Adapting to Flooding

An *Adapt-action* Summary Report

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Adapting to Floods

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

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Adapt-action

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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 Floods**' 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 Flooding

Flooding is not a new phenomenon to Alberta, but the floods of 2013 represented a significant ramping up of the potential risk for Alberta municipalities. The flood levels were historic, and not surprisingly, the cost of damage was unprecedented. Insured losses were $1.7 billion in southern Alberta, with damage to City of Calgary infrastructure of $445 million, and another $55 million in emergency response costs (Calgary's Flood Resilient Future: Report from the Expert Management Panel on River Flood Mitigation

Climate change projections indicate that extreme storm events, and variability in flow rates will increase (meaning increased droughts and floods are likely in our future). Flooding - both repeated small events and 1:100+ year events - have a tremendous impact on Alberta communities, including effects on infrastructure, agriculture, human health, recreation and biodiversity.

The good news is that municipalities, and the communities they represent, can do a lot to prepare and become more flood-resilient in face of a changing climate regime. This requires understanding the local implications and undertaking targeted strategies and actions. Many Alberta municipalities are already taking action.

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

Weather causes major flood events, not climate. However, climate variability makes it difficult to predict the timing and intensity of these individual events. A changing climate regime, as we are projected to have due to global warming, would increase that variability, very likely leading to increases in the severity and unpredictability of flooding.

The result of this change in climate 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

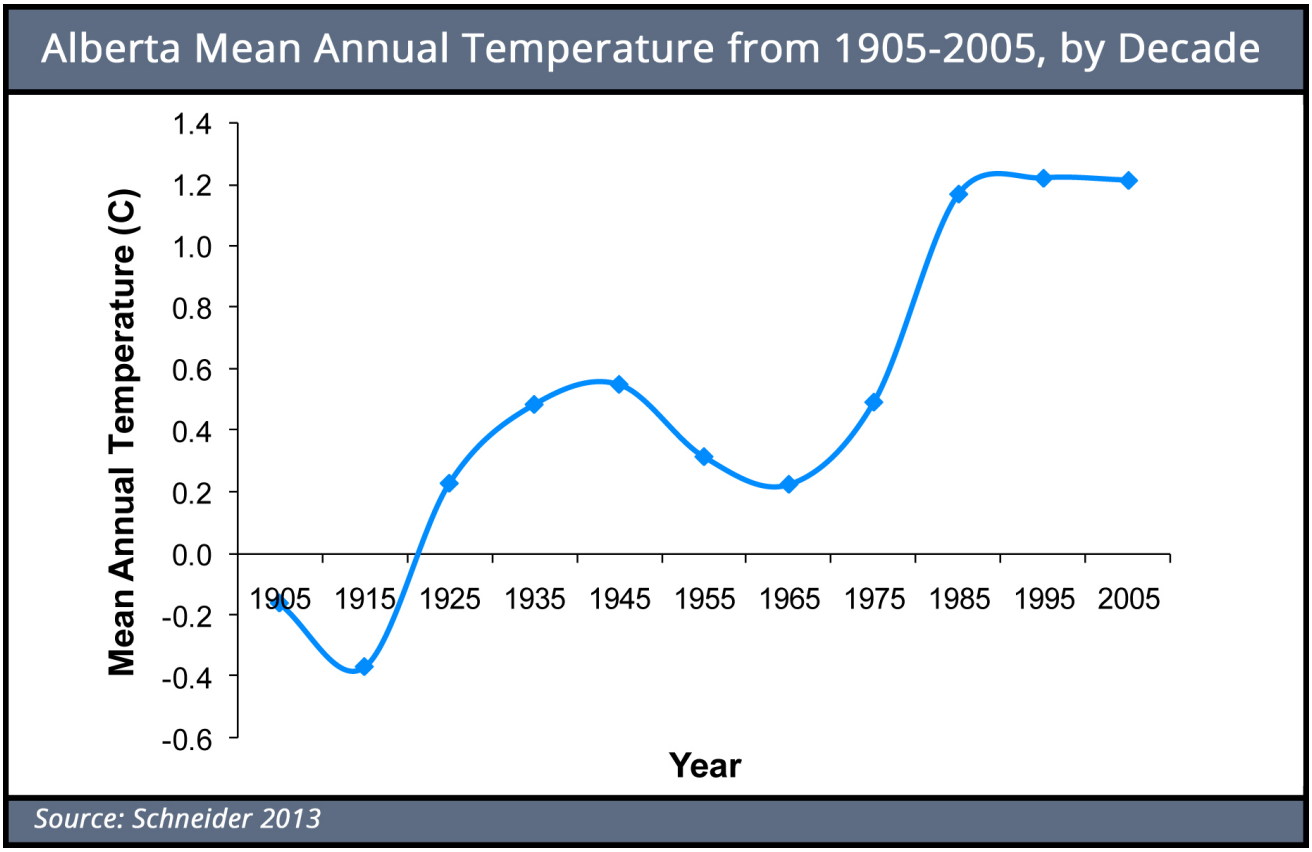
	Current	A2 Scenario	B1 Scenario
Variable - Average Annual			
Temp (°C)	4.0 °C	+ 4.8 °C	+ 2.8 °C
Precipitation (mm)	371.6 mm	+21.8 mm	+16.2 mm
Variable - Average Seasonal			
Mean Temp Coldest Month (°C)	-11.7 °C	+ 4.5 °C	+ 3.3 °C
Mean Temp Warmest Month (°C)	17.8 °C	+5.3 °C	+3.1 °C
Growing Degree Days	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, seasonal decreases in stream flow, changes in stream flow timing, and increased extreme storm events. Although overall decreases in available water are expected, overall precipitation is expected to increase, where less arrives in the summer months, but disproportionately more in the other months, with expected increases in localized flood events.

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

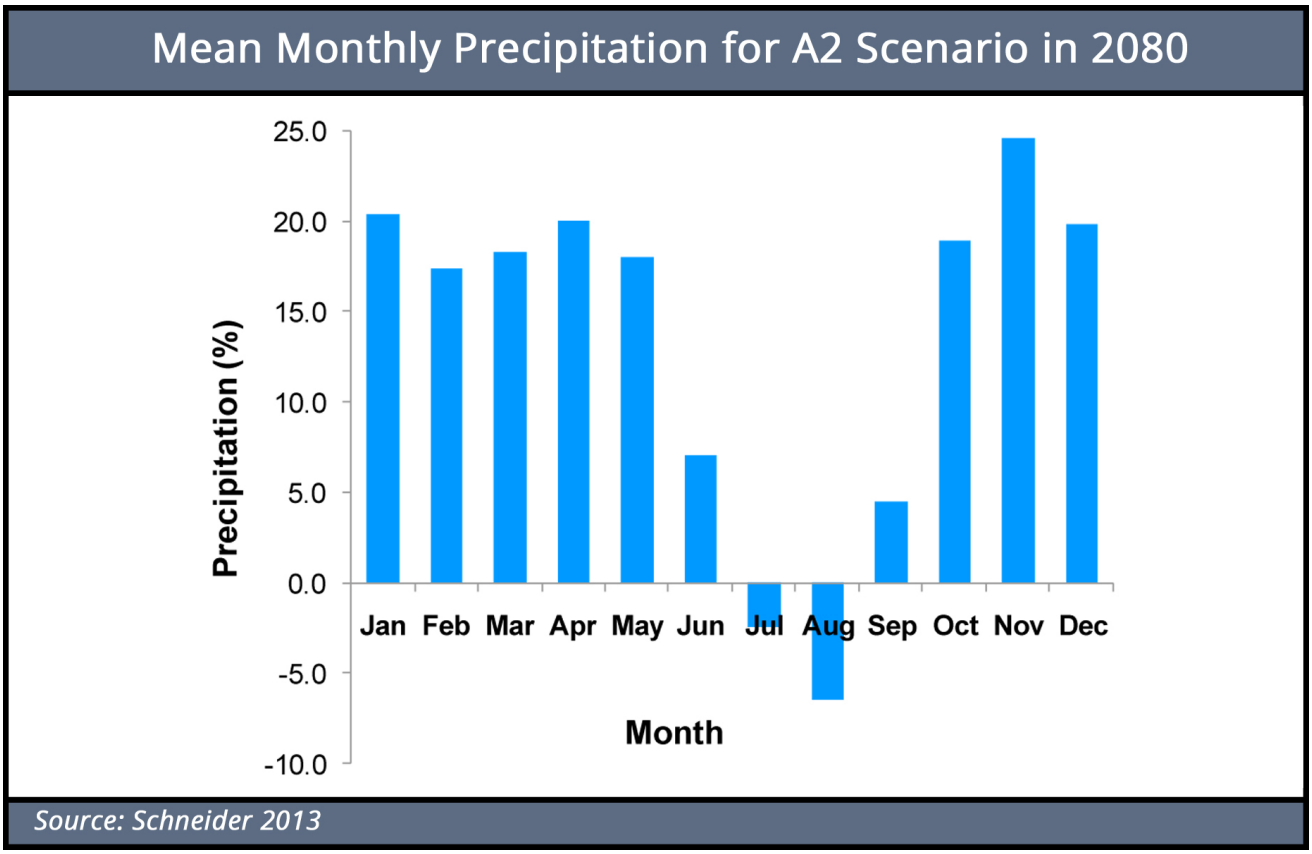
Schneider, Richard. 2013. Alberta Natural Subregions Under a Changing Climate: Past, Present and Future. University of Alberta: Prepared for the Biodiversity Management and Climate Change Adaptation Project.

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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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

Impacts to crop yield (and cropping systems)

How does climate change affect crop yield?

The impact that floods have on agriculture depends on the timing of the flood and the severity of the flood. Predictions for an increase in extreme precipitation events could contribute to an increase in flooding and predictions for rapid snowmelt could compound this risk in the spring. Floods in the spring can lead to late seeding and thus late harvest. Short-lived floods that are relatively shallow, may cause some localized impacts to crop yield but typically don't impact the long-term yields of the land. Total loss of crops typically only occurs with extreme flooding events that have deeper water left standing on the land for extended time, a week or more. When there are re-occurring flood events in the same year, this magnifies the impacts and larger losses can be expected.

Floods that occur in the early spring, prior to seeding, can delay seeding but may cause little to no impact on crop production. In 2013 extreme flooding of the Bow and Elbow rivers occurred prior to seeding. Agricultural yields that year remained average to above average in the region. The floods occurred early enough in the season and when the summer brought adequate sun and wind to dry out the fields, the crop yields were able to "catch up" to production averages (Agriculture & Agri-Food Canada, 2014). Negative impacts of flooding also depend on the soil's ability to absorb or withstand excess soil moisture. This is a result of many factors including type of crop, soil saturation and duration of flooding. Wet spring conditions can cause shallow root systems because of lack of oxygen in the soil. This can impact the ultimate growth of a crop. This water logging of soil due to high water tables and/or flooding stresses plants and can delay harvesting when machinery is unable to operate.

Underlying Environmental Changes

Precipitation
Glacier area
Wetlands

WHY ARE WE CONCERNED?

Flooding may cause loss in crop production. In 2011 the Prairies saw 5.3 million hectares that didn't produce crops because of spring flooding and excessive moisture early in the season, which prevented seeding and caused drowning of some already seeded areas (Agriculture & Agri-Food Canada 2012).

In addition to late seed and delayed harvest, wet soil can cause root rot, and asphyxiation. Wet soil and flooded fields can cause problems for harvesting and quality of crops. Wet soil can present less opportunity to apply pesticides and thus decrease the quality. Crops that cannot be harvested can spoil and cause problems for subsequent seeding including increased pesticide use and increased cultivation costs.

Ultimately lower yields create a higher per unit cost on farmers, decreased revenues and could eventually lead to higher food prices in the long term. A 2010 flood in Fraser Valley caused $30 million in damage to food crops; predictions for a similar event in the future indicate that value could be higher due to predicted increases in price (ACT 2013).

What we can we do about it?

Strategies to prevent crop loss and damage during flooding has to do with restoring land uses to allow natural flood buffers to act. Early spring floods don't necessarily cause extensive damage to agricultural yield as long as the absorptive capacity of the landscape is intact. Poor irrigation management following floods can increase negative impacts, which is easily avoidable. Specific strategies include:

Update Sustainability Plans
Update Municipal Development Plan
Create climate-ready land use zones
Promote stormwater capture
Economic scenario planning
Create flood management plans
Beaver reintroduction
Wetland/recharge protection
Constructed wetlands
Identify important wetlands
Develop State of Watershed
Know ecological infrastructure
Map drought, flood, and recharge areas
Understand projected changes in water
Calculate water storage capability
Understand headwaters impacts
Raise awareness of ag issue/options
Assess at-risk infrastructure
Built infrastructure scenarios
Low-risk infrastructure siting
Abandon marginal infrastructure
Minimize floodplain development

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Livestock health may be impacted by decreased water quality

How does climate change affect livestock?

