



Miistakis
Institute

Municipal Flood and Drought Action Planning Primer



Innovative research. Engaged communities. Healthy landscapes.

PREPARED BY

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01 Overview: Planning for Flood and Drought

This Primer uses a question and answer approach to provide a starting point for municipal staff and elected officials thinking about initiating a flood and drought mitigation planning process.

The Flood and Drought Primer is the first part of a two-part process. The intent of the Primer is to provide a starting point for municipalities to understand the type of information, data, and programs available to inform and support flood and drought mitigation planning. The second part of the process (not yet underway) will be to develop a step-by-step guide for municipalities to develop their own flood and drought mitigation plans. While this project is focused on the South Saskatchewan River Basin because of the risk of flood and drought, the Primer could be used by any municipality in Alberta.

From a municipal planning perspective, some initial questions may be:

- what monitoring is done?
- who is monitoring?
- what do I need to consider when talking about flood and drought?
- what types of actions may be identified as a result of a flood and drought mitigation planning process?



02 Why Plan for Flood and Drought?

The water supply outlook for Alberta predicts longer, more frequent droughts and increases in flooding events. Municipalities that have implemented mitigation strategies will have a shorter recovery time and reduced impacts on residents and infrastructure than those who have not.

(ALBERTA ENVIRONMENT AND SUSTAINABLE RESOURCE DEVELOPMENT, 2012; ALBERTA WATERPORTAL, 2017C; ALL ONE SKY FOUNDATION, ALBERTA BIODIVERSITY MONITORING INSTITUTE, MUNICIPAL CLIMATE CHANGE ACTION CENTRE, & MIISTAKIS INSTITUTE, N.D.; MIISTAKIS INSTITUTE, 2014; WATERSMART SOLUTIONS LTD., 2013)

2017 Weather Stories

Wettest spring followed by driest summer ever

Bridge washed out by flooding Summer electricity use pushed to all-time highs

Grazing land dried up

Less than half their rainfall during the growing season

Wildfires raged Record breaking summer temperatures

Heavy rainfall warnings

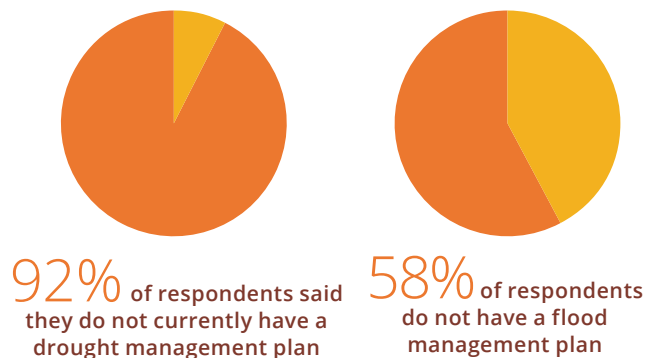
Attendance at outdoor attractions dropped Driest summer in 70 years

Impacts related to weather extremes will affect our water supply and water quality provincially, regionally and locally. The main objective of municipal flood and drought planning is to preserve essential public services and minimize the adverse effects of a water supply emergency on public health and safety, economic activity, environmental resources, and individual lifestyles. Effective mitigation plans remove the “crisis” from response efforts, reduce the hardship caused by water events, and raise public confidence in the actions taken to address the issue (Colorado Water Conservation Board, 2013).

Studies have shown the crisis management approach used in many municipalities, states and provinces has proved to be ineffective over the long term and in the context of more frequent, severe extremes in weather and events. The realization that crisis management or reactive planning has been relatively ineffective, has resulted in greater interest in the adoption of a more pro-active, risk based management approach (Wilhite et al., 2005).

The Province is planning for flood and drought at a regional scale but local level action is still required to achieve successful mitigation. In the South Saskatchewan River Basin, local level mitigation planning is not wide spread or a current priority because many municipalities have stated they feel flood and drought planning are Provincial responsibilities.

SURVEY RESULTS: RESPONDENTS IN THE SOUTH SASKATCHEWAN RIVER BASIN WITH NO DROUGHT/FLOOD MANAGEMENT PLAN (26 respondents)



A municipal flood and drought mitigation planning process involves:

- Analysis of water supply in the context of flood and drought impacts;
- Investigating historical floods and droughts have impacted the community in the past;
- Understanding potential impacts of flood and drought today and into the future as a community grows; and,
- Developing strategies around what can be done now to reduce risk to the community.

This type of local process and analysis will not be undertaken at the provincial level so it is up to a municipality to complete this process.

