Design**
http://cmsdata.iucn.org/downloads/draft_guidelines_eba_final_7_12.pdf

A relatively high-level description of how Ecosystem-based Adaptation can be integrated into applied projects and the policy context within which they sit, including several practical guidelines and principles.

**Ecosystem-Based Adaptation Guidance: Moving from Principles to Practice**
http://www.unep.org/climatechange/adaptation/Portals/133/documents/Ecosystem-Based Adaptation/Decision Support Framework/EBA Guidance_WORKING DOCUMENT 30032012.pdf

A more academic consideration of Ecosystem-based Adaptation, but with a clear intent to inform the transition from principles to application.

**Ecosystem-based Adaptation: A natural response to climate change**
https://portals.iucn.org/library/efiles/documents/2009-049.pdf

A short readable primer on Ecosystem-based Adaptation, providing a practical description, augmented by several applied examples from developed and developing countries.

**Making the Case for Ecosystem-based Adaptation: Building Resilience to Climate Change**
http://www.ebaflagship.org/images/ContentsForPublications/eba policy brochure web.pdf

A concise description of what Ecosystem-based Adaptation is, showing the connection to ecosystem services and biodiversity in a comprehensive but succinct way.

**The Social Dimension of Ecosystem-based Adaptation**
http://www.unep.org/ecosystemmanagement/Portals/7/Documents/policy_series_12-small_Nov_2013.pdf

A short introduction to integrating social considerations into an Ecosystem-based Adaptation approach, including green economy, food security, livelihoods, gender, and land use conflicts.

## Biodiversity

**Alberta's Natural Subregions under a Changing Climate (ABMI)**
http://www.biodiversityandclimate.abmi.ca/docs/Schneider_2013_AlbertaNaturalSubregionsUnderaChangingClimate.pdf

A data-based and visual report on how Alberta's natural regions are – and will continue to – shifting as a result of climate change, and the implications of that for how we manage biodiversity in the province.

**Alberta Riparian Habitat Management Society (Cows and Fish)**
http://www.cowsandfish.org

More commonly known as 'Cows and Fish', the Alberta Riparian Habitat Management Society works to improve management of riparian areas, and does assessments of riparian health, and provides information about riparian management.

**Biodiversity Management and Climate Change Adaptation Project (ABMI)**
http://www.biodiversityandclimate.abmi.ca

Web page of the Alberta Biodiversity Monitoring Institute's *Biodiversity Management and Climate Change Adaptation* Project, mother project to the Resilience-based Adaptation for Local Communities (RALC) project which produce the *Adapt-action* Tool.

**Cities and Biodiversity Case Study Series: Canadian Best Practices in Local Biodiversity Management (ICLEI)**
http://www.icleicanada.org/images/icleicanada/pdfs/Cities_and_Biodiversity_Case_Study_Series_english.pdf

A collection of case studies highlighting municipal best practices in urban biodiversity management and protection, created as a learning tool for local governments.

**Climate Change Adaptation and Biodiversity (ACT)**
http://act-adapt.org/biodiversity/

A BC-focused report that looks at high-level impacts to biodiversity under a changing climate, and their adaptive capacity; because of its structure it is very applicable to Alberta.

**Climate Change and Biodiversity (IPCC)**
https://www.ipcc.ch/pdf/technical-papers/climate-changes-biodiversity-en.pdf

The International Panel on Climate Change's (IPCC) quite-readable technical paper on how a changing climate – and the things we do in response to it – are likely to affect biodiversity.

**Climate Change Vulnerability of Alberta's Terrestrial Biodiversity: A Preliminary Assessment (ABMI)**
http://www.biodiversityandclimate.abmi.ca/docs/ShankandNixon_2014_ClimateChangeVulnerabilityofAlbertasTerrestrialBiodiversity_ABMI.pdf

The results of an assessment of over 200 species representative of Alberta's biodiversity, and their vulnerability to projected changes in climate.