Livestock health depends on climatic conditions and climate change could bring different precipitation regimes, higher temperatures and create flooding from early snowmelt. This can impact livestock through decreased food supplies, contaminated water and increased incidence of disease. Flooding can impact food supplies when floodwaters run through urban areas and bring debris to pastures. This can also contaminate water supplies when it becomes unsuitable for drinking. Lack of food and water can decrease growth rates, especially in younger animals (ADAS 2007).

Wet conditions can increase vulnerability to diseases. Stress as well as favorable conditions for disease growth contributes to increased incident rates. Damp conditions contribute to growth of undesirable bacteria and parasites such as liver fluke and foot rot (ADAS 2007). Flooding conditions can create ideal conditions for parasite growth leading to increased populations. Liver fluke requires shallow water for growth and is therefore more abundant in wet conditions impacting livestock performance and liver functions (Ominski 2014). Anthrax spores in the soil can also come to the surface in floods and infect livestock.

Underlying Environmental Changes

- Temperature
- Precipitation
- Glacier area

Why are we concerned?

When flooding washes away hay and silage this results in costs to farmers for additional feed or pasture to supplement losses. Water contamination can also result in additional costs as well as time for animals to reach market weight. Loss of livestock due to drowning or disease is a direct loss to farmers. The 2013 floods caused livestock fatalities in localized areas and resulted in high associated insurance claims (Agriculture and Agri-Food Canada 2014).

What we can we do about it?

Emergency planning and information sessions to help farmers plan for flooding and how to prevent disease outbreaks can contribute to mitigating these impacts. Specific strategies include:

- Create climate-ready land use zones
- Coordinate with Watershed Mgmt Plans
- Economic scenario planning
- Create flood management plans
- Beaver reintroduction
- Wetland/recharge protection
- Constructed wetlands
- Retain native riparian vegetation
- Map drought, flood, and recharge areas
- Identify water quality risks
- Understand projected changes in water
- Understand headwaters impacts
- Raise awareness of ag issue/options
- Promote natural Infrastructure
- Climate proof culverts
- Reduce waterway channelization
- Minimize floodplain development
- Create flood buffers

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Damage to infrastructure impacts agricultural operations and businesses

How does climate change affect agricultural infrastructure?
Climate change models predict an increase in flood frequency and intensity due to increasing temperature, precipitation events and melting glaciers, and may cause damage to agricultural infrastructure, potentially impacting homes, storage buildings, wells, irrigation and other farm equipment. Damage to public infrastructure around farms such as roads and wastewater treatment plants also impact farm operations. Key impacts from the 2013 Alberta floods included damage to agricultural operations and businesses (ESRD 2014).

Underlying Environmental Changes

- Temperature
- Precipitation
- Glacier area

Why are we concerned?

If a flood impacts roads, bridges, power plants, irrigation systems, or farming equipment it can lead to an economic standstill causing dysfunction of normal life for a period much beyond the duration of the flooding.

Damage to personal agricultural equipment, especially if the equipment is non-functioning can result in lost time and production to the producers. Damaged equipment can delay time sensitive operations and reduce crop yields. In addition, repairs or replacement of equipment may be costly. Also after a flooding event, monitoring wells and drinking water on rural properties is an issue. If damaged, areas could be without clean water until repairs and treatment can be completed.

Damage from 2011 Alberta floods had an impact on farm operations. One of the biggest problems was impassable or washed out roads. This can cause rural residents to be trapped in their homes, unable to reach other resources until floodwaters recede and repairs are made.

Road closures and washed out bridges also make it difficult or impossible to access field or pasture. This causes difficulty moving equipment and attending to livestock. If livestock cannot be reached they risk starvation. Sometimes this requires finding alternate routes to access livestock. Other times, flooded pastures require moving livestock to dry land.

Flooded pastures and feed supplies could result in significantly decreased food available for livestock potentially leading to health problems or starvation. Flooding can also increase the risk of waterborne diseases in livestock. In the most extreme cases livestock are susceptible to drowning.

Irrigation infrastructure can also be damaged in floods. After floods, it is important to monitor equipment for ruptures and any damage that could cause leaks. All engines and moving parts should be thoroughly cleaned and lubricated before use. More significantly, flooding can damage the canals and reservoirs that feed irrigation systems. This could impact the available water to many farms if canals, reservoirs, and pipes from the canals are damaged due to floods. Most reservoirs are built to collect floodwaters so it is important they are properly maintained. Also a concern is contaminated water entering irrigation systems, which could have negative impacts on crops and soil health.

What can we do about it?

Consider flood plains when building agricultural infrastructure and where equipment is stored. Maintain roads and bridges.

Create climate-ready land use zones
Coordinate with Watershed Mgmt Plans

Emergency scenario planning
Economic scenario planning
Create flood management plans
Beaver reintroduction
Wetland/recharge protection
Constructed wetlands
Maximize infiltration
Identify important wetlands
Develop State of Watershed
Map drought, flood, and recharge areas
Understand projected changes in water
Understand headwaters impacts
Raise awareness of ag issue/options
Assess at-risk infrastructure
Built infrastructure scenarios
Low-risk infrastructure siting
Adapt infrastructure for climate change
Abandon marginal infrastructure
Promote natural infrastructure
Climate proof culverts
Minimize floodplain development
Implement flood-resilience standards
Create flood buffers

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RESOURCES:

Water Infrastructure Damage (Alberta 2011 floods) http://alberta.ca/Water-Infrastructure-Damage.cfm

Contaminants found in groundwater http://water.usgs.gov/edu/groundwater-contaminants.html
Farming after the flood https://www.soils.org/files/science-policy/caucus/briefings/farming-after-flood.pdf

Disease of Soybean https://www.extension.purdue.edu/extmedia/BP/BP-58-W.pdf

Flood Damaged Farm Equipment http://texashelp.tamu.edu/005-agriculture/machinery-and-equipment.php http://www.tractorlife.com/how-to-recondition-flood-damaged-farm-equipment/ http://content.ces.ncsu.edu/livestock-and-poultry-buildings-after-the-flood/

Pastureland may become unfit for grazing

How does climate change affect grazing?

Climate change predictions include increased extreme events, variability in stream flow and periods of high soil moisture leading to increased incidents of flooding. The impact of flooding on pastures depends on the severity and duration of the flood. Concerns for pastures include contamination or loss of pastureland. In areas where floodwaters inundate pasturelands for 5 or more days, grass die back can occur and cause problems for feed supply later in the season (ADAS 2007). When floodwaters are contaminated with rubbish or sediment that settles on the pasture this can cause pastureland to be unfit for grazing. Farmers may have to wait for new growth, for debris, oil and soil to be washed away, or have to clean the land themselves when urban run off brings litter. Flooding can also create favorable conditions for weeds and put pressure on pastures, making them vulnerable to disease (Irmak 2014). Flooding can cause stunted growth, making way for weeds to persist.

<u>Underlying Environmental Changes</u>

Precipitation
Available moisture
Stream flow

Why are we concerned?

When hay, silage and grass become inundated they may be washed away or be unfit for consumption. When pasture damage is severe enough to cause food shortages for farmers, this can result in additional costs as they may be required to bring in additional feed or relocate livestock. In 2011, the flood on the prairies put up to 30% of pasture underwater in heavily impacted areas. Livestock had to be relocated to rented pastures due to impassable roads and lack of feed. Farmers saw impacts on livestock growth rate with lighter calves and cattle than usual (Agriculture and Agri-Food Canada 2012).

What we can we do about it?

- Create climate-ready land use zones
- Coordinate with Watershed Mgmt Plans
- Economic scenario planning
- Create flood management plans
- Beaver reintroduction
- Wetland/recharge protection
- Develop State of Watershed
- Map drought, flood, and recharge areas
- Identify water quality risks
- Understand projected changes in water
- Understand headwaters impacts
- Raise awareness of ag issue/options
- Promote natural infrastructure
- Climate proof culverts
- Reduce waterway channelization
- Minimize floodplain development
- Create flood buffers

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Soils may be subjected to erosion, nutrient leaching and changes in salinity

How does climate change affect soils?

Although flooding is a natural process, climate change predictions foresee more extreme precipitation events, rapid snowmelt and increased flooding events. Changes in stream flow, such as faster flow and increased volume can erode soils away from adjacent land in the floodplain. When there is excessive soil moisture and large precipitation events leading to overland flooding, waters can leach nutrients from the soil and leave gullies in fields where soil was eroded away. Water logged soils can also create areas of salinization, which can impact plant growth in those localized areas (Agriculture and Agri-Food Canada 2007).

Underlying Environmental Changes

- Precipitation
- Available moisture
- Growing degree days
- Stream flow

Why are we concerned?

The erosion of soils can mean the disappearance of pesticides, herbicides and important nutrients such as nitrogen and phosphorous, away from agricultural lands. Farmers may have to compensate with additional application of fertilizers to avoid decreased yields. Pesticides may also leach from the soil into groundwater, which can impact the quality of well water as well as creating the need for additional pesticides. Soils that are flooded for

prolonged periods can lose beneficial fungi, which aid plants in accessing nutrients in the soil, this is called flooded soil syndrome. When this occurs landowners may need to stimulate microbial activity with cover crops or other strategies (Farming After the Flood).

Excess sediment that is present in water can settle in drainage systems or further downstream. In cases where sediment clogs on-farm drainage or when erosion coming from lands upstream settles silt and debris on the land, farmers will incur increased costs and labour for clean-up.

What we can we do about it?

Erosion occurs less in well vegetated areas with good riparian buffers. Cover crops help to prevent soil leaching and fungi loss. These and other good land management practices can help act to prevent severe impacts. Specific strategies include:

- Coordinate with Watershed Mgmt Plans
- Economic scenario planning
- Create flood management plans
- Beaver reintroduction
- Wetland/recharge protection
- Constructed wetlands
- 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
- Understand headwaters impacts
- Raise awareness of ag issue/options
- Promote natural infrastructure

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Water quality may decrease impacting livestock production and irrigation

How does climate change affect water quality?

Climate change models predict an increase in flood frequency and intensity due to increasing temperature, precipitation events and melting glaciers, which amplifies soil erosion and silt in waterways. Along with other pollutants, river chemistry will change leading to significant implications on water quality and species composition (IPCC 2002). Samples of flooded waterways found that physical, chemical and microbiological contaminants in high flow conditions exceeded guidelines for protection of agriculture involving irrigation and livestock watering (ESRD 2014).

Underlying Environmental Changes

- Temperature
- Precipitation
- Glacier area

Why are we concerned?

Intense flooding can cause large amounts of overland runoff and soil erosion, which adds high levels of pollutants into the waterways. This occurred during the Alberta floods of 2013. Contaminants of primary concern were microbiological and came from many sources including human sewage, livestock manure, fuel from flooded vehicles, leakage from facilities storing fuel, pesticides, fertilizers and industrial chemicals (ESRD 2014).

Water testing following the 2013 Alberta floods also identified high concentrations of total dissolved solids. This includes inorganic salts, calcium, magnesium, cations,

carbonate, bicarbonate, chlorides, sulphate, and nitrate anions. High levels of these salts effect irrigation by changing soil permeability and can be toxic to crops (ESRD 2014). This is most concerning if there is long term exposure, as most areas will recover from instantaneous exceedances of total dissolved solids. In healthy systems the high levels of total dissolved solids will dissipate within a few weeks.

Agricultural operations both impact and are impacted by water contamination levels. Fertilizers, pesticides and manure are significant causes of water contamination. In particular nitrogen and phosphorus cause toxic algae blooms and high biotic growth in aquatic plants. There is also higher risk of E. coli contamination from manure following high runoff periods. Once contaminated, the water may not be useable for livestock and irrigation until treated. In a healthy system, concentrations of contaminants are shown to decrease within a few weeks of the flooding event.

Water quality has a significant impact on livestock health. An Agricultural and Agri-food study found that yearlings will gain 23% more weight and calves and cows gain 9% more weight with access to clean drinking water. Cattle are healthier and more productive with clean water (Fitch 2003, P.27).

What can we do about it?

Maintaining water quality prior to flooding will help. Considering runoff and proper storage and placement of manure will reduce contaminants. Maintaining healthy wetlands and riparian zones will filter water and reduce contamination level. The healthy riparian zones will filter and trap sediments, preventing huge amounts of contaminants to flow downstream and filtering the water into useful sediments (Fitch 2003).