This Primer asks questions from the point of view of a municipal staff person or elected official that is beginning the process of planning for flood and drought mitigation at the local scale.

In the directory, you will find information about:

- Flood and drought priority areas identified by the Province
- Defining flood and drought
- How flood or drought warnings are issued by the Province
- The potential impacts of flood and drought on a municipality
- Examples of actions that could reduce the impacts of flood and drought
- Monitoring data municipalities can use to find out about their flood and drought context (historical, current, projected)
- Potential resources municipalities can use to support local planning for flood and drought.

Highlights from the Flood and Drought Planning Municipal Survey (November 2017):

Currently we feel this [drought management plan] would be more of plan the Province would implement.

...developed a number of storm water management facilities and plans but never a flood management plan. Again, it has never been identified as a municipal issue.

It has never really been identified as a municipal issue.

Not a priority.

Too many other projects underway.

This [flood management plan] would be a higher priority than a drought mitigation plan. Lots of work and planning is underway to mitigate flooding though I would not specifically call it a flood management plan. It's more of a drainage management strategy.

Not a priority at this time.

Council has not addressed this matter.

We have water conservation protocols on our public water systems but have not considered an overall plan.

Not a priority of Council at this point.

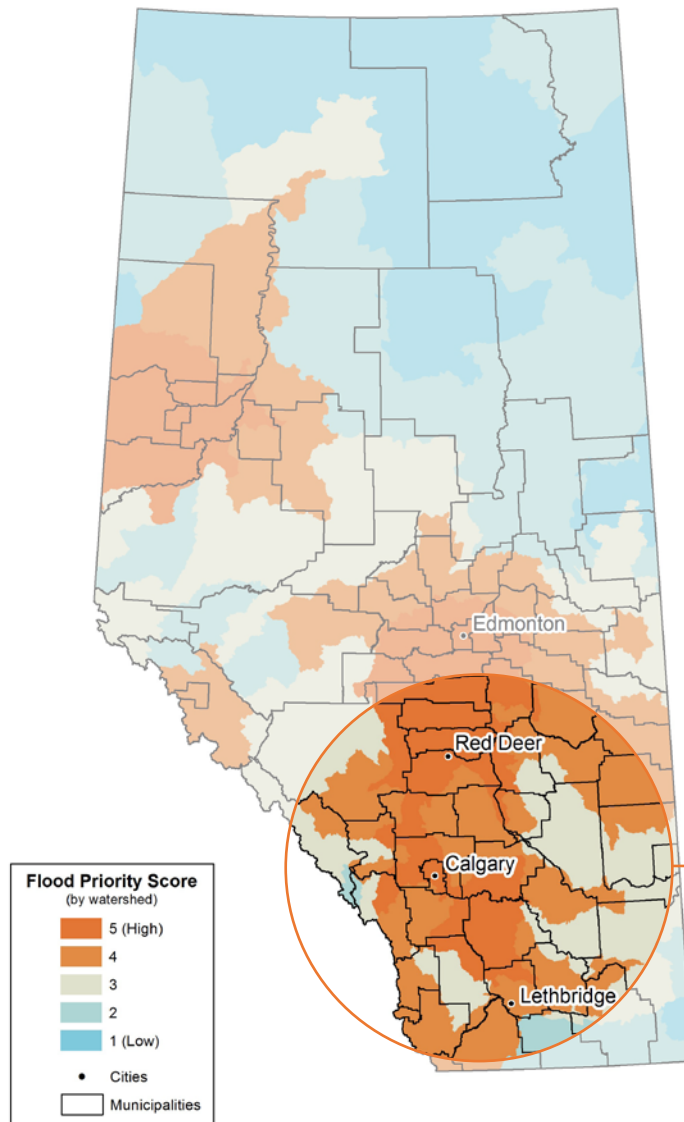
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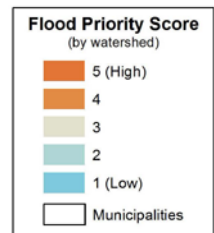
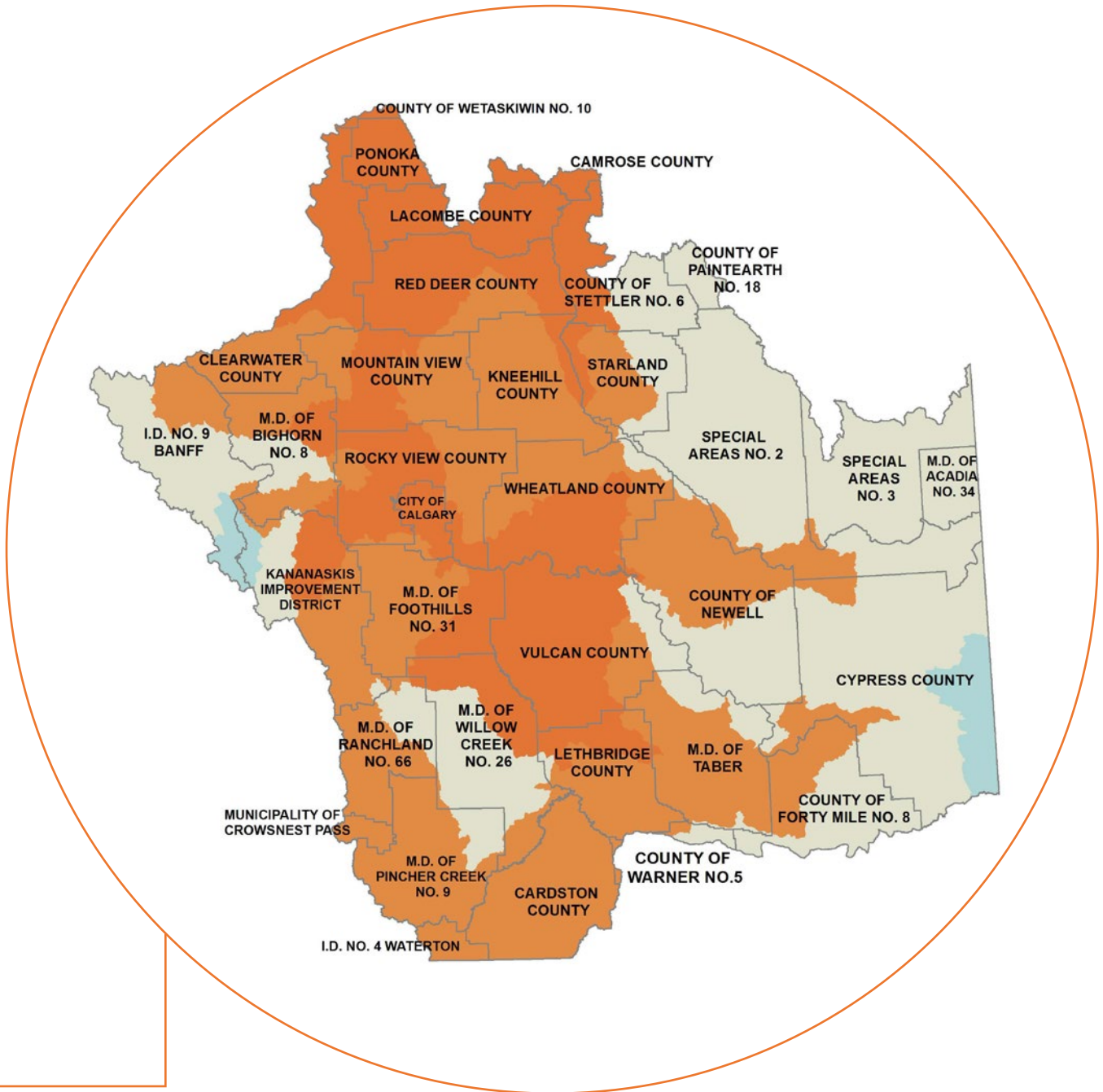
Is flood or drought a high risk for my municipality?

The Government of Alberta developed the following maps using criteria to identify areas of risk for flood and drought. This is at the provincial scale, so will not be detailed enough for local level assessment but will provide a municipality with an indication of whether they should consider prioritizing flood and drought mitigation planning.