**Ecosystem Services Approach Pilot on Wetlands: Integrated Assessment Report**
http://environment.gov.ab.ca/info/library/8493.pdf

The summary report of a collaborative effort to develop and operationalization an ecosystem services based approach to conserving wetlands within the regulatory approvals process for residential subdivision development in southern Alberta.

**The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States (US Climate Change Science Program)**
http://www.usda.gov/oce/climate_change/SAP4_3/CCSPFinalReport.pdf

As the name implies, a comprehensive summary of effects at a national level (and thus applicable across the continent) of climate change with a sound scientific basis, but accessible framing and language.

**Exploring Climate Change Adaptation and Biodiversity (ICLEI)**
http://www.icleicanada.org/images/icleicanada/pdfs/Nexus_Series_Adaptation_Biodiversity_Final_sm.pdf

A brief fact sheet looking at how municipal climate resilience strategies can dovetail with municipal biodiversity conservation strategies.

**ICLEI Canada's Municipal Biodiversity Program**
http://www.icleicanada.org/programs/biodiversity

LCLEI's (Local Governments for Sustainability) program aims to empower the local level with what they need to integrate biodiversity management into their sustainability planning, focused on awareness-raising, networking, and resource Development

**Impacts of Climate Change on Biodiversity, Ecosystems, and Ecosystem Services: Technical Input to the 2013 National Climate Assessment**
http://downloads.globalchange.gov/nca/technical_inputs/Biodiversity-Ecosystems-and-Ecosystem-Services-Technical-Input.pdf

A surprisingly-readable comprehensive, technical summary of the impacts climate change is expected to have on biodiversity and ecosystem services, and why that matters.

**Predicting New Invasive Plant Threats to Alberta**
http://www.biodiversityandclimate.abmi.ca/docs/Chai_etal_2014_PredictingInvasivePlantResponsetoClimateChangeinAlberta_ABMI.pdf

An assessment of 16 invasive plants that may not yet be on the horizon for management in Alberta, but which may become issues for southern Alberta as their ranges move due to climate change.

**Provincial Wetland Restoration Guide**
http://www.waterforlife.alberta.ca/01533.html

Alberta Environment and Sustainable Resource Development's (AESRD) Water for Life website that gives direction for wetland restoration and compensation, including information on wetland restoration agency status, for which municipalities are eligible.

**Rare Grasslands Birds and Extreme Weather**
http://www.biodiversityandclimate.abmi.ca/docs/FisherandBayne_2013_ProtectingRareGrasslandBirdsFromExtremeWeatherEvents.pdf

An assessment of the vulnerability of Burrowing Owl and Ferruginous Hawks to the sorts of extreme weather events that are expected to increase with the increasing change in climate.

**Riparian Area in Calgary (City of Calgary)**
http://www.calgary.ca/UEP/Water/Pages/Watersheds-and-rivers/Riverbanks-and-Floodplains-in-Calgary.aspx

The website of the City of Calgary's Riparian Strategy, which contains a framework that provides direction for the protection, restoration and management of riparian ecosystems within Calgary's watersheds.

## Human Health

**Climate Change and Health Portal (New Zealand)**
http://haifa.esr.cri.nz

Includes a number of on line tools that can assist municipalities in framing their vulnerability assessments, including a water supply vulnerability assessment and environmental health indicators.

**Climate Change and Public Health**
http://www.phac-aspc.gc.ca/hp-ps/eph-esp/fs-fi-a-eng.php

A web site by the Public Health Agency of Canada that provides information on the potential human health impacts of a changing climate regime, highlighting the differences between regions, the related health risks, and resources for protecting yourself.

**Climate Change and Health & Well-Being: A Policy Primer**
http://publications.gc.ca/collections/Collection/H46-2-01-260E.pdf

A dated, but still valuable primer on the human-health vulnerabilities related to a changing climate regime, how they can be managed, and a list of adaptation measures.

**Enhancing Health Care Resilience for a Changing Climate**
http://toolkit.climate.gov/sites/default/files/SCRHCFI%20Best%20Practices%20Report%20final2%202014%20Web.pdf

The goal of this toolkit is to assist health care providers, design professionals, policymakers, and others with roles and responsibilities in assuring the continuity of quality health and human care before, during and after extreme weather events.