- Create climate-ready land use zones
- Coordinate with Watershed Mgmt Plans
- Economic scenario planning
- Create flood management plans
- Retain native riparian vegetation
- Maximize infiltration
- Identify important wetlands
- Know ecological infrastructure
- Map drought, flood, and recharge areas
- Identify water quality risks
- Understand projected changes in water
- Raise awareness of ag issue/options

Low-risk infrastructure siting
Promote natural infrastructure
Reduce waterway channelization
Minimize floodplain development
Create flood buffers

REFERENCES

Alberta Environment and Sustainable Resources Development (ESRD). 2014. Flood Recovery Detailed Ambient Water Quality Report. Accessed February 2015 from: http://esrd.alberta.ca/focus/esrd-2013-flood-recovery-programs/documents/FR-DetailedAmbientWaterReport-May01-2014A.pdf

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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).

Disruption of health services

How does climate change affect health services?

Climate change will bring about extreme weather events, such as flooding, that can act to interrupt health services, creating health implications for people. During and immediately after flooding events, infrastructure and transportation may be limited. When bridges are main arteries connecting communities, transportation may be cut off due to structural stability of bridges. The inability to use roads or bridges may impact the delivery of emergency services and ability of first responders to access those in need. Power outages due to damage to power networks can interrupt services at health care facilities. Floods may also act to increase the pressure on health systems due to increased risk of waterborne illnesses, vector borne illnesses, acute injuries and trauma, respiratory illness and communicable disease outbreaks.

Underlying Environmental Changes

- Temperature
- Precipitation
- Stream flow

Why are we concerned?

Health systems under stress may reduce capacity for treatment of other ailments and 'normal' health care activity (Kricun et al 2013). There may be a disruption in outpatient, inpatient and home health services. Disruption may occur due to infrastructure damage, closures and evacuation orders that cut off pharmacies and healthcare facilities. This could limit access to medication and treatments for individuals in need. Supply shortages may also occur if transportation closures prevent access to communities or facilities in need of deliveries of medication or equipment.

WHAT WE CAN WE DO ABOUT IT?

- Update Sustainability Plans
- Update Municipal Development Plan
- Create climate-ready land use zones
- Emergency scenario planning
- Map drought, flood, and recharge areas
- Monitor waterway flows
- Assess at-risk infrastructure
- Built infrastructure scenarios
- Low-risk infrastructure siting
- Climate proof culverts
- Minimize floodplain development
- Implement flood-resilience standards
- Ensure developments consider climate change
- Create flood buffers

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Increased risk of chemical exposure from leaching, ruptured chemical infrastructure

HOW DOES CLIMATE CHANGE AFFECT CHEMICAL EXPOSURE?

Increased incident of flooding, extreme precipitation and excessive soil moisture may rupture chemical storage infrastructure and lead to chemical pollution. Intense rainfall can cause chemical leaching from the environment, mobilizing pesticides, heavy metals, waste and/or herbicides into the water supply. Whereas saturated soils and flooding can

rupture underground storage tanks for chemicals such as fuel, causing leaks and spills. Increased concentrations of chemicals in floodwater or groundwater, can expose populations to chemical poisoning with greater risk to populations in close proximity to chemical sources.

Underlying Environmental Changes

- Precipitation
- Available moisture

WHY ARE WE CONCERNED?

Chemicals in a contaminated water supply can leach into soil and air, increasing potential for impacts to health. Overflow of toxic waste sites or ruptured fuel tanks can lead to chemical fires, which pose a threat via air and water. High concentrations of chemicals in drinking water can lead to headaches, fever, nausea and other symptoms of chemical ingestion. Pollution can be acute or chronic, potentially having symptoms persisting beyond immediate concerns. An additional chemical threat comes from the use of generators and poor ventilation during times of power outages and energy service disruption. Poor ventilation or generators can lead to carbon monoxide poisoning.

WHAT WE CAN WE DO ABOUT IT?

- Update Municipal Development Plan
- Emergency scenario planning
- Create flood management plans
- Climate proof drainage plans
- 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
- Minimize floodplain development
- Implement flood-resilience standards
- Ensure developments consider climate change
- Create flood buffers

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Increased risk of vector-borne diseases

How does climate change affect vector borne illnesses?

An increase in severity and frequency of flooding due to increases in precipitation and melting events may indirectly impact disease carrying vector populations leading to an increase in incidents of disease outbreaks. Vector-borne diseases are infectious agents (such as viruses, bacteria and parasites) that an animal can carry and pass on to other animals. Disease carriers are called "vectors," and include mosquitoes, ticks and mammals. Flooding events create small stagnant pools of water and increase surface water, which creates ideal breeding grounds for vectors like mosquitos. Increased temperatures can alter life cycles of pathogens and hosts and create enhanced conditions for vector propagation. This could correspond to in an increase in mosquito borne diseases such as West Nile Virus, and Eastern and Western Encephalitis (Warren 2004).

Changes in climatic conditions increases the risk of the emergence of new vector borne illnesses from entering areas not previously impacted. In the Red River Valley in 1975 following a severe flooding event there was an outbreak of western equine encephalitis, a disease not normally found in Canada, but that succeeded due to climatic conditions post flood (Charron et al 2005).

Flooding can also increase the incidence of rodent-borne illnesses by changing patterns of exposure between humans and rodents. Increased interaction between rodents, their fleas and their feces and humans can increase potential for diseases such as hantavirus. When flooding eliminates habitat for vector populations, such as rodents, it can force vectors into close contact with humans.

Underlying Environmental Changes

- Temperature
- Precipitation
- Glacier area

WHY ARE WE CONCERNED?

Increased transmission of vector borne illnesses puts populations' health at risk, especially those in vulnerable populations. West Nile, hantavirus and other vector borne illnesses can be mild or in rare cases can lead to severe life threatening symptoms. Often, 70-80% of cases, West Nile virus results in no symptoms. However, for those in vulnerable populations, infection can lead to mild symptoms such as fever and body aches or in rare cases severe symptoms such as meningitis or encephalitis (Public Health Agency of Canada 2014). Outbreaks of disease can also put stress on health systems, when not prepared. Western health care systems do have treatment for many vector-borne diseases which can act to prevent the spread of new diseases as well as prevent outbreaks of existing.

WHAT CAN WE DO ABOUT IT?

Preparation, education and planning can help to prevent outbreaks. Specific strategies include:

- Emergency scenario planning
- Create flood management plans
- Climate proof drainage plans
- Map drought, flood, and recharge areas
- Identify water quality risks
- Understand projected changes in water
- Use climate-adjusted IDF curves
- Built infrastructure scenarios
- Climate proof culverts

Minimize floodplain development

RESOURCES:

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Health risks associated with living in post flood conditions

HOW DOES CLIMATE CHANGE AFFECT LIVING CONDITIONS POST FLOOD?

Increases in flooding and increased precipitation can impact homes and buildings, creating damp environments and leading to microbial growth that can lead to adverse health effects. Flooding and precipitation cause buildings and their contents to become damp. Without proper cleaning and drying out, this creates ideal conditions for the growth of moulds, mildews and bacteria. Moulds can cause respiratory ailments, allergic reactions and irritation from inhaling spores. Skin rashes and congestion are also common. Exposure to bacteria can lead to illness including gastrointestinal problems.

Underlying Environmental Changes

Precipitation
Available moisture

Why are we concerned?

Respiratory problems resulting from living in damp buildings can result in wheezing, coughing, irritation, congestion and difficulty breathing. For vulnerable populations, including elderly people, children, and people with existing conditions such as asthma, even low exposure to mould can cause these symptoms, increasing in severity with increased exposure. Fungal infections can result from routine exposure. These impacts could be exacerbated as floods can also cause disruption to health services.

Evacuation of inundated or condemned homes to shelters can also cause concentration of illnesses in a crowded place. This can lead to increased transmission of communicable diseases, such as influenza or gastrointestinal viruses/pathogens. Conditions and crowded volumes increase risks of localized outbreaks (Kricun et al 2013). In addition, evacuation and condemned homes can results in anxiety, depression and other mental health issues.

What can we do about it?

Post flood living conditions can create fewer health impacts as long as there is proper cleaning and drying of flooded homes, and proper hygiene and sanitation occurs at evacuation shelters. Specific strategies could include:

Update Sustainability Plans
Emergency scenario planning
Create flood management plans
Identify water quality risks
Understand projected changes in water
Assess at-risk infrastructure
Built infrastructure scenarios
Minimize floodplain development
Implement flood-resilience standards
Ensure developments consider climate change
Create flood buffers

REFERENCES:

Ahern, M., Kovats, R.S., Wilkinson, P., Few, R. & Matthies, F. 2005. Global Health Impacts of Floods: Epidemiologic Evidence. Epidemiologic Reviews 27: 36-46

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Mental health impacts to communities

HOW DOES CLIMATE CHANGE AND FLOODING AFFECT MENTAL HEALTH?

Climate change forecasts an increase in large precipitation events, variability in stream flow, rapid spring melt and as a result more frequent flooding events. Flooding events can cause distress for people living in flood affected communities. Increases in flooding events may have links to increases in psychosocial impacts associated with loss and displacement associated with floods. Studies on flood affected communities in Bristol and Brisbane showed an increase in anxiety, depression and sleeplessness in post flood areas compared to unaffected areas (Ahern et al 2005). The psychological impacts from losing homes, personal loss, displacement, evacuation and other secondary stressors can cause long term mental health problems. Loss of homes can also create economic hardship and increase stress. Post-traumatic stress disorder has also been reported in some instances.

<u>Underlying Environmental Changes</u>

Precipitation
Stream flow
Glacier area

WHY ARE WE CONCERNED?

The mental health of families and community members can impact wellbeing, relationships and health. This can exacerbate existing mental problems, and also put a stress on health systems if they are not in place. After the Alberta floods of 2013, Albertans in affected areas sought out additional access to mental health services. This included a significant increase in calls to crisis lines, increase in anxiety and depression in school children and increase in prescriptions for mental health drugs (Alberta Government 2013). Mental health problems may have the most serious impact on longer time scales, and without adequate support in the long term can cause greater impacts for families and communities.

WHAT WE CAN WE DO ABOUT IT?

Update Municipal Development Plan
Emergency scenario planning
Create flood management plans
Retain native riparian vegetation
Minimize floodplain development

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Increased risk of injury, trauma and drowning

How does climate change affect injuries, trauma and mortality?

Flash floods and flooding brought on by heavy rainfall, early snowmelt and excessive soil moisture brought on by climate change, may lead to injury and in worse case, mortality. Acute injuries can happen during flooding when fast moving and rising water interact with people and leave them injured. Debris caught in floodwaters, deep water and risky behavior can all contribute to the severity of injuries. Floodwater is typically colder than body temperature and prolonged exposure can lead to hypothermia. In worst-case and rare scenarios, flooding can lead to mortalities.

Flood clean up can also be hazardous due to the nature of debris left behind. People can be subject to electrocutions, lacerations and other injuries. Sewer ruptures and back flow can also expose people to illness and infection (through exposed wounds, injuries). In most cases injuries come from misjudgment of water flow, depth or degree of hazard (Public Health Agency 2013). In floods with slower onset, most injuries and deaths are preventable through evacuations and preventative measures. Flash floods are more risky for mortality and severe injury.

Underlying Environmental Changes

- Precipitation
- Available moisture
- Glacier area

Why are we concerned?

Acute injuries, especially severe ones may be prolonged due to health service interruption during floods. If roads or bridges are compromised then access to health services may be disrupted. Although mortalities are usually prevented due to preventative measures, absence of warnings can increase risks. Injury and mortality can be traumatic for individuals, families and communities. They can cause psychosocial impacts and create mental health impacts on communities (Stanke et al 2012).

What can we do about it?

Injuries and mortalities can be prevented with advance warnings, information and emergency planning. Specific strategies include:

- Recreation scenario planning

Emergency scenario planning
Economic scenario planning
Create flood management plans
Climate proof drainage plans
Constructed wetlands
Map drought, flood, and recharge areas
Understand projected changes in water
Use climate-adjusted IDF curves
Built infrastructure scenarios
Adapt infrastructure for climate change
Climate proof culverts
Minimize floodplain development
Implement flood-resilience standards
Create flood buffers

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Impacts on surface water and risk of waterborne illness

How does climate change affect surface water?

Climate change projections for extreme rainfall events and shifts in streamflow leading to increased flooding may have negative implications for potable water. Without proper awareness and treatment this could mean impacts on human health. High flow and faster water increase turbidity of streams causing contaminants and run-off to be incorporated in water bodies. Heavy rainfall can also change flow of run-off into areas outside normal patterns, such as agricultural fields. Run-off from urban and agricultural wastes can contaminate water, and make it unsuitable for drinking, recreation or irrigation. Contamination includes feacal contaminants from agricultural wastes or sewer backup, chemical run-off and other organic wastes.

When combined with higher temperatures, which are expected with climate change, the risk of outbreaks of viral, bacterial and parasitic water borne illnesses increases (Hunter 2003). This can include giardia, cryptosporidiosis, and other gastrointestinal illnesses (Warren 2004). Transmission of waterborne diseases can occur through drinking contaminated water, contact with water, or recreational use of water.