Flood priority areas in the South Saskatchewan River Basin





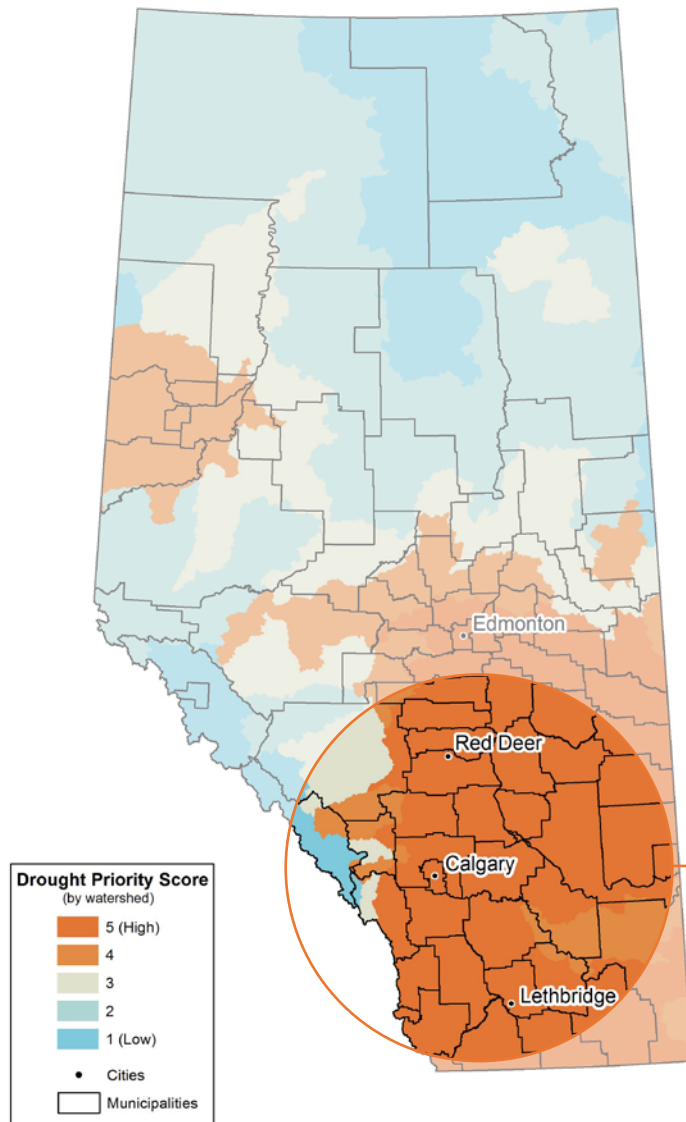
Summit Environmental Consultants Inc., Fiera Biological Consulting, & Associated Engineering, 2015

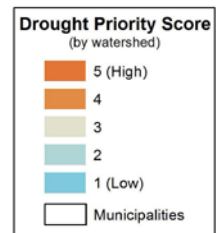
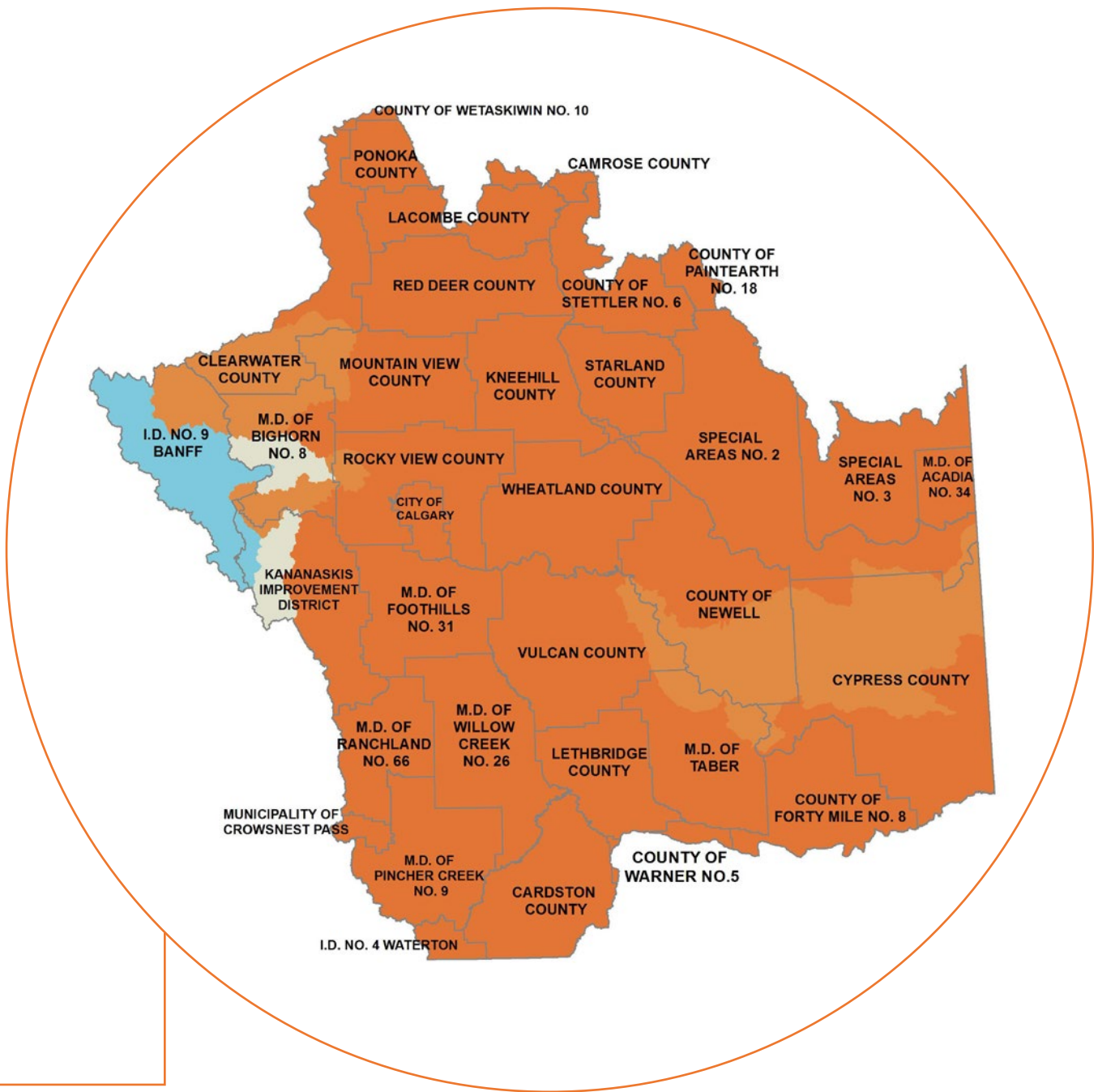
To understand which areas of the province were at the highest risk, maps were developed using specific indicators representing criteria related to hazard, consequence, and resilience. These maps were done by watershed but provide municipalities with an indication of whether they are in a high priority flood or drought risk area.