**Primary Protection: Enhancing Health Care Resilience for a Changing Climate**
http://toolkit.climate.gov/sites/default/files/SCRHCFI%20Best%20Practices%20Report%20final2%202014%20Web.pdf

A toolkit aimed at supporting a local assessment of the health-related infrastructure on which a community relies to determine its vulnerability due to climate change and the potential adaptation approaches that may be taken.

**Protecting health from climate change - World Health Organization**
http://www.who.int/world-health-day/toolkit/report_web.pdf

A summary of the human health issues associated with climate change, developed with the belief that creating a greater appreciation of the human health dimensions of climate change is necessary for both the development of effective policy and the mobilization of public engagement.

**Regional Climate Dialogues**
http://www.phac-aspc.gc.ca/hp-ps/eph-esp/rccd-dccr-eng.php

The Public Health Agency of Canada has convened regional dialogues aimed at raising awareness and local adaptive capacity for the health risks associated with climate change.

## Flood Mitigation

**Adaptive Land use for Flood Alleviation (ALFA)**
http://alfa-project.eu/en

Web site of a multi-partner project in Belgium, France ,Germany, United Kingdom and The Netherlands that works to increase the capacity of their rivers for storing and conveying water.

**Alberta Flood ReLeaf**
https://treecanada.ca/en/programs/operation-releaf/

The Alberta Urban Forest ReLeaf program, in partnership with TELUS, provides funding to homeowners, private landowners and municipalities to replace trees on private or municipal land that have been severely damaged by the 2013 flooding 2014 snow storm.

**Best Practices for Reducing the Risk of Future Damage to Homes from Riverine and Urban Flooding**
http://www.iclr.org/images/Alberta_flood_risk_2013_PDF.pdf

A report from the Institute for Catastrophic Loss Reduction based on lessons learned from the 2013 floods in southern Alberta.

**Calgary River Flood Mitigation Program**
http://www.calgary.ca/UEP/Water/Pages/Flooding-and-sewer-back-ups/Flood-Mitigation-Panel/Flood-panel.aspx

Web site of the Calgary River Flood Mitigation Program, including links to their flood preparation site for residents, and to the expert panel's report on the 2013 flood.

**Calgary's Flood Resilient Future: Report from the Expert Management Panel on River Flood Mitigation**
http://www.calgary.ca/UEP/Water/Documents/Water-Documents/Flood-Panel-Documents/Expert-Management-Panel-Report-to-Council.PDF

As part of their effort to learn from the 2013 floods, the City of Calgary convened an arms-length body of experts to bring current knowledge into the flood mitigation issues and responses discussions. The report presents the Panel's recommendations for making Calgary more resilient and prepared for future events.

**City of Calgary Flood Mapping**
http://www.calgary.ca/General/flood-preparation/Pages/Understand/02-Maptypes.aspx

The City of Calgary flood mapping site includes flood hazard maps, inundation maps, river valley maps, and new river modeling.

**Conservation Authority (Ontario) Flood Management Library**
http://www.conservation-ontario.on.ca/library?view=category&id=56

A library of local flood management resources from the Ontario conservation authorities (set up in the 1950s in response to widespread flooding in the province).

**District of Squamish Integrated Flood Hazard Management Plan**
http://www.squamish.ca/yourgovernment/projects-and-initiatives/floodhazard/

The District of Squamish's (BC) new Integrated Flood Hazard Management Plan (IFHMP) is intended to guide development and land use in Squamish, incorporating the latest flood management guidelines, new engineering modeling tools and techniques, and best planning practices.

**Flood Hazard Identification / Mapping / Studies (Alberta Environment and Sustainable Resource Development)**
http://esrd.alberta.ca/water/programs-and-services/flood-hazard-identification-program/default.aspx

The website of Flood Hazard Identification Program (FHIP), which provides Draft Flood Hazard Studies, Flood Hazard Mapping, and Flood Hazard Studies.