Underlying Environmental Changes

- Temperature
- Precipitation
- Stream flow

Why are we concerned?

Heavy rainfall events are associated with an increase in bacterial counts in river water and storm water run off (Hunter 2003). Without proper treatment this poses risks to people that come into contact with the water. However, large amount of dissolved solids in water during flooding makes water treatment facilities less effective and during heavy flooding water treatment facilities may be totally compromised. During the 2013 flood in Southern AB, the Bonnybrook water treatment facility was inundated and flushing untreated waste into the Bow River. This lead to increased levels of fecal coliforms and other pathogens downstream and rendered water unsuitable for use for 2-3 weeks (AB Gov 2014).

Elevated contaminant levels can lead to boil water advisories and other health precautions including limiting recreational access to water bodies and bans on using water for gardening or irrigating certain crops. During the 2013 flood in Southern Alberta, resulted in boil water advisories for: Canmore, Black Diamond, Siksika First Nation, Exshaw, Lake Louise, High River, Harvie Heights, MD of Big Horn and Kananaskis. Exposure to untreated water can lead to outbreaks of diseases through drinking water, or recreational water with faecal or other contamination. After the flooding in High River in 2013, high levels of a dangerous E. Coli strain were found in the soil in residence backyards as well as 5 bodies of water in the town. Exposure to contaminated water can also lead to wound infections, ear/nose/throat infections and conjunctivitis. Generally, waterborne illnesses are most serious for vulnerable populations.

What can we do about it?

Proper preparation in the form of emergency planning and awareness can help to reduce impacts from waterborne illnesses. Specific strategies include:

- Emergency scenario planning
- Create flood management plans
- Climate proof drainage plans
- Map drought, flood, and recharge areas
- Identify water quality risks
- Understand projected changes in water
- Use climate-adjusted IDF curves
- Built infrastructure scenarios
- Climate proof culverts
- Minimize floodplain development

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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.

Disruption to fishing activities due to temporary decrease in fish populations

How does climate change affect fish populations?

An increase in extreme weather events such as heavy precipitation, can lead to the flooding of rivers and streams. Following a flood, fish populations can be reduced by up to 30-60% (Kirn 2011). With stable conditions in the following years, populations are able to grow and become stable again. For this to happen the overall quality and diversity of the ecosystem needs to remain intact.

Impacts to fish populations from flooding include the relocation of fish to different environments, reshaped streambeds, levels of sedimentation harmful to fish populations, and loss of spawning and nesting ground.

The timing, extent and magnitude of flooding will determine the seriousness of impact to fish populations. It is possible for fish populations to come back within a year of flooding events if there are healthy habitat conditions in place to allow the remaining populations to reproduce. Should healthy habitats not exist it could take decades for streambeds to reestablish a healthy water flow for fish populations.

Underlying Environmental Changes

- Precipitation
- Stream flow

WHY ARE WE CONCERNED?

Immediately after a flood fishing activities will be negatively affected. The drop in fish populations will make it more difficult to find fish. When water levels are still high it could also be dangerous to enter common fishing areas. Also with such dramatic drops in the fish populations, it could require restrictions on fishing until the populations recover.

Long term effects of reshaped streambeds, water levels and loss of spawning ground could alter the type of fish in certain areas as well as the number. Some popular fishing areas could be too damaged and anglers will have to find new locations.

WHAT CAN WE DO ABOUT IT?

Coordinate with Watershed Mgmt Plans
Recreation scenario planning
Beaver reintroduction
Wetland/recharge protection
Retain native riparian vegetation
Identify important wetlands
Develop State of Watershed
Know ecological infrastructure
Map drought, flood, and recharge areas
Identify valuable water-affected habitat
Identify water quality risks
Understand projected changes in water
Understand headwaters impacts
Promote natural infrastructure
Reduce waterway channelization
Create flood buffers

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Damage of Recreational Infrastructure

How does climate change affect recreational infrastructure?

Predictions for future climate condition under climate change include increase in frequency of flooding. More extreme rainfall events and rapidly melting snow pack in the spring can damage recreation areas and infrastructure. Outdoor recreation infrastructure such as hiking trails, campgrounds, parks, golf courses, pathways and bridges that are in close proximity to water bodies and/or in the floodplain stand to be impacted during floods.

Infrastructure can be washed out by fast moving water, damaged beyond use or end up littered with debris from floodwaters. The 2013 flooding event in Alberta destroyed 170 km of pathways and trails, some beyond repair, and damaged 60 day use areas and 50 campgrounds in Alberta parks (Alberta Government 2014). It also washed out city pathways adjacent to rivers, took out multiple pedestrian bridges and deposited debris in Calgary city parks. The Kananaskis golf course saw damage to all holes except for 4. Indoor recreation complexes can also be impacted when located in the floodplain and extreme flooding occurs. In 2013, during the large flooding event, the Talisman Centre in Calgary suffered $3 million in repair costs due to flood damage (CBC News 2014). The floods also damaged major highways, which are used to access recreation areas, including the Trans-Canada highway near Banff.

Underlying Environmental Changes

- Precipitation
- Stream flow
- Glacier area

Why are we concerned?

The damage to infrastructure, from roads and trails to golf courses can be extensive and takes time and money to repair. This process can take years. From the 2013 floods in Alberta it is estimated costs will be over $80 million over 4 years to repair the trails,

roads, signs, visitor areas, campgrounds and bridges. Countless volunteer hours will also be needed for repairs.

The damaged infrastructure could result in closures of areas, damaged aesthetics, reduced size of recreational areas and the amenities they offer. Full recovery of recreational infrastructure damage from the Alberta 2013 flood was predicted to take up to 3 years (Alberta Government 2014). This can have negative impacts on other associated industries, such as tourism. For activities such as hiking and biking trails, safety and rout finding can be more difficult due to flood damage. When many bridges are washed away, many trails and the extent to which they can be used is also compromised.

What can we do about it?

In order to prevent impacts to recreation infrastructure, planning for flooding events during the design process may act to mitigate damages. Specific strategies include:

- Update Sustainability Plans
- Coordinate with Watershed Mgmt Plans
- Recreation scenario planning
- Economic scenario planning
- Create flood management plans
- Climate proof drainage plans
- Impervious surface reduction
- Map drought, flood, and recharge areas
- Understand projected changes in water
- Assess at-risk infrastructure
- Adapt infrastructure for climate change
- Minimize floodplain development
- Implement flood-resilience standards

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Closure of recreation areas

How does climate change affect recreation areas?

Climate change will increase the frequency and intensity of flooding events. Many recreation activities take place on, in or near water: canoeing, rafting, kayaking, swimming, and fishing. Many other recreation areas are built in watersheds such as campgrounds and picnic areas. Significant increases in water levels can have impact the safety of these activities and infrastructure, often resulting in closures until water levels recede or until infrastructure is repaired.

Underlying Environmental Changes

- Precipitation
- Stream flow

Why are we concerned?

The river can be closed to users due to high and fast moving waters. Rivers may also be filled with more debris, making it more difficult to navigate as a user and making rescues

more difficult. This could result in river closures, such as the one during the 2013 flood in Calgary, until water levels become safe.

Areas such as beaches, campgrounds, golf courses and picnic areas are unsafe when they are flooded and will be closed until water levels recede. Closures could be in place for months or years while repairs to infrastructure are completed. Road damage is also possible with flooding, which would impact the ability to access recreation areas.

During flooding events, these closures may be put into place very quickly and evacuations from recreation areas such as golf courses, campgrounds and resorts may be necessary. This would disrupt recreational activities and holidays.

Recreation facilities and community centers can also be damaged in flooding events. The closure of these buildings could result in the temporary cancellation or relocation of community programs, sports events and classes.

The economic costs of closures can include repair to damaged facilities as well as loss of visitors and use of areas, decreasing revenue.

What can we do about it?

Respect closure areas. When planning infrastructure in flood zones, ensure wastewater and electrical systems can be dealt with in a flood do avoid further contamination or electrocution. Plan for safety and evacuation routes. Maintain healthy ecosystems, even when used for recreation.

- Coordinate with Watershed Mgmt Plans
- Recreation scenario planning
- Economic scenario planning
- Create flood management plans
- Map drought, flood, and recharge areas
- Climate proof culverts
- Minimize floodplain development
- Create flood buffers

References:

Alberta Environmental and Sustainable Development (ESRD). 2014. Flood Recovery Quick Facts. Published May 12 2014. Retrieved March 2015 from

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Decreased Recreational Water Quality

How does climate change affect water quality?

The increase in flood frequency and intensity will increase soil erosion and silt in waterways. Along with other pollutants, river chemistry will change which will have significant implications on water quality and species composition (IPCC 2002). These pollutants can have serious health risks to recreational users participating in activities including swimming, wading, bathing as well as windsurfing, waterskiing, canoeing, kayaking, rafting and fishing. Human health risks associated with exposure to recreational waters can be increased following flooding events, primarily relating to infection from pathogenic microorganisms causing and injury or illness caused by physical and chemical properties of the water.

Underlying Environmental Changes

- Precipitation
- Available moisture
- Stream flow

Why are we concerned?

Due to the increase in potential hazards to human health found in water systems, it is important to closely monitor and test recreational areas following a flood. Complete guidelines to for recreational water quality can be found in Health Canada's The Guidelines for Canadian Recreational Water Quality

In post flood conditions, water is typically not safe for recreational activities because of the risks of high fecal coliforms/E. coli levels and other pathogens in the first few weeks

following the flood (ESDR 2014, p.7). Commonly found microbiological contaminants from flooding events include fecal coliforms and E.coli, which create conditions where waters are poorly suited for recreation several weeks post flood. Suspended solids/turbidity, organic carbon levels, phosphorous, and nitrogen can also be found in concentrations too high for safe recreational use 2-3 weeks post flooding. Metals including aluminum, mercury iron silver zinc, selenium and manganese can also be found in excessively high concentration immediately following floods. (ESRD 2014, p.7)

These contaminants will have negative effects on recreational activities temporarily. This could be area closures or activity restrictions. Should areas flooded waters be used recreationally too soon, illness or injury could occur. In a healthy system the excess pollutants will disperse within a few weeks and recreational activities can resume.

Litter, debris and other matter brought in by floods can potentially cause health risks to recreational water users. Some materials can be harmful to recreational water users who come in direct contact with them. Also disrupting recreational users of an area is biting insects that can be attracted to litter. (Health Canada 2012).

What can we do about it?

Establish procedures and actions to monitor, restore and communicate water quality in recreational areas. This could include actions like beach cleanups and grooming, identifying common run off areas and contaminant sources, and maintain effective recreational water management programs (Health Canada 2012, p.13).

- Coordinate with Watershed Mgmt Plans
- Recreation scenario planning
- Create flood management plans
- Identify water quality risks
- Understand projected changes in water
- Promote natural infrastructure

References:

Alberta Environment and Sustainable Resources Development (ESRD) Flood Recovery Detailed Ambient Water Quality Report. (2014), (March), 1-101. Accessed February 2015 from: http://esrd.alberta.ca/focus/esrd-2013-flood-recovery-programs/documents/FR-DetailedAmbientWaterReport-May01-2014A.pdf

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Aesthetic damage to recreational areas

How does climate change affect the aesthetics of recreational areas?

Climate change may results in periods of higher water levels and velocities due to extreme precipitation events and increased snowmelt which can change river channels. Intensification of the flow rates and eroding stream banks increases movement of nutrients and pollutants to downstream ecosystems, restructuring processes, biota, and habitats (Staudinger 2013). Debris of all sorts is dropped in the water system. These effects of flooding will have significant impact on the visual aesthetics of recreational areas, affecting many activities such as picnics, wildlife viewing, fishing, bird watching, walking and hiking and photography.

Underlying Environmental Changes

Precipitation
Stream flow
Glacier area

Why are we concerned?

The Alberta Recreational Water Quality Guidelines identify the aesthetics of an area to be an important component of water quality (2012). Physical, aesthetic and chemical characteristics of water can have an impact on recreational water users. The physical aesthetic of recreational waters should be of good quality. Aesthetic components also have an impact on health and safety of users, particularly when visibility becomes impaired. This means that recreational waters should be free from:

- substances producing objectionable colour, odour, taste or turbidity;
- floating debris, oil, scum and other matter;

- materials that will settle to form objectionable deposits;
- substances and/or conditions that produce undesirable aquatic life; and
- litter.

Following floods it is possible for recreational areas to be contaminated by some or all of these factors. This will cause recreational areas to be displeasing to the eye, potentially dangerous and less enjoyable places to spend time.

In addition to this, as water levels recede there is often mud, silt and other debris coating the area, requiring cleaning before use. All these factors contribute to recreational areas being less enjoyable to look at or be at in post-flood conditions. With time and cleaning efforts, most areas can restore the aesthetic appeal of an area.