See appendix A for an overview of the indicators and criteria used to assess hazard, consequence and resilience at a watershed scale.



Drought priority areas in the South Saskatchewan River Basin





Summit Environmental Consultants Inc., Fiera Biological Consulting, & Associated Engineering, 2015

04 How is flood defined?

Flooding is slightly less complex to define than drought because it is a tangible event that is typically a quick onset. The following examples are flood definitions from different provincial departments and organizations. As part of a flood mitigation planning process, it will be important for municipalities to define flood for their community. The examples below provide a starting point.

Resources

Agriculture Drought and Excess Moisture Risk Management Plan for Alberta

Alberta Agriculture and Forestry

For the purposes of the Alberta Drought and Excess Moisture Risk Management Plan, “‘excess moisture’ is defined as excess rains or sudden melting of snow or river or lake floods, resulting in water covering land that is normally dry land.”

(ALBERTA AGRICULTURE AND FORESTRY, 2016A)

Stepping Back from the Water: A Beneficial Management Practices Guide for New Development Near Water Bodies in Alberta’s Settled Region

Alberta Environment and Sustainable Resource Development

“Floods occur when excess water goes over the top of the watercourse bank or beyond the basin of a wetland, pond or lake, and on to the floodplain.”

Many municipalities use the following definitions in their municipal development plans and land use bylaws to define areas subject to flooding in their municipality.

Floodplain (flood hazard area): “A floodplain consists of the low-lying land next to a watercourse that is subject to periodic inundation. A 1:100- year floodplain, which is the result of a flood having a 1 per cent chance of being equalled or exceeded in any given year, is used for purposes of development. In the absence of information that identifies the 1:100-year floodplain elevation, the best available information must be used to establish the historic high-water level for a water body. The floodplain can be divided into two zones once a flood hazard mapping study has been completed:

1. **Floodway:** the area within which the entire design flood can be conveyed while meeting certain water elevation rise, water velocity and water depth criteria. Typically, the floodway includes the river channel and some adjacent overbank areas.
2. **Flood Fringe:** the land along the edges of the flood risk area that has relatively shallow water (less than 1 metre deep) with lower velocities (less than 1 metre/s).”

(ALBERTA ENVIRONMENT AND SUSTAINABLE RESOURCE DEVELOPMENT, 2012)

Flood Hazard Identification Program Guidelines

Alberta Environment: Water Management Operations – River Forecast Section

Although the following descriptions are similar to the information from Stepping Back from the Water, the Flood Hazard Identification description provides a water level rise of “0.3 metres or more”.

Regulatory Flood: 1 in 100 years

Floodway: the floodway includes areas where the water is one metre deep or greater, the local velocities are one metre per second or faster and if the river were encroached upon, the water level rise would be 0.3 metres or more.