**Flood Mitigation Methods (Alberta Water Portal)**
http://albertawater.com/flood-mitigation/

The Alberta Water Portal's flood mitigation methods page includes descriptions of community scale infrastructure, natural, and policy mitigation methods used to address flooding.

**Flood Risk Management Plans (UK)**
https://www.gov.uk/flood-risk-management-plans-what-they-are-and-whos-responsible-for-them

An example from the UK with specifics that are not applicable, but contains good direction on what a municipal Flood Risk Management Plan should contain.

**Floods in Boulder: A Study of Resilience**
http://i-s-e-t.org/resources/case-studies/floods-in-boulder.html

An analysis of the flooding in Boulder, Colorado in 2013, drawing lessons learned from a consideration of physical systems, human systems, and legal and cultural norms.

**Lower Mainland Flood Management Strategy**
http://www.fraserbasin.bc.ca/_Library/Media/backgrounder_lmfls.pdf

The Lower Mainland Flood Management Strategy focuses on communities along the lower Fraser River and coast, and seeks to identify opportunities to strengthen flood management policies and practices as well as flood protection works across the Lower Mainland of BC.

**Room for the River**
http://www.ruimtevoorderivier.nl/english/

A program in the Netherlands operating at more than 30 locations which is designed to give the river more natural space to flood, using measures intended to improve the quality of the immediate surroundings.

**Stepping Back from the Water: A Beneficial Management Practices Guide for New Development Near Water Bodies in Alberta's Settled Region**
http://environment.gov.ab.ca/info/library/8554.pdf

This AESRD document provides decision makers with information for determining setback widths and designing effective buffers adjacent to water bodies, and contains information on riparian areas, recommended setbacks, conservation measures, relevant legislation, and case samples.

## Agriculture

**Agricultural Decision Matrix Tool for Beaver Management**
http://www.cowsandfish.org/pdfs/Beaver-Matrix-FINAL.pdf

A decision tool for agricultural landowners regarding management of beavers, created by the Cows and Fish organization.

**Agricultural Land Resource Atlas of Alberta - Surface Water Quality Risk for the Agricultural Area of Alberta**
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex10338

A map-based assessment of surface water quality risk for the agricultural area of Alberta.

**Agricultural Moisture Situation Updates**
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/ppe9917

Government of Alberta site provides Agricultural Moisture Situation Updates, developed by their drought modelling team and published frequently as appropriate during the growing season and less frequently during winter months.

**AgroClimatic Information Service (Government of Alberta)**
http://www.agriculture.alberta.ca/acis/

An interactive web tool maintained by Alberta Agriculture and Rural Development that displays Alberta's weather forecasts; contains over 10000 maps of Alberta weather and climate-related information, and real time station data from over 350 meteorological stations operating in the province of Alberta.

**Analysis of EG&S Policy Options Fostering Adaptation of Canadian Farmers to Climate Change and Development of a Decision-making Tool.**
http://capi-icpa.ca/pdfs/2011/CAPI_EG&S_English_final.pdf

Excellent resource that presents the broad concept of ecosystem services as a vehicle for agricultural producers to address climate change; covers the concepts of monitoring, BMPs, and policy change.

**BC Agriculture Climate Change Action Plan 2010-2013**
http://www.bcagclimateaction.ca/wp/wp-content/media/BC-Agriculture-Climate-Change-Action-Plan.pdf

A joint project of the BC Agriculture Council and the Investment Agriculture Foundation intended to increase industry understanding of the implications of climate change, address issues, strengthen networks, and share resources. The Action Plan is its primary deliverable.

**Climate-Smart Agriculture (CSA)**
http://www.fao.org/climate-smart-agriculture/en/

An information site on Climate Smart Agriculture prepared by the Food and Agriculture Organization (FAO) of the UN, describing the concept, providing several downloadable publications, nd profiling several applications around the world.

**Conservation Agriculture**
http://www.fao.org/ag/ca/1a.html

An information page on Conservation Agriculture prepared by the Food and Agriculture Organization (FAO) of the UN, describing the concept, providing the supporting rationales, and giving several examples.