What can we do about it?

Ensure well-planned recreation areas and anticipate where run off will come from. Maintain water quality and facilities. Minimize litter and other objectionable objects before and after flooding. Get community involvement in the care of recreational waters.

Update Sustainability Plans
Coordinate with Watershed Mgmt Plans
Recreation scenario planning
Create flood management plans
Retain native riparian vegetation
Assess at-risk infrastructure
Promote natural infrastructure
Climate proof culverts
Minimize floodplain development
Create flood buffers

References:

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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 water treatment infrastructure

How does climate change affect water treatment infrastructure?

Predictions for future climate scenarios include increased precipitation events, rapid spring melt and as a result increased incidents of flooding events. Heavy precipitation and flooding conditions may act to overwhelm water treatment plants, causing failure of treatment systems and consequences for human health. Increased volumes of water may exceed the capacity of treatment plants, such as in Calgary in 2013 when one of the treatment plants became inundated and was discharging untreated waste into the Bow River (Danyluk 2014).

Floodwater can also contain increased sediment, organic matter, bacteria and chemicals. Intense rainfall can cause run off from upstream urban or agricultural land, carrying such wastes downstream and possibly into drinking water for other communities (Warren 2004). This creates the need for increased water treatment during flooding to prevent contamination of drinking water. This increase in contaminants in the water can create difficulties in the water treatment process for 2-3 weeks after a flooding event, such as in Alberta in 2013 (AB Government 2014). The quantity and quality of water entering the treatment facility may overwhelm the system and cause failure and/or damage.

Underlying Environmental Changes

- Temperature
- Precipitation
- Glacier area

WHY ARE WE CONCERNED?

The failure of water treatment infrastructure can lead to untreated water full of bacteria, organic matter and chemicals, entering source water. This means that drinking water, or water used for irrigation, or recreational water bodies may be unfit for use. Exposure to untreated water can have implications for human health, including disease and infection (Sauchyn and Kulshreshtha 2008). Local authorities may issue boil water advisories in the case that drinking water becomes contaminated. Any damage to water treatment infrastructure may also increase costs for maintenance and repair of the facilities, in order to maintain function.

WHAT CAN WE DO ABOUT IT?

- Update Sustainability Plans
- Update Municipal Development Plan
- Coordinate with Watershed Mgmt Plans
- Emergency scenario planning
- Create flood management plans
- Climate proof drainage plans
- Beaver reintroduction
- Wetland/recharge protection
- Constructed wetlands
- Maximize infiltration
- Know ecological infrastructure
- 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
- Minimize floodplain development

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Premature weathering and damage to building infrastructure

How does climate change affect buildings?

An increase in frequency and intensity of extreme rainfall events expected with climate change can lead to flooding causing damage to buildings and in extreme cases, buildings may be completely destroyed. Flooding creates problems for the structural integrity of buildings and can increase repair and insurance costs (Boyle et al 2013). Foremost flooding can flow into basements due to sewer backups and infiltration from high groundwater tables or saturated soils, creating debris and loss for home and business owners. Water flowing through cracks in foundations can further damage foundations and cause weathering of input materials. Buildings in close proximity to rivers breaching their banks may be subject to overland flooding, when water traverses dry land causing damage to property and building facades, structures and interiors. Excess water in buildings can cause leaching of chemicals, corrosion of metals and lead to mold growth.

Individually, and especially when combined, these processes lead to premature degradation, decreased durability of materials and can compromise structural integrity (Boyle et al 2013). In extreme cases, buildings may be condemned or destroyed completely.

Underlying Environmental Changes

- Precipitation
- Available moisture

WHY ARE WE CONCERNED?

Flooding of homes and businesses leads to increased costs for repairs, maintenance, upgrades and rising insurance for owners. Unfortunately overland flooding is tough to insure in many places and may even be uninsurable, leaving the costs on homeowners (Danyluk et al 2014). Flooding can cause damage to property in the form of debris, wash outs and riverside property may be eroded away.

WHAT CAN WE DO ABOUT IT?

In Calgary the bylaws for development in a floodway changed in 1985 however many of the property damaged in the 2013 flood was grandfathered in and did not meet this bylaw. Changing development bylaws to reflect all development in a floodway could prevent excess damage. Accounting for flooding in the development process could help mitigate major impacts. Specific strategies include:

- Update Sustainability Plans
- Update Municipal Development Plan
- Emergency scenario planning
- Economic scenario planning
- Create flood management plans
- Climate proof drainage plans
- Maximize infiltration
- Map drought, flood, and recharge areas
- Understand projected changes in water
- Use climate-adjusted IDF curves
- Assess at-risk infrastructure
- Built infrastructure scenarios
- Low-risk infrastructure siting
- Adapt infrastructure for climate change

Climate proof culverts
Reduce waterway channelization
Minimize floodplain development
Implement flood-resilience standards
Ensure developments consider climate change
Create flood buffers

REFERENCES:

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Premature weathering and damage to bridges

HOW DOES CLIMATE CHANGE IMPACT BRIDGES?

Future predictions for more sporadic and intense rainfall, earlier spring melt and more rain on snow events may lead to an increase in frequency and intensity of flooding events. Flood conditions impact bridges through prolonged, premature weathering or destruction of bridges through washouts and collapse. Larger, faster moving bodies of water can scour river substrate and erode away at riverbed exposing bridge foundations leading to instability (Wright et al 2012). Increased moisture in river bank soil can increase the risk for erosion of banks also compromising stability of bridges and the roads leading up to them. During higher intensity flooding events (which are predicted to increase in frequency) bridges, especially in low lying areas, become vulnerable to washouts or collapse. This is especially applicable for older bridges, which may already be deficient.

Underlying Environmental Changes

- Precipitation
- Available moisture
- Stream flow

WHY ARE WE CONCERNED?

Increased flow causing the premature weathering of bridges increases the lifecycle cost of maintaining bridges. If bridges are unable to meet a minimum service level then they may be closed, preventing use for transport of goods, services and people across rivers. Extreme flooding can cause bridges to be washed downstream, or damaged beyond repair resulting in either absence of bridges or high costs to replace the bridge. In the 2013 flood in Southern Alberta 200 bridges were susceptible to damage or damaged resulting in closures. The Bow River bridge on Highway 547 was extensively damaged cutting off access for approximately a year at this junction before $2.1million repairs were slated to begin (Alberta Government 2014).

WHAT CAN WE DO ABOUT IT?

Bridges are naturally vulnerable due to their proximity to water bodies. "No-regrets" planning that accounts for higher intensity floods prior to development can help to reduce major impacts including wash out. Specific strategies include:

- Coordinate with Watershed Mgmt Plans
- Emergency scenario planning
- Create flood management plans
- Climate proof drainage plans
- Maximize infiltration
- Map drought, flood, and recharge areas
- Understand projected changes in water
- Use climate-adjusted IDF curves
- Monitor waterway flows
- Calculate water storage capability
- Assess at-risk infrastructure
- Built infrastructure scenarios
- Low-risk infrastructure siting
- Adapt infrastructure for climate change
- Abandon marginal infrastructure

Climate proof culverts
Reduce waterway channelization
Minimize floodplain development
Create flood buffers

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Damage to energy and communications networks

HOW DOES CLIMATE CHANGE AFFECT ENERGY AND COMMUNICATION NETWORKS?

Increased extreme weather events such as heavy precipitation can damage energy and communications networks by washing away infrastructure. Heavy flooding can down power lines, damage towers and interrupt services from substations because of damage or inundation. Heavy rains can also erode soils and expose pipelines, making them vulnerable to weathering and damage. Flooding can wash out roads and damage underlying infrastructure, such as high pressure gas mains and telephone, hydro and cable service lines (IISD 2013). Damage to any critical infrastructure can result in interruption of service for homes and businesses in the form of power outages and

cable/phone disconnection, inside and outside the flood zone. The 2013 floods in southern AB left the community of Black Diamond without power or phone and cellphone service after a bridge that had telecommunication cables installed in it was wiped out (Glass 2014).

Underlying Environmental Changes

Precipitation
Stream flow

WHY ARE WE CONCERNED?

Interruption of power and communication services can result in loss of economic productivity and costs for both residents and business owners. In Calgary in 2013 35,000 customers saw power outages due to flooding of a substation and precautionary shut offs including in areas unaffected by the flood (Danyluk et al 2014). Such power outages can be very negative for storm water and waste water systems. When sump pumps don't have power it can lead to sewer backups and basement flooding. This can also cause property losses and repair costs, and general inconvenience for homeowners.

WHAT CAN WE DO ABOUT IT?

Update Municipal Development Plan
Emergency scenario planning
Create flood management plans
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
Minimize floodplain development
Create flood buffers

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Weathering and failure of storm water and drainage infrastructure

How does climate change affect storm water systems?

Historically, cities are not planned for flood prevention. Municipalities have traditionally relied on historic climate data to plan storm water systems and many climate stations in Alberta use predictions based on rainfall from the 1960s to 1990s (AUMA/AMSC 2014). With predictions for more variable climate these drainage capabilities may not be sufficient. Many cities in Canada have infrastructure designed to deal with 1 in 25 year floods, and on average 1 in 5 year floods (Sandink 2009). An increase in frequency and intensity of precipitation events may overwhelm these stormwater systems. If rainfall exceeds the capacity of sewers, culverts and drainage systems, the systems could fail causing localized flooding of roads, buildings, parks, farmland, or other areas. Dated infrastructure, such as insufficient pipe size, and increases in population can exacerbate impacts and contribute to more frequent failures (IISD 2013).

Underlying Environmental Changes

Precipitation
Stream flow

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?

The restoration of natural drainage systems can help to prevent the failure of drainage infrastructure. Planning for the protection of important ecosystems features, such as wetlands, as well as updating the climate projections used in planning will act to inform development and prevent large scale negative impacts. Specific strategies include:

Update Sustainability Plans
Update Municipal Development Plan
Coordinate with Watershed Mgmt Plans
Emergency scenario planning
Create flood management plans
Climate proof drainage plans
Beaver reintroduction
Wetland/recharge protection
Constructed wetlands
Retain native riparian vegetation
Maximize infiltration
Map drought, flood, and recharge areas
Understand projected changes in water
Use climate-adjusted IDF curves
Monitor waterway flows
Calculate water storage capability
Understand headwaters impacts
Assess at-risk infrastructure
Built infrastructure scenarios

Low-risk infrastructure siting
Adapt infrastructure for climate change
Promote natural infrastructure
Climate proof culverts
Reduce waterway channelization
Ensure developments consider climate change

RESOURCES:

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Premature weathering, wash outs and decreased service life of roads

How does climate change affect roads?

More frequent and intense rainfall leading to widespread or localized flooding may act to deteriorate roads. Flooding conditions can cause road closures and deterioration, resulting in traffic disruption. Low-lying roads are especially vulnerable to damage in flooding conditions from intense rainfall, pooling water and/or proximity to overflowing rivers and streams (Canadian Council of Engineers 2008). Large volumes of water and heavy precipitation can cause wash outs and in worst cases can collapse roadways. Unpaved roads are particularly vulnerable to washout due to the nature of their composition (Arent et al 2014).

Water can also cause premature deterioration of concrete, compromising roads and creating the need for earlier service and replacement. Roads on slopes become vulnerable to saturated soils and the associated potential for landslides causing damage, collapse and closure of roads (Canadian Council of Engineers 2008).

Underlying Environmental Changes

Precipitation
Stream flow

Why are we concerned?

Flood induced damage to roads has associated costs and inconveniences. Road closures can create service disruption, traffic problems and impacts to industry and quality of life. Flooding can leave debris on roads, leading to the need for clean up. Premature weathering also creates the need for earlier service and replacement. After the 2013 floods in Southern Alberta, the government required the inspection of over 1000 Km of roads. Resulting closures and damages cost the provincial government $40 million, including repair of Highway 758 where it washed out and cut off access to Bragg Creek from the South (Alberta Government 2013). Payment for repair and replacement depends on the jurisdiction of the infrastructure. The provincial government covers Alberta highways and bridges. Municipalities are responsible for the costs associated with damaged local road infrastructure, pathways and transit routes (Alberta Water Portal 2013). The costs for repair to private roads falls onto landowners.

What can we do about it?

Preventative measures in the planning process, such as location of roads, can help to mitigate major to damage to road infrastructure. Specific strategies include:

- Emergency scenario planning
- Create flood management plans
- Climate proof drainage plans
- Retain native riparian vegetation
- Map drought, flood, and recharge areas
- Understand projected changes in water
- Use climate-adjusted IDF curves
- Monitor waterway flows
- Calculate water storage capability
- Understand headwaters impacts
- Assess at-risk infrastructure
- Built infrastructure scenarios
- Low-risk infrastructure siting
- Adapt infrastructure for climate change
- Abandon marginal infrastructure
- Climate proof culverts
- Minimize floodplain development

Resources:

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Warren, F. J. 2004. Climate Change Impacts and Adaptation: A Canadian Perspective. Natural Resources Canada, Ottawa, Ontario.