Flood Fringe: the flood fringe is the land along the edges of the flood hazard area that has relatively shallow water (less than one metre deep) with lower velocities (less than one metre per second).

(ALBERTA ENVIRONMENT: WATER MANAGEMENT OPERATIONS - RIVER FORECAST SECTION, 2011)

05

How is drought defined?

Defining drought is not as straight forward as defining flood. Flooding is a distinct event; drought evolves overtime and does not have a clear start and end. In Alberta, there are several ways drought is being defined. Each municipality will need to define drought according to their context and needs.

“Preparing for and developing policy is challenging because of the slow-onset characteristics of drought and the lack of a universal definition. These characteristics make early warning, impact assessment, and response difficult for scientists, natural resource managers, and policy makers. The lack of a universal definition often leads to confusion and inaction on the part of decision makers because scientists may disagree on the existence of drought conditions and severity. Severity is also difficult to characterize because it is best evaluated on the basis of multiple indicators and indices rather than a single variable.”
P. 95 – 96 (WILHITE ET AL., 2005).

Drought and water scarcity are related but not the same thing. Water scarcity can be described as an excess of water demand over available supply and can result from existing institutional arrangements, overdevelopment or over allocation of the water resource. Water scarcity can be exacerbated by drought in that drought affects the supply side due to a deficiency of precipitation (WILHITE, 2009).

Municipalities will have varied impact areas* to analyze and need to define drought according to their context. Drought definitions tend to consider:

- time/duration (i.e. more than 1 season)
- severity
- sectors impacted (i.e. agriculture, municipal water supply, recreation, etc.)
- natural precipitation levels (and the affects on available supply)

* See page 10 for impact area examples

Resources

What is Drought

Alberta WaterPortal Society

“In the simplest terms, drought is the absence of water over an extended period of time. There are different ways drought can occur, and for this reason, there are four different definitions of drought. Drought is something that happens slowly, and as “persistent and abnormal moisture deficiency” [(National Weather Service, n.d.)] continues, ecosystems, people and the economy can be adversely impacted.”

“TYPES OF DROUGHT

Drought is a natural occurrence that is part of the climate cycle. Drought can develop in any region and can last for a varying length of time: anywhere from a matter of weeks (“flash droughts”) to decades [(National Weather Service, n.d.)].

There are four classifications of drought. All of these drought types can occur simultaneously, but they can also occur independently of one another.

Meteorological Drought: Meteorological drought usually comes before other forms of drought, and is a result of less precipitation than normal over a prolonged period in a specific region. Meteorological drought can begin and end quickly, or it can continue on for a longer period of time.

Agricultural Drought: Agricultural drought occurs when there is not enough soil moisture to meet the needs of crops. Agricultural drought is usually the next type of drought to occur after meteorological drought. Agricultural drought can occur without affecting water supply for other uses, such as municipal drinking water.

Hydrological Drought: Hydrological drought occurs when lake, river, reservoir or groundwater supplies fall to below average levels due to a lack of precipitation. Hydrological drought occurs much more slowly than meteorological and/or agricultural drought, as it depletes water that is stored but not easily replenished.

Socioeconomic Drought: Socioeconomic drought occurs when the prolonged absence of water in a region begins to impact people and the economy.”

Alberta’s Agriculture Drought and Excess Moisture Risk Management Plan

Alberta Agriculture and Forestry

“For the purposes of the Alberta Drought and Excess Moisture Risk Management Plan, “Drought” is defined as an extended period of below-normal precipitation resulting in decreased soil and subsoil moisture levels and diminished surface water supplies affecting crop growth, livestock water and irrigation water”

(ALBERTA AGRICULTURE AND FORESTRY, 2016B).

Water Quantity: Droughts

Government of Canada

“A drought is a sustained and regionally extensive occurrence of appreciably below-average natural water availability in the form of precipitation, streamflow, or groundwater. Droughts are natural events of varying duration that have occurred throughout history and they are part of the cyclical fluctuations of our planet’s climate system.

Droughts can occur anywhere. However, regions with a semi-arid or arid climate, and only marginal annual precipitation to meet their water demands, are more vulnerable to droughts. In Canada, southern Saskatchewan and the interior valleys of British Columbia experience frequent droughts.”

(GOVERNMENT OF CANADA, 2014)

What is Drought?