**Drought Management Decision Support Resources**
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/ppe1111

Government of Alberta site Includes a number of drought management decision support tools for all seasons, as well as a drought management checklist.

**Drought Science and Indices**
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag5779?opendocument

Government of Alberta site created to educate the agricultural industry about the costs and benefits of planning for and managing drought risk. Includes database of references to scientific literature, government documents, web sites, and expertise that describes the technical, environmental and economic aspects of drought.

**Large-scale implementation of adaptation and mitigation actions in agriculture**
http://ccafs.cgiar.org/publications/large-scale-implementation-adaptation-and-mitigation-actions-agriculture#.VFFn8Idx8ag

A summary report of 16 cases of larger, regional scale actions in agriculture aimed at responding to climate change; includes lessons learned.

**Options for Alberta Producers During Dry Conditions**
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/dis12713

Government of Alberta site provides information and tools on business management and production issues surrounding managing a farm during dry conditions.

**Organizing Local Food Events**
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex14043

Alberta Agriculture and Rural Development's Explore Local Initiative created this guide to organizing a local food event, including challenges, tips, and sample formats.

## Infrastructure

**Adaptive Approaches in Stormwater Management Plan (City of Ottawa)**
http://documents.ottawa.ca/en/node/6048

The City of Ottawa's stormwater management plan including a framework for considering stormwater management adaptation, stormwater infrastructure assessments, and sample tools and approaches from case studies.

**Adaptation to the Impacts of Climate Change on Transportation (National Academy of Engineering)**
https://www.nae.edu/Publications/Bridge/24514/24525.aspx

A collection of papers by the National Academy of Engineering focused specifically on adapting infrastructure to the impacts of climate change; key papers focus on transportation, and risk management.

**Alberta Fire Smart**
http://wildfire.alberta.ca/fire-smart/default.aspx

The web site for the FireSmart program in Alberta, including guides for homeowners, communities and industry, as well as information regarding grants and partnerships; FireSmart uses preventative measures to reduce wildfire threat to Albertans and their communities while balancing the benefits of wildfire on the landscape.

**Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide**
http://www.asla.org/contentdetail.aspx?id=31301

A well-supported, and readable consideration of the economic advantages of using green infrastructure for purposes such as flood management.

**Beaver and Climate Change Adaptation in North America: A Simple, Cost-Effective Strategy**
http://www.wildearthguardians.org/site/DocServer/Beaver_and_Climate_Change_Final.pdf?docID=3482

As the name says, an experience-based examination of how beavers can provide a cost-effective approach to climate resiliency.

**Beaver As a Climate Change Adaptation Tool: Concepts and Priority Sites in New Mexico**
http://static1.squarespace.com/static/54c6efebe4b05d1a1cc71a3f/t/54d3a9c4e4b04682afea3b39/1423157700638/Beaver+As+a+Climate+Change+Adaptation+Tool+-+Concepts+and+Priority+Sites+in+New+Mexico.pdf

An exploration of beaver as a climate change adaptation tool, looking at how specific ecosystem modifications resulting from beaver presence can address climate change threats.

**City of Castlegar – Stormwater Infrastructure Climate Change Vulnerability Assessment**
http://www.pievc.ca/e/casedocs/castlegar/Castlegar-StormwaterInfrastructureReport.pdf

A stormwater infrastructure appraisal that directly incorporates climate change assumptions into the vulnerability assessment, showing the protocols, infrastructure types, and climate data used.

**Climate Change Adaptation and Canadian Infrastructure**
http://www.iisd.org/pdf/2013/adaptation_can_infrastructure.pdf

A thorough but brief overview of the potential impacts to infrastructure in Canada, with practical lists that can inform municipal risk assessments and scenario building.

**Climate Change and Infrastructure, Urban Systems, and Vulnerabilities: Technical Report for the US Department of Energy in Support of the National Climate Assessment**
http://www.esd.ornl.gov/eess/Infrastructure.pdf

A comprehensive, and integrated, guide to municipal infrastructure vulnerability analysis in the face of a changing climate;

**Comprehensive Stormwater Management Master Plan Guidelines:**
http://www.lsrca.on.ca/pdf/reports/swm_master_plan_guidelines.pdf

Guidelines for the development and implementation of comprehensive stormwater management master plans in the lake Simcoe watershed.