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. In general, those that are better-suited to drier conditions, including invasive species, will adapt better.

Flooding is a natural occurrence and critical for ecological processes such as seed dispersal. However, a change in the intensity, timing and duration of flooding events may have significant effects on biological diversity through degradation of riparian areas, scouring of in-stream habitats, and water contamination.

Degradation of riparian habitats

How does climate change affect riparian habitat?

Riparian habitats exist on the edges of streams, rivers, lakes, and wetlands and are characterized by the interaction of water, soil, and vegetation. Sometimes referred to as floodplains, these areas play a key role in stabilizing precipitation volume for the surrounding landscape.

Riparian areas are highly biodiverse, supporting sensitive and unique vegetation and providing ideal habitat for wildlife. 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).

Shifting stream flows, caused by flooding could contribute to the damage and degradation of riparian areas. Studies suggest climate change will increase the frequency and intensity of storms and floods (IPCC 2002, p. 13). This could cause more frequent and detrimental disruption to riparian areas, particularly through erosion and sedimentation

Underlying Environmental Changes

Stream flow

Wetlands

Why are we concerned?

Climate change increases the occurrence of storms that go beyond the natural range of variability, significantly decreasing the resilience of ecosystems during extreme weather events like flooding.
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).

Developed or compromised riparian areas magnify the effects of flooding often resulting in altered drainage and sedimentation processes, decreased bank stability, increased erosion and pollutants, introduction of invasive species, habitat loss, and degraded visual impacts (ESRD 2012). These changes in steam flow have major impacts on the biodiversity of a watershed (IPCC 2002).

What can we do about it?

Update Sustainability Plans
Create climate-ready land use zones
Coordinate with Watershed Mgmt Plans
Create flood management plans
Beaver reintroduction
Retain native riparian vegetation
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
Understand headwaters impacts
Promote natural infrastructure
Minimize floodplain development
Create flood buffers

References

Alberta Environment and Sustainable Resource Development (ESRD). 2012. Stepping Back from the Water: A Beneficial Management Practices Guide for New Development Near Water Bodies in Alberta's Settled Region. Calgary, AB. Accessed December 14 at: http://esrd.alberta.ca/water/education-guidelines/documents/8554.pdf

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Increased risk of water contamination

How does climate change increase risks of water contamination?

Water can be contaminated by many different causes. Point sources are clearly identifiable pipes or industries, where as non-point sources are more difficult to identify and are often associated with run off from agricultural and urban areas. As a result, non-point sources are more difficult to regulate and control. The most common pollutants found in watersheds are sediments, pesticides, microbes, and heavy metals, coming from non-point sources.

Climate change will result in higher flows of water and more frequent flood events which will likely increasing the risk of pollutants entering the water. The three most significant pollutants are sediments, nitrogen and phosphorous, all of which can negatively impact the biodiversity in watersheds.

Underlying Environmental Changes

Precipitation
Stream flow

Why are we concerned?

An increase in flood frequency and intensity will increase soil erosion and silt in waterways. Along with other pollutants, river chemistry will change which will have significant implications on water quality and species composition (IPCC 2002).

More specifically the three most common pollutants will have the following effects:

- *Sediments* Normal sedimentation amounts are beneficial to aquatic ecosystem, but become detrimental in higher concentrations or if sediment loading occurs more frequently. Levels of sedimentation that go beyond background levels can inhibit breathing, feeding and effective spawning of fish. Increased levels of sediment can also damages fish gills, shifts fish communities to species more tolerant of sediments, decreases aquatic plant growth, and reduces filtering efficiency of zooplankton. (ESRD 2012, p.36)
- *Nitrogen* Nitrogen is commonly linked to fertilizers and manure, but urban areas also contribute to nitrogen levels in waterways. Extreme water levels increase the nitrogen entering waterways. The excess nitrogen causes algal blooms; the increased plant growth harms aquatic animals and creates toxic water, which stresses not only aquatic life but humans as well. A healthy system can filter nitrates out of the water, this filtering is much less effective with high levels of runoff.
- *Phosphorous* Certain levels of phosphorous are essential to healthy aquatic ecosystems. Nature produces minimal amounts of phosphorous, which organisms absorb quickly when it is present. This means that an ecosystem will hold onto phosphorous for long periods of time after it has been introduced. High levels of phosphorous reduce biodiversity.

What we can we do about it?

Update Sustainability Plans
Coordinate with Watershed Mgmt Plans
Create flood management plans
Beaver reintroduction
Wetland/recharge protection
Constructed wetlands
Maximize infiltration
Identify important wetlands
Develop State of Watershed
Identify valuable water-affected habitat
Identify water quality risks

Understand projected changes in water
Understand headwaters impacts
Raise awareness of ag issue/options
Promote natural infrastructure
Reduce waterway channelization

References

Alberta Environment and Sustainable Resource Development (ESRD). 2013. Flood Recovery Detailed Ambient Water Quality report. Accessed January 2015 from: http://esrd.alberta.ca/focus/esrd-2013-flood-recovery-programs/documents/FR-DetailedAmbientWaterReport-May01-2014A.pdf

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Increases in the variability of water flow

How does climate change affect water flow?

Grassland aquatic ecosystems are made up of a network of rivers, lakes, wetlands and small watercourses. These networks are essential for the survival of aquatic species and are maintained by flowing water. Climate change may result in more extreme and frequent flooding events, which increase stream flows. A healthy watershed has plants and animals that are able to adapt to changes in water flows; many species even benefit from and require periodic flooding (ESRD 2012).

When natural habitats are destroyed due to flooding, it is often a result of human made infrastructure and flood control measures. Infrastructure such as dams, roadways, and wetland drainage compromises the systems ability to manage hydraulic variability. Intensification of the water cycle increases movement of nutrients and pollutants to downstream ecosystems, restructuring processes, biota, and habitats (Staudinger 2013).

Underlying Environmental Changes

Stream flow

WHY ARE WE CONCERNED?

The most critical impacts to fish and habitats are a result of responses to flooding. Emergency efforts to repair damage to infrastructure and public property often have detrimental effects on aquatic environment. Human changes to streams in response to flooding have the potential to cause significant alteration, disruption and destruction of aquatic habitat (ESRD 2014). Furthermore, new studies are linking changes in stream hydraulics to alterations of food-web structure and general biological integrity in streams and rivers (Staudinger 2013).

Infrastructure that is commonly implemented to control water flow and flooding, but is known to substantially increase water velocity and erosion includes:

- River channeling When dealing with and planning for spring floods, one technique is to cut through river bends to channel the water flow away from buildings and infrastructure to speed it though developed areas. While this does direct the river away from infrastructure, channeling also increases the horsepower of the stream. Inevitably this causes erosion downstream and the higher velocities of water pushing through the channel damage habitats that would otherwise be able to withstand flood impacts.
- Culverts We have many reasons to cross rivers and streams. Culverts are a cost effective option, compared to bridges, and commonly used for stream crossings. When they are not maintained or installed properly and sized accordingly they may fail during flooding events and cause higher stream velocities. The high stream velocities can trap fish on either side and will cause erosion downstream.
- Alteration of vegetation on riverbanks Human influence on riparian habitat occurs for many reasons, particularly from livestock grazing and development. When riverbank vegetation is altered from human activities, natural defenses against erosion are removed and invasive plant species are able to move in. Invasive plants are typically not as adapt at binding soils or stabilizing stream banks. As a result they are not able to provide for wildlife or trap sediments in the water resulting in less suitable habitat and a loss of biodiversity (ESRD 2012).
- Urban area runoff Urban areas have little natural vegetation; instead there are many impervious covers like rooftops, parking lots, sidewalks, driveways, and roads. This infrastructure channels water directly into the river, causing increased volumes of water to enter the waterways. This can cause channeling and

decreases the distance runoff travels to reach the watercourse. The channeling and direct flow to water sources increases the velocity of water. Riparian areas will have difficulty absorbing the added energy, which will increase erosion and decrease water retention on the landscape.

What we can we do about it?

Coordinate with Watershed Mgmt Plans
Create flood management plans
Beaver reintroduction
Wetland/recharge protection
Constructed wetlands
Retain native riparian vegetation
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
Understand headwaters impacts
Promote natural infrastructure

References

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Temporary Disturbance to Fish Populations

How does climate change affect fish populations?

Climate change will impact fish habitat. Climate Change is predicted to lead to increases in the frequency of extreme and unpredictable weather, including more frequent floods, downpours, and periods of drought. This could cause dramatic changes in water level, which will have a significant impact on aquatic organism habitat. Changes include scourging of new river channels, piles of debris and streambed erosion.

When flooding occurs, there are dramatic short-term effects that can impact fish populations. Flooding will cause large-scale movement of streambeds, debris and displace plants and animals, causing short-term stress on aquatic ecosystems including fish and aquatic organisms. As water levels recede, debris and fish will be deposited in new locations and environments. In the cases of healthy intact habitats, aquatic populations will be more able to quickly recover from the disruptions caused by floods.

Underlying Environmental Changes

- Temperature
- Precipitation
- Stream flow
- Wetlands

Why are we concerned?

Following a flood, fish populations can be reduced by 30-60% (Kirn 2011). With stable conditions in the following years, populations are able to grow and become stable once again. But for this to happen, the overall quality and diversity of the ecosystem must be and remain healthy.

Fish populations are impacted in a number of ways due to flooding. Disturbances to fish populations include:

- Relocation of fish to new environments. High stream velocities relocate the fish downstream or to newly created channels. This can be beneficial in some situations where fish repopulate off channel wetlands and previously isolated streams. Other times fish are deposited in fences, debris, vegetation, roads and even houses, where they cannot survive. After the flooding in Calgary fish were found anywhere from storm water ponds to basements. In cases where fish are displaced beyond water networks, manual movement of the fish is the only way to ensure survival.
- Reshaped streambeds High velocities of water can significantly change the shape of streambeds through erosion and movement of debris. While this change can be beneficial, providing more varied stream movement, intensive flooding can also homogenize the stream creating an inhospitable environment for fish and other aquatic organisms. A stream is labeled as unhealthy when they have little variations, are shallow, wide and featureless.
- High levels of sedimentation High levels of sediments can have serious impacts to fish health including damage to gills and breathing as well as inhibiting feeding and spawning.
- Loss of spawning/nesting groundMany species require specific environments for different lifecycle stages. In particular shallow gravel pools are used for spawning. Flooding can remove this habitat feature entirely or cover riverbeds with too many sediments for successful reproduction. On the flip side, infrequent and moderate flooding can help to clean out sediments for trout spawning grounds.

The timing, extent and magnitude of flooding will dictate how serious the disturbance of the flood is to fish populations. It is possible for fish populations to come back within a year of flooding events if there are healthy habitat conditions in place to allow the remaining populations to reproduce. Should healthy habitats not exist it could take decades for streambeds to reestablish healthy water flow for fish populations.

What we can we do about it?

Coordinate with Watershed Mgmt Plans
Create flood management plans
Beaver reintroduction
Wetland/recharge protection
Constructed wetlands
Retain native riparian vegetation
Identify important wetlands
Develop State of Watershed

Know ecological infrastructure
Identify valuable water-affected habitat
Identify water quality risks
Understand projected changes in water
Promote natural infrastructure
Create flood buffers

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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 and strategies.

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.

Concerns around flooding increase the importance of a municipality working to protect existing water capture capacity, improving flood dissipation mechanisms, and promoting resilient design and development. Ensuring resilience to both minor and catastrophic flood events is important for agriculture, recreation, health, infrastructure, and biodiversity components of a vital community.

Climate-proof municipal plans

'Climate-proofing' municipal plans refers to assessing existing policies and plans at the municipal level to understand the climate-change related risks, and modifying those policies and plans to mitigate the risks.

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 flooding threats.

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.

References

- Alberta Urban Municipalities Association (AUMA) sustainability plan template and guide

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

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)

Adjust master drainage plans to accommodate climate change

As the intensity and frequency of extreme rainfall or run-off events are predicted to increase, so too are the challenges for municipal stormwater infrastructure. While large-scale floods make the news, cases of stormwater simply outstripping the capability of municipal infrastructure are likely to be much more frequent. When considering their stormwater or drainage master plans, municipalities need to consider two areas in particular. First, the assessment of the risk need to be climate-change-adjusted, with that updated data informing IDF curves. Second, municipalities should consider the multitude of innovative approaches to dissipating stormwater. Every municipality is different (soils and absorption / groundwater flow rates, vegetation density, existing infrastructure, etc.), but many 'green' approaches and technologies can expand the capacity of the traditional stormwater infrastructure, including green roofs, downspout disconnection programs, curb removals, and maintenance of natural infrastructure associated with landscapes such as riparian areas and wetlands.