National Drought Mitigation Center

“In the most general sense, drought originates from a deficiency of precipitation over an extended period of time—usually a season or more—resulting in a water shortage for some activity, group, or environmental sector. Its impacts result from the interplay between the natural event (less precipitation than expected) and the demand people place on water supply, and human activities can exacerbate the impacts of drought. Because drought cannot be viewed solely as a physical phenomenon, it is usually defined both conceptually and operationally.”

“Conceptual definitions may also be important in establishing drought policy.”

“Operational definitions help define the onset, severity, and end of droughts. No single operational definition of drought works in all circumstances, and this is a big part of why policy makers, resource planners, and others have more trouble recognizing and planning for drought than they do for other natural disasters.”

(NATIONAL DROUGHT MITIGATION CENTER, 2017)



For an introduction to droughts in Alberta visit the [Alberta Water Council](#) site.

06 How could flooding impact a municipality?

Development has increased the flood-producing characteristics of our rivers and streams with the result that one inch of rainfall now will produce several times the quantity of water flowing down a stream in a given time.

(ASTORINO, 2010).

A flood event may result in numerous impacts to a municipality however these are all context specific and need to be discussed at the local level in order to assess mitigation actions.

(ALBERTA ENVIRONMENT AND SUSTAINABLE RESOURCE DEVELOPMENT, 2012; MIISTAKIS INSTITUTE, 2014)

Impacts from flooding may include:

Environmental Impacts

- Riverbank erosion and sedimentation
- Nutrient and pollution dispersal
- Local landscape alterations/damage
- Fish and wildlife habitat and well-being
- Replenishment of surface and groundwater (considered a positive impact)

Water Supply/Provider Impacts

- Infrastructure damage and/or loss (water treatment, roads, buildings, etc.)
- Water contamination
- Water supply disruption

Community/Citizen Impacts

- Emergency service requirements
- Public safety
- Displacement due to evacuations
- Injury
- Loss of life
- Mental and physical stress
- Reduced quality of life
- Loss of property
- Property damage

Economic Impacts

- Agriculture production/function
- Industry production/function
- Time away from employment
- Insurance
- Cost of recovery
- Diversion of dollars from other areas of the economy (i.e. dollars spent on repairs instead of vacation)

07

How could drought impact a municipality?

Drought is a natural event that results in precipitation deficiencies. As the natural event occurs, emphasis on water and natural resource management increases in order to address the growing socio-economic impacts.

(AMEC Earth & Environmental, 2010; Miistakis Institute, 2014).

Impacts from drought may include:

Environmental Impacts

- Increased risk of frequency and severity of wildfires
- Increased vegetation susceptibility to beetle kill
- Stress to surrounding natural environment
- Loss of wetlands
- Lower streamflows
- Lower lake/reservoir levels
- Increased susceptibility to plant disease
- Increased wind and water erosion
- Reduced flow from springs
- Air quality effects (i.e. dust and pollutants)
- Visual and landscape quality (i.e., dust, vegetative cover, etc.)
- Stress to fish and other wildlife
- Lower water quality in streams and/or lakes/reservoirs
- Land subsidence

Water Supply/Provider Impacts

- Loss of revenue from reduction in water sales
- Reduction in municipal well production
- Reduction in storage reserves
- Disruption of water supplies
- Degraded water quality
- Higher water treatment costs
- Sediment and fire debris loading to reservoirs following a wildfire
- Increased costs and staff time to implement drought plan
- Increased data/information needs to monitor and implement drought mitigation plan
- Costs to acquire/develop new water supplies/ water rights transfers
- Costs to increase water use efficiency
- Public favorable/unfavorable perception of provider regarding drought response
- Scarcity of equipment and other water related services (i.e., contractors to repair wells)

Community/Citizen Impacts

- Domestic landscaping stressed or killed
- Public landscaping stressed or killed
- Lower quality drinking water (i.e., poor taste and odor)
- Reduced firefighting capability
- Cross-connection contamination as a result of lower pressures
- Increased pollutant concentrations
- Reduced quality of life
- Loss of human life (i.e., heat stress)
- Public safety from wildfires
- Increased respiratory ailments
- Increased disease caused by wildlife concentrations
- Mental and physical stress
- Increased political conflict
- Reduction or modification of recreational activities
- Campfire bans
- Inequal distribution of drought response measure implementation
- Changes to population growth trends (more likely during a long-term drought)
- Heightened awareness about water conservation
- Change in water use behavior to conserve water
- Re-evaluation of social values (priorities, needs, rights)

Economic Impacts

- Decreased land prices
- Land subsidence as a result of groundwater depletions
- Income loss to farmers that indirectly affects municipal businesses
- Loss to recreation and tourist industry
- Reduction of economic development
- Increase in food prices
- Restrictions/limitations on landscaping harms landscaping companies
- Impacts to large scale commercial water users (i.e., golf courses)
- Loss in hydropower energy

08

What kind of actions could reduce the impacts of flooding on our municipality?