**Ecological Infrastructure in the Calgary Region: What We Now Know**
http://www.rockies.ca/files/reports/Ecological Infrastructure in the Calgary Region - What we know now.pdf

A report by University of Calgary researchers on their assessment of the ecological infrastructure of importance in the Calgary region.

**EPA – Climate Change Adaptation - Transportation**
http://www.epa.gov/climatechange/impacts-adaptation/transportation-adaptation.html

Web site that deals with transportation-related aspects of climate change, with several specific examples of adaptation activities that been undertake in the US.

**Green Infrastructure in Calgary's Mobility Corridors**
http://www.dcs.sala.ubc.ca/docs/calgary_green_infrastructure_mobility_corridors_sec.pdf

Integrated with Plan It Calgary, this research developed principles and strategies for maximizing environmental benefits in Calgary's mobility corridors, focusing on facets that have typically harmful impacts, and proposing green infrastructure strategies that – among other things – can promote climate resiliency.

**How Will Climate Change Affect Civil Infrastructure**
http://www.toolkit.bc.ca/Program/FCM-Workshop-How-Will-Climate-Change-Affect-Civil-Infrastructure-Canadian-Municipalities%3F

Website of the FCM's (Federation of Canadian Municipalities) workshop on risk assessment for municipal infrastructure, including all of the presentations on protocols and case studies.

**Impacts of Climate Change on Stormwater Management (Town of Stratford)**
http://atlanticadaptation.ca/sites/discoveryspace.upei.ca.acasa/files/Final%20Report_Stratford%20SWM_Impacts%20of%20Climate%20Change.pdf

An assessment by the Town of Stratford, PEI, of their stormwater infrastructure, and plan to manage for it in the face of climate change.

**Innovative Stormwater Management Practices**
http://www.iswm.ca/

An online database of innovative and low impact development stormwater management practices in Ontario, from an organization established for this purpose.

**Innovative Stormwater Management: Translating Science Into Actions**
http://www.cwn-rce.ca/assets/resources/pdf/CWN-EN-Stormwater-Report-FINAL.pdf

A short fact sheet on potential stormwater management techniques at different spatial scales, all of which contribute to climate resiliency.

**Integrated Stormwater Management Plans: Lessons Learned to 2011 (Metro Vancouver)**
http://www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/ISMP_Lessons_Learned-April_2012.pdf

A study that gathered and documented the "lessons learned" by member municipalities (in Metro Vancouver) who had created Integrated Stormwater Management Plans.

**Leave it to Beavers (Miistakis Institute)**
http://www.rockies.ca/beavers/index.php

The website of a citizen science project examining the reintroduction of beavers as a watershed stewardship tool at the Ann & Sandy Cross Conservation Area (ASCCA) in southern Alberta.

**Managing Municipal Infrastructure in a Changing Climate**
http://www.municipalnl.ca/userfiles/files/DEC-00306-Infrastructure%20Workbook%20(Web-Email%20Quality).pdf

Municipalities Newfoundland and Labrador created this simple workbook for doing a municipal infrastructure assessment; though the issues in coastal Newfoundland are different, the structure of the workbook makes an excellent template for any community.

**Public Infrastructure Engineering Vulnerability Committee - PIEVC (Engineers Canada)**
http://www.pievc.ca/

A portal of infrastructure vulnerability information, including links to case studies and consultant contacts.

**Reduce Impervious Surfaces – Vermont Green Infrastructure Initiative**

A fact sheet from the Vermont government that provides several practical examples of how municipalities can promote the reduction of impervious surfaces.

**Reduce Impervious Surfaces (CRD)**
https://www.crd.bc.ca/education/our-environment/concerns/impervious-surfaces

A web site of the Capital Region District in British Columbia that outlines the challenges with impervious surfaces, and several practical techniques usable at the planning and individual levels.