RESOURCES

- Riparia Ltd (Calgary-based landscape architecture firm)
- Greenfield Tool Box: Ecological Infrastructure Modeling
- Public Infrastructure Engineering Vulnerability Committee - PIEVC (Engineers Canada)

- How Will Climate Change Affect Civil Infrastructure
- Managing Municipal Infrastructure in a Changing Climate
- Adaptive Approaches in Stormwater Management Plan (City of Ottawa)
- City of Castlegar - Stormwater Infrastructure Climate Change Vulnerability Assessment
- Comprehensive Stormwater Management Master Plan Guidelines:
- Flood Mitigation Methods (Alberta Water Portal)
- Green Infrastructure in Calgary's Mobility Corridors
- Innovative Stormwater Management Practices
- Innovative Stormwater Management: Translating Science Into Actions
- Integrated Stormwater Management Plans: Lessons Learned to 2011 (Metro Vancouver)
- Reduce Impervious Surfaces - Vermont Green Infrastructure Initiative
- Reduce Impervious Surfaces (CRD)

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

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)

Develop comprehensive flood management plans

Communities in southern Alberta are much more aware of the need for, and necessary components of, comprehensive or integrated flood management plans. Many Alberta municipalities have these in place. There is no simple recipe, as each community is different, but there are many examples that municipalities can look to, and general principles to incorporate.

Flood management plans should be based on a risk management approach, considering both reduction of risk as well as post-event response. That risk assessment needs to use flood mapping and flood risk assessments that are climate-change-adjusted. The foundation of the plans should be goal-based, with targets and measures. Threat assessments should be locally-relevant (much flood risk assessment for municipalities is based on rising sea levels; not an issue for Alberta municipalities as of yet). Management responses should weigh 'soft' and 'hard' engineering approaches, and integrate with land use, conservation, development, transportation, recreation, human health, and other goals. Organizations like the WPACs and the Alberta Water Portal are sources of planning expertise and partnership for municipalities.

Resources

- City of Leduc Weather and Climate Readiness Plan
- Adaptive Land use for Flood Alleviation (EU)
- Room for the River (Netherlands)
- Resilient Communities Project (All One Sky Foundation)
- 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

- Flood Hazard Identification / Mapping / Studies (Alberta Environment and Sustainable Resource Development)
- Alberta Water Portal - Maps
- Alberta River Basin Maps and Data Summaries
- Preparing for a Changing Climate: Washington State's Integrated Climate response Strategy
- A Guide for Incorporating Adaptation to Climate Change into Land-use Planning
- Best Practices for Reducing the Risk of Future Damage to Homes from Riverine and Urban Flooding
- Calgary River Flood Mitigation Program
- Calgary's Flood Resilient Future: Report from the Expert Management Panel on River Flood Mitigation
- City of Calgary Flood Mapping
- Conservation Authority (Ontario) Flood Management Library
- District of Squamish Integrated Flood Hazard Management Plan
- Flood Mitigation Methods (Alberta Water Portal)
- Flood Risk Management Plans (UK)
- Lower Mainland Flood Management Strategy

Promote flood-resilient design and development

Flood resiliency is very much about recognizing that flood events are inevitable and then building the capacity to accommodate them to the greatest degree through thoughtful, innovative, and pragmatic design, an effort which municipalities are ideally suited to initiate. Approaches can include changing standards for the municipality and its partners, and encouraging design principles that work with nature's natural flows instead of against them.

Minimize development in flood plains, floodways

If one strategy can be said to most effectively build flood-related resiliency in a community, it would be to not create residential or other flood-vulnerable infrastructure in flood plains. The first step in this is to understand spatially where flood risk exists, an assessment that needs to be updated to reflect climate change-based projections.

Though this strategy appears to be simple self-evident logic, it can be incredibly difficult to implement, and creative tools may be required. Municipalities can support this through the use of cluster development planning, climate-change-based land use zones, conservation directives, and Transfer of Development Credits.

And as unpopular as they will be, discussions need to start about de-development in flood risk areas. Despite the resistance, citizens need only look at what flood ravaged landscapes look like, and consider if they want to live there after a flood.

RESOURCES

- Enhancing Health Care Resilience for a Changing Climate (Infrastructure placement)
- Stepping Back from the Water: A Beneficial Management Practices Guide for New Development Near Water Bodies in Alberta's Settled Region
- Best Practices for Reducing the Risk of Future Damage to Homes from Riverine and Urban Flooding
- Resilient Design Principles (Resilient Design Institute)
- A Guide for Incorporating Adaptation to Climate Change into Land-use Planning
- Transfer of Development Credits (TDCs) in Alberta
- Conservation Easements in Alberta (online guide)
- Adapting to Climate Change: An Introduction for Canadian Municipalities
- Calgary River Flood Mitigation Program

- Canadian Communities' Guidebook for Adaptation to Climate Change
- Cities Impact and Adaptation Tool (CIAT)
- Lower Mainland Flood Management Strategy
- 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
- Primary Protection: Enhancing Health Care Resilience for a Changing Climate
- ReTooling for Climate Change
- Natural Step Integrated Community Sustainability Planning Guide
- California Water Plan Update, Recharge Areas Protection
- Large-scale implementation of adaptation and mitigation actions in agriculture
- Conservation Easements in Alberta (online guide)
- Adaptive Land use for Flood Alleviation (EU)
- Room for the River (Netherlands)
- Resilient Communities Project (All One Sky Foundation)
- Flood Hazard Identification / Mapping / Studies (Alberta Environment and Sustainable Resource Development)
- How Will Climate Change Affect Civil Infrastructure
- Managing Municipal Infrastructure in a Changing Climate
- Climate Change and Infrastructure, Urban Systems, and Vulnerabilities: Technical Report for the US Department of Energy in Support of the National Climate Assessment
- The People, Economy, Land, and Resources of Missoula County and Potential Vulnerabilities to Climate Change
- Preparing for a Changing Climate: Washington State's Integrated Climate response Strategy
- BC Agriculture Climate Change Action Plan 2010-2013
- Floods in Boulder: A Study of Resilience

Ensure planning and development activities consider climate change projections

The majority of the construction in a community is not undertaken directly by a municipality, so much of the effect a local government can have in climate-proofing buildings comes through creating land and building development standards that are informed by climate projections (including scenario planning done by municipal departments). Example, include requirements on limiting impervious surfaces, use of flood-resistant building materials, flood-aware infrastructure siting, etc.

That said, the local government is a significant developer in a community when roads, community facilities, and operational infrastructure is taken into account. Municipalities can have a direct effect on the climate-resilience of these structures by developing internal guidelines for the creation and maintenance of municipal buildings. As well, municipalities can require climate-change-adjusted projections be factored in by sub-contractor in bids, tenders, and contracts.

RESOURCES

- Resilient Design Principles (Resilient Design Institute)
- Natural Step Integrated Community Sustainability Planning Guide
- Enhancing Health Care Resilience for a Changing Climate (Infrastructure placement)
- Communities Adapting to Climate Change Initiative (Columbia Basin Trust)
- City of Calgary Water Efficiency Plan
- How Will Climate Change Affect Civil Infrastructure
- What Will Adaptation Cost? An Economic Framework for Community Planners
- Best Practices for Reducing the Risk of Future Damage to Homes from Riverine and Urban Flooding
- ReTooling for Climate Change
- Greenfield Tool Box: Ecological Infrastructure Modeling
- Computerized Tool for the Development of Intensity-Duration-Frequency-Curves under Climate Change
- Public Infrastructure Engineering Vulnerability Committee - PIEVC (Engineers Canada)
- Managing Municipal Infrastructure in a Changing Climate
- A Guide for Incorporating Adaptation to Climate Change into Land-use Planning
- Reduce Impervious Surfaces - Vermont Green Infrastructure Initiative
- Reduce Impervious Surfaces (CRD)
- Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide
- Climate Change Adaptation through Land Use Planning (Manitoba)
- Comprehensive Stormwater Management Master Plan Guidelines:
- From Impacts to Adaptation: Canada in a Changing Climate
- Riparian Area in Calgary (City of Calgary)
- Riparian Land Conservation and Management (Rocky View County)
- Source Water Protection Plan: Edmonton's Drinking Water System (EPCOR)
- Tools of the Trade: Urban Environmental Improvement Options

Implement flood-resilient building and development standards

One of the greatest financial risks in a flood event is damage to buildings and associated infrastructure. Municipalities have a significant ability to address this at the planning stage (both planning for land use and for building).

The key is to institutionalize these approaches, and to ensure they are based on climate-change-adjusted scenarios. Techniques can included standards for riparian vegetation for erosion control, considered placement of buildings within riverfront properties, increased setback requirements, improvement/maintenance of water infiltration, removal of downspouts and curbs, installation of backwater valves, prohibition of basements as living spaces in flood zones.

Institutionalization of these can happen through changes in development standards, grandfathering through re-development standards, incentives for retrofits, and deliberate awareness raising of the existence and value of these revised standards.

RESOURCES

- Resilient Design Principles (Resilient Design Institute)
- Stepping Back from the Water: A Beneficial Management Practices Guide for New Development Near Water Bodies in Alberta's Settled Region
- Tools of the Trade: Urban Environmental Improvement Options
- Groundwater Protection Through Local Land-use Controls
- Climate Change Adaptation Planning: A Handbook for Small Canadian Communities
- Communities Adapting to Climate Change Initiative (Columbia Basin Trust)
- Best Practices for Reducing the Risk of Future Damage to Homes from Riverine and Urban Flooding
- Calgary's Flood Resilient Future: Report from the Expert Management Panel on River Flood Mitigation
- Canadian Communities' Guidebook for Adaptation to Climate Change
- Public Infrastructure Engineering Vulnerability Committee - PIEVC (Engineers Canada)
- How Will Climate Change Affect Civil Infrastructure
- Managing Municipal Infrastructure in a Changing Climate
- A Guide for Incorporating Adaptation to Climate Change into Land-use Planning
- Alberta Flood ReLeaf (available to Alberta municipalities)

- Alberta Riparian Habitat Management Society (Cows and Fish)
- Alberta Fire Smart
- Resilient Communities Project (All One Sky Foundation)

Create climate-based flood buffers around streams / rivers

Municipalities already have setback guidelines from water bodies, based on provincial legislation and local policies. Minimums are outlined in the Environmental Reserve provisions of the Municipal Government Act, and in Alberta tend to be in the 20m-30m range for larger waterways.

However, these guidelines tend to be based on older assessments of the high-water-line, and the 1:100 year flood projections. These setbacks and buffers should be fundamentally re-thought both in terms of size and function. Climate-change-adjusted distances for setbacks should likely be increased significantly. These buffers can be multi-purpose, and include swales, parks, playing fields, etc. The 2013 floods showed parks to be some of the most resilient land uses when faced with flood, in particular natural area parks.

Resources

- Riparian Land Conservation and Management (Rocky View County)
- Source Water Protection Plan: Edmonton's Drinking Water System (EPCOR)
- Municipal Government Act
- Transfer of Development Credits (TDCs) in Alberta
- Resilient Design Principles (Resilient Design Institute)
- Adaptive Land use for Flood Alleviation (EU)
- Room for the River (Netherlands)
- Best Practices for Reducing the Risk of Future Damage to Homes from Riverine and Urban Flooding
- A Guide for Incorporating Adaptation to Climate Change into Land-use Planning
- Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide
- Calgary's Flood Resilient Future: Report from the Expert Management Panel on River Flood Mitigation
- Climate Change Adaptation through Land Use Planning (Manitoba)
- Green Infrastructure in Calgary's Mobility Corridors
- Riparian Area in Calgary (City of Calgary)
- Alberta Riparian Habitat Management Society (Cows and Fish)

- 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
- Public Infrastructure Engineering Vulnerability Committee - PIEVC (Engineers Canada)
- How Will Climate Change Affect Civil Infrastructure
- Integrated Stormwater Management Plans: Lessons Learned to 2011 (Metro Vancouver)
- Alberta River Basin Maps and Data Summaries
- Managing Municipal Infrastructure in a Changing Climate
- Climate Change and Infrastructure, Urban Systems, and Vulnerabilities: Technical Report for the US Department of Energy in Support of the National Climate Assessment
- The People, Economy, Land, and Resources of Missoula County and Potential Vulnerabilities to Climate Change
- Preparing for a Changing Climate: Washington State's Integrated Climate response Strategy
- Source of Opportunity: A Blueprint for Securing Source Water in Southern Alberta

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)

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

Establish flow monitoring on waterways that provide municipal water or drainage

Although much attention is - rightfully - placed on large-scale flooding events, climate-change-influenced flood risk plays out in smaller events as well. Understanding that dynamic at a local level helps municipalities prepare for flooding of all scales.