**Resilient Design Principles (Resilient Design Institute)**
http://www.resilientdesign.org/the-resilient-design-principles/

A series of simple design principles that can be applied in the built environment to ensure that buildings and structures are more resilient to the variety and intensity of negative impacts resulting from a change climate.

**Riparia, Ltd.**
http://riparia.ca/portfolio-1/

Portfolio of Calgary-based landscape architecture firm Riparia, including southern Alberta examples of stream restoration, sustainable urban drainage, an wetland design

**The Beaver Solution: The Lands Council**
http://www.landscouncil.org/beaversolution/

A readable web-based primer on how beavers can be deployed to build climate resiliency, using the example of initiatives in Washington State, USA.

## Cases

**Boston Groundwater Conservation Overlay District**
http://www.bostongroundwater.org/groundwater-conservation-overlay-district-gcod.html

A description of the novel planning technique used in Boston to assure that construction projects do not cause reductions in groundwater, and also to recharge groundwater with storm-water.

**Building Climate Resiliency in the Lower Willamette Region of Western Oregon**
http://www.theresourceinnovationgroup.org/building-climate-resiliency/

An excellent example of an ecosystem-based adaptation approach to climate resiliency, from assessment to action, including companion reports that are summarized for decision makers.

**California Water Plan Update, Recharge Areas Protection**
http://www.waterplan.water.ca.gov/docs/cwpu2005/vol2/v2ch15.pdf

A description of the California's water recharge area protection efforts, including keeping groundwater recharge areas from being paved over or otherwise developed and guarding the recharge areas so they do not become contaminated.

**City of Leduc Weather and Climate Readiness Plan**
http://www.leduc.ca/Assets/Departments/Environmental+Services/Weather+and+Climate+Readiness+Plan.pdf

The City of Leduc's assessment of their most pressing weather-related issues, and their plan to become more resilient to those threats.

**City of Prince George, BC**
http://www.retooling.ca/prince_george.html

A case study of the City of Prince George's climate resiliency efforts, including their climate change projections, impacts, strategies and potential adaptation actions.

**City of Red Deer Climate Change Adaptation Plan**
http://www.reddeer.ca/media/reddeerca/city-services/environment-and-conservation/our-corporate-initiatives/Council-Climate-Change-Adaptation-Plan-March-4-2014.pdf

Part One of the Plan contains overall goals, anticipated climate change impacts, and broad groupings/themes of response actions; Part Two is currently being developed and will provide detailed actions under each major theme.

**City of Windsor Climate Change Adaptation Plan**
http://www.citywindsor.ca/residents/environment/environmental-master-plan/documents/windsor climate change adaptation plan.pdf

The City of Windsor's climate change adaptation plan focuses on identified risks related to Increased operating/maintenance demands, chance of flooding, severe storm response, and development policies which were not climate-change-sensitive.

**Climate Adaptations in the Methow Valley (Video)**
https://vimeo.com/98496024

A concise, high-quality video from the Methow Beaver Project in Washington, USA showcasing the role of beavers in improving water storage in headwater creeks in the face of a changing climate regime.

**Climate Wisconsin (Video)**
http://climatewisconsin.org/

Web site for an educational multimedia project featuring high-quality video stories of climate change impacts in Wisconsin, USA, from fly fishing to phenology to sugaring to great lakes shipping.

**County of Lethbridge Integrated Community Sustainability Plan**
http://www.lethcounty.ca/home/showdocument?id=256

The County of Lethbridge's Sustainability Plan which includes numerous climate resiliency strategies, only some of which are labeled as such.

**District of Saanich, BC**
http://www.retooling.ca/district_saanich.html

The District of Saanich's 2011 climate change adaptation plan addresses impacts in 10 key sectors, and lists actions that residents, businesses and municipal operations can take.

**Halifax Regional Municipality, Climate Smart**
http://www.halifax.ca/climate/

The web site of the Halifax Regional Municipality's Cliamte Smart program, including background reports and studies, as well as guides for community action, economic implications, and risk management.