Flow monitoring resources exist that are accessible even to municipalities with limited resources (see Resources, below). However, having the data, and using the data in planning are two different steps. Municipalities should be monitoring flow rates (and flow rate changes) on waterways that provide municipal water or drainage. Those data can be gathered on an on-going basis, then analyzed to see what the historic trends and recent changes are. Those trend data can then be used to develop locally-relevant changes in infrastructure and other planning.

It will be important to integrate this monitoring and analysis effort with the local WPAC and their Integrated Watershed Management Plan. Also, municipalities should communicate to the Government of Alberta if local flow stations are not adequate to provide this information to a given municipality.

RESOURCES

- Toward a Resilient Watershed: Addressing Climate Change Planning in Watershed Assessments
- Alberta River Basin Maps and Data Summaries
- Computerized Tool for the Development of Intensity-Duration-Frequency-Curves under Climate Change
- Public Infrastructure Engineering Vulnerability Committee - PIEVC (Engineers Canada)
- Declining summer flows of Rocky Mountain rivers: Changing seasonal hydrology and probable impacts on floodplain forests
- Modelling Climate Change Impacts on Spring Runoff for the Rocky Mountains of Montana and Alberta II: Runoff Change Projections using Future Scenarios
- Climate change and future flows of Rocky Mountain rivers
- Real time hydrometric data

Understand impacts of headwaters activity

Much of what influences a municipality's flood risk, as well as its water quality protection calculations, happen well outside of the municipal boundaries. Understanding the impacts of activities in the headwaters on municipality's surface water sources is

important for planning such things as total water storage capacity, flood risk, and development capacity.

Activities which can require particular notice include forestry and recreational activity (e.g., ATV's) that reduces erosion resilience upstream, as well as upstream flood plain development.

Municipalities can play a role and be part of these discussions by first being clear on the impacts, then working to raise awareness of the issues, and working collaboratively with others through Integrated Watershed Management Plans, Intermunicipal Development Plans, regional and sub-regional plans, and source water protection plans.

RESOURCES

- Source of Opportunity: A Blueprint for Securing Source Water in Southern Alberta
- Source Water Protection Plan: Edmonton's Drinking Water System (EPCOR)
- 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
- Ecological Infrastructure in the Calgary Region: What We Now Know
- Provincial Groundwater Inventory Program (Alberta Geological Survey)
- Alberta Water Portal - Maps
- Alberta River Basin Maps and Data Summaries
- 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
- Atlas of Alberta Lakes - Water Quality
- Toward a Resilient Watershed: Addressing Climate Change Planning in Watershed Assessments
- Soil Erosion Risk for the Agricultural Area of Alberta
- Alberta Riparian Habitat Management Society (Cows and Fish)
- Beaver As a Climate Change Adaptation Tool: Concepts and Priority Sites in New Mexico
- Adaptive Land use for Flood Alleviation (EU)
- Lower Mainland Flood Management Strategy

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

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

Use IDF curves to inform engineering design standards

IDF or Intensity Duration Frequency curves are a critical infrastructure planning tool for municipalities. In simple terms, they describe the likelihood that a given rainfall event (i.e., a rainfall of a certain intensity and duration) will occur. New data tools make this information much more readily available, even for municipalities with more limited

resources. Specific engineering decisions require additional and more varied data and information, but the IDF curves provide a baseline policy planning tool.

However, IDF curves are often based on historical data that do not incorporate projected variations as a result of a changing climate. New tools such as the IDF CC Tool, created at the University of Western Ontario, can provide more accurate projections of the rainfall intensity, and flood risk, a municipality may face.

RESOURCES

- Toward a Resilient Watershed: Addressing Climate Change Planning in Watershed Assessments
- Alberta River Basin Maps and Data Summaries
- Computerized Tool for the Development of Intensity-Duration-Frequency-Curves under Climate Change
- Public Infrastructure Engineering Vulnerability Committee - PIEVC (Engineers Canada)
- Modelling Climate Change Impacts on Spring Runoff for the Rocky Mountains of Montana and Alberta II: Runoff Change Projections using Future Scenarios
- Climate change and future flows of Rocky Mountain rivers
- Alberta Flow Quantity Index
- Real time hydrometric data

Calculate total municipal water storage capability

Flood planning and management requires understanding the physical capacity of a community's landscape to hold water in a rainfall event (or series of events). Matching this with climate-change-adjusted IDF curves (indicating the potential volumes of water that may arrive in a 1:100 or 1:500 flood event) gives municipalities a basis for assessing potential risk.

Though the built water storage infrastructure is a big part of this calculation, it is also important to also identify areas that represent natural infrastructure capacity, or which may store water temporarily.

Natural infrastructure includes wetland capacity (capability of absorbing additional surface water), infiltration capacity (the ground under some communities will absorb rainfall more readily than that under others), and prevalence of beavers in the

watershed. Temporary water storage areas might include parks, golf courses, farms adjacent to waterways, and wetland complexes.

Such assessments need to include areas upstream of the municipality (tying into the Integrated Watershed Management Plan), flood mapping (indicating where flood waters are likely to go), and an assessment of remediation costs associated with impacts to the agricultural, recreational or other lands.

RESOURCES

- California Water Plan Update, Recharge Areas Protection
- Alberta Water Well Information Database
- Greenfield Tool Box: Ecological Infrastructure Modeling
- Flood Hazard Identification / Mapping / Studies (Alberta Environment and Sustainable Resource Development)
- Alberta Water Portal - Maps
- Alberta River Basin Maps and Data Summaries
- Real time hydrometric data
- Preparing for a Changing Climate: Washington State's Integrated Climate response Strategy
- 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
- Calgary's Flood Resilient Future: Report from the Expert Management Panel on River Flood Mitigation
- City of Calgary Flood Mapping
- Comprehensive Stormwater Management Master Plan Guidelines:
- Conservation Authority (Ontario) Flood Management Library
- Flood Mitigation Methods (Alberta Water Portal)
- Beaver and Climate Change Adaptation in North America: A Simple, Cost-Effective Strategy
- Organizing Local Food Events (Alberta Agriculture and Rural Development)
- Beaver, Climate Change and Resilience; Seventh Generation Institute
- Provincial Wetland Restoration Guide
- Adaptive Land use for Flood Alleviation (EU)
- Room for the River (Netherlands)
- Centre for Hydrology, University of Saskatchewan
- Green Infrastructure in Calgary's Mobility Corridors

- 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
- Declining summer flows of Rocky Mountain rivers: Changing seasonal hydrology and probable impacts on floodplain forests
- Modelling Climate Change Impacts on Spring Runoff for the Rocky Mountains of Montana and Alberta II: Runoff Change Projections using Future Scenarios

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

Improve flood dissipation capability

As the volume of water entering a landscape becomes increasingly erratic, municipalities can implement programs and create/revise policies which support or augment the ability of local landscapes to naturally retain greater amounts of the water that comes into the system.

A critical part of becoming more resilient to flooding is increasing the ability of natural landscapes and the built environment to capture and slowly release increased rainfall, at both the micro and macro scales. In preparation for the increased frequency and intensity of flood events in the non-summer months, municipalities can implement programs and create/revise policies which support or augment the ability of local landscapes to naturally capture and store the greater amounts of the water coming 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)

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)

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

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:

Create/improve natural and engineered infiltration opportunities

A key part of the water cycle that is often overlooked in flood-resilience planning is the ability of the upland (away from the rivers and streams) landscapes to soak up and hold water in extreme rainfall events. The more opportunities taken to allow water to absorb more gradually, and move slowly to the riverways, the lower the flood risk.

Becoming more resilient to the increasing flood risk in this way includes both large scale and micro-scale, and both regulatory and voluntary mechanisms which municipalities can catalyze.

Examples include planning protocols that require more boulevards, fields, and other infiltration areas; information and incentives for voluntary micro-measures such as vegetated swales, curb removal, green roofs, and constructed wetlands.

Resources

- Reduce Impervious Surfaces - Vermont Green Infrastructure Initiative
- Reduce Impervious Surfaces (CRD)
- Boston Groundwater Conservation Overlay District
- California Water Plan Update, Recharge Areas Protection
- Groundwater Protection Through Local Land-use Controls
- Resilient Design Principles (Resilient Design Institute)
- Riparia Ltd (Calgary-based landscape architecture firm)

- Greenfield Tool Box: Ecological Infrastructure Modeling
- Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide
- Green Infrastructure in Calgary's Mobility Corridors
- Provincial Groundwater Inventory Program (Alberta Geological Survey)
- Best Practices for Reducing the Risk of Future Damage to Homes from Riverine and Urban Flooding
- Comprehensive Stormwater Management Master Plan Guidelines:
- Flood Mitigation Methods (Alberta Water Portal)
- Innovative Stormwater Management Practices
- Tools of the Trade: Urban Environmental Improvement Options

Plan for 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

Climate proof culvert infrastructure

A significant component of flooding and the damage it causes is as a result of blocked culverts. Because a significant proportion of a municipality's budget is road maintenance, this is both a challenge and an opportunity for adapting to an increasing number and intensity of floods.

There are several aspects of adaption related to culverts which municipalities can readily incorporate. Maintenance and upgrade schedules for culverts should be updated based on climate change projections. Inspection protocols should be adapted to account for increased frequency and severity of flood events. At the design and construction phases, municipalities should seek to minimize the number of stream culverts they create, identifying more robust mechanisms for accommodating swollen streams. Upstream of culverts, there should be an effort to minimize 'straightening' of waterways, as straighter

channels exponentially increase the speed - and therefore the scouring power - of streams.

Resources

- Innovative Stormwater Management Practices
- Innovative Stormwater Management: Translating Science Into Actions
- Integrated Stormwater Management Plans: Lessons Learned to 2011 (Metro Vancouver)
- Impacts of Climate Change on Stormwater Management (Town of Stratford)
- Comprehensive Stormwater Management Master Plan Guidelines:
- City of Castlegar - Stormwater Infrastructure Climate Change Vulnerability Assessment
- Green Infrastructure in Calgary's Mobility Corridors

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

Reduce channelization of waterways

When water flow is doubled, it's ability to carry sediment is increased by four times. This scouring power leads to greater downstream damage in a heavy rainfall event (more debris carried to culverts and bridges, greater siltation, greater bank erosion). As flooding due to heavy rainfall events is projected to increase under a changing climate regime, this dilemma will be worsened.

A fundamental principle for reducing flood damage, therefore, is to slow the water down. Unfortunately, our tendency has been to straighten waterways for efficiency purposes, increasing the speed of the water, and increasing the flood damage risk.

Municipalities can reduce this issue by promoting the maintenance or creation of meanders in streams and other waterways. This is particularly the case at the planning stage, where Area Structure Plans (especially larger ones) can require the maintenance of stream meanders, and park planning can promote greater capacity for stream meanders and migration. These meanders also increase visual interest on the landscape, and habitat conservation.

Additionally, municipalities can ensure these considerations are included in upstream planning through Integrated Watershed Management Plans. In local or regional cases, an assessment of the requirement for the stream to migrate is needed, which can then inform the development of riverine development buffers.

RESOURCES

- Alberta Riparian Habitat Management Society (Cows and Fish)
- Adaptive Land use for Flood Alleviation (EU)
- Room for the River (Netherlands)
- Climate Change Adaptation Planning: A Handbook for Small Canadian Communities
- Resilient Design Principles (Resilient Design Institute)
- Toward a Resilient Watershed: Addressing Climate Change Planning in Watershed Assessments
- Provincial Wetland Restoration Guide
- Riparia Ltd (Calgary-based landscape architecture firm)
- Communities Adapting to Climate Change Initiative (Columbia Basin Trust)
- 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
- Ecological Infrastructure in the Calgary Region: What We Now Know
- Flood Hazard Identification / Mapping / Studies (Alberta Environment and Sustainable Resource Development)
- Preparing for a Changing Climate: Washington State's Integrated Climate response Strategy
- A Guide for Incorporating Adaptation to Climate Change into Land-use Planning
- Alberta Flow Quantity Index
- Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-wide
- Beaver, Climate Change and Resilience; Seventh Generation Institute
- Leave it to Beavers; Miistakis Institute
- Beaver As a Climate Change Adaptation Tool: Concepts and Priority Sites in New Mexico
- Centre for Hydrology, University of Saskatchewan
- City of Castlegar - Stormwater Infrastructure Climate Change Vulnerability Assessment
- District of Squamish Integrated Flood Hazard Management Plan
- Flood Mitigation Methods (Alberta Water Portal)
- Real time hydrometric data
- Riparian Area in Calgary (City of Calgary)
- Riparian Land Conservation and Management (Rocky View County)
- Source of Opportunity: A Blueprint for Securing Source Water in Southern Alberta
- Tools of the Trade: Urban Environmental Improvement Options

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.

- 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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