**King County Strategic Climate Action Plan 2012**
http://your.kingcounty.gov/dnrp/climate/documents/2012_King_County_Strategic_Climate_Action_Plan.pdf

Comprehensive climate action plan of King County, Washington, USA

**Lacombe County Environmental Management Plan**
http://www.lacombecounty.com/index.php/news-releases/2014/916-lacombe-county-environmental-management-plan

Lacombe County's Environmental Management Plan includes many strategies that promote climate resilience, whether under that banner or not.

**Methow Valley Beaver Project (Methow Conservancy)**
http://www.methowconservancy.org/beaver_project.html

The website of the Methow Beaver Project, a collaborative initiative working to improve water quantity and quality using 'nature's wetland engineers' in Washington State, USA.

**Missoula County Climate Change Planning**
http://headwaterseconomics.org/land/reports/climate-change-adaptation-in-missoula-county

Website for the various background reports and action plan documents prepared for Missoula County by Headwaters Economics, the Geos Institute and the Clark Fork Coalition to assist the municipality's efforts to become more climate resilient.

**Missoula County Climate Change Planning (Wildfire)**
http://headwaterseconomics.org/land/reports/climate-change-adaptation-in-missoula-county

A detailed and practical consideration of wildlife as a climate change vulnerability in a rural municipality.

**Portage County, WI, Groundwater Protection Overlay District**
http://www.epa.gov/safewater/sourcewater/pubs/techguide_ord_wi_portage_gwp.pdf

The full text of the Groundwater Protection Overlay District ordinance from Portage County, Wisconsin, created to protect key groundwater recharge areas by imposing appropriate land use restrictions in these areas.

**Preparing for a Changing Climate: Washington State's Integrated Climate response Strategy**
http://www.ecy.wa.gov/climatechange/ipa_responsestrategy.htm

An excellent and comprehensive vision and plan for a state-level response to climate change with reference to many of the same issues Alberta is facing, including projections, issue assessment/strategies, and decision making considerations.

# Final Words

How Did This Tool Come About?

The *Adapt-action* online tool was the result of a three-year research project into how local communities could better adapt to a changing climate regime.

The overarching project - the *Biodiversity Management and Climate Change Adaptation* project - was created by the Alberta Biodiversity Monitoring Institute to develop essential knowledge and tools to support the management of Alberta's biodiversity in a changing climate.

The Miistakis Institute was asked to lead the *Resilience-based Adaptation for Local Communities* sub-project, with a goal of supporting Alberta communities to better understand climate-related risks and adaptations in the context of ecosystem services and biodiversity.

The ultimate result was the creation of the *Adapt-action* tool. It was developed with the support of numerous municipalities, individuals, and agencies who vetted concepts, wrote content, provided data, tested usability, and gave critical feedback on both the background research and the *Adapt-action* tool.

For those interested, all of the background research reports are available on the *Biodiversity Management and Climate Change Adaptation* website: www.biodiversityandclimate.abmi.ca

## Disclaimer

- The creators of the Adapt-action tool (the Miistakis Institute) have been diligent in acquiring the most accurate information possible, and attributing the information to its sources. However, we cannot guarantee the accuracy of any of the information included in the *Adapt-action* online tool.

- Many of the suggested strategies require specialized knowledge to undertake, and users of the *Adapt-action* tool should sure to determine where that specialized knowledge is required and seek to acquire it.

## Final Words

- No part of this tool or the information contained within it should be taken as legal advice or warrantied technical advice. Before pursuing any course of action based on the information in the *Adapt-action* tool, users should secure the legal and technical expertise needed.

- Though the creators of the *Adapt-action* tool will seek to maintain the information contained herein in as current a form as possible, information may be out of date.

- The Alberta Biodiversity Monitoring Institute (ABMI), as the lead of the *Biodiversity Management and Climate Change Adaptation* project, assumes no liability in connection with the Adapt-action tool and disclaims any liability in negligence or otherwise for any loss or damage which may occur as a result of reliance on the Adapt-action tool

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