There are numerous resources available to municipalities to determine detailed action on how to reduce the impacts of flooding. The list below provides a high-level overview for those considering initiating a flood mitigation strategy. Actions marked with an asterisk (*) have the potential to reduce impacts for both flood and drought.

(Alberta Environment and Sustainable Resource Development, 2012; Alberta Low Impact Development Partnership, 2018b; Alberta North American Waterfowl Management Plan Partnership, 2016; Alberta WaterPortal, 2017b; Bentrup, 2008; Miistakis Institute, 2014; World Wildlife Fund & United States Agency for International Development, 2016).

Complete a local assessment

- Map/identify flood and re-charge zones*
- Identify wetland complexes of importance*
- Catalogue local ecological infrastructure existence and vulnerability*
- Understand historical and projected changes in local water flow and storage*
- Identify potential impacts on your community related to flood
- Identify water quantity and quality risks* (see impacts section)
- As resources allow, develop a municipal flood mitigation plan that includes operating principles, risk assessment, impact analysis and mitigation actions*
- (See section on resources to support local flood and drought action planning).

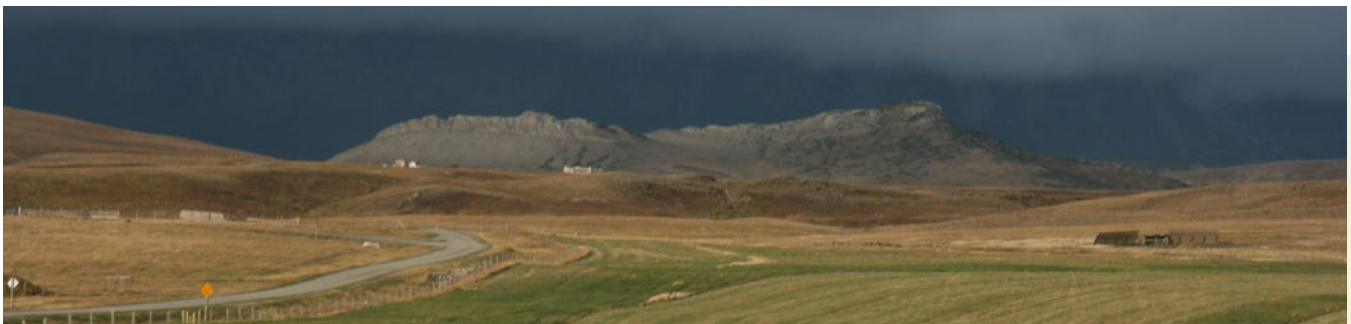
Education and Awareness

This is a suggested action after you have completed a risk assessment and impact analysis related to flood.

- Raise awareness of flood prone areas in your community if sufficient data is available
- Ensure an emergency response plan is in place.

Consider flood-resilient design and low impact development

- Do not development in flood plains
- Reduce impervious surfaces
- Create flood buffers around streams/ivers (See [Stepping Back from the Water](#))
- Improve flood dissipation capability
- Promote beaver reintroduction and retention*
- Construct and restore wetlands*
- Retain native vegetation, especially in riparian areas*
- Protect wetlands and other recharge areas*
- Rainwater harvesting*
- Increase soil depths and reduce compaction*
- Downspout redirection*
- Rain gardens*
- Green roofs
- Biofiltration (sometimes called bioretention)
- Bioswales*
- Tree canopy retention* (reduces erosion)
- Implement flood-resilient building and development standards



09

What kind of actions could reduce the impacts of drought on our municipality?

Many of the actions used to reduce the impacts of flooding also reduce the impacts of drought.

(Alberta Low Impact Development Partnership, 2018a; Alberta North American Waterfowl Management Plan Partnership, 2016; Alberta WaterPortal, 2017a; Miistakis Institute, 2014).

Complete a local assessment

- Map/identify flood and re-charge zones*
- Identify wetland complexes of importance*
- Catalogue local ecological infrastructure existence and vulnerability*
- Understand historical and projected changes in local water flow and storage*
- Identify potential impacts on your community related to drought
- Identify water quantity and quality risks*
- As resources allow, develop a municipal drought mitigation plan that includes operating principles, risk assessment, impact analysis and mitigation actions* (see section on resources to support local flood and drought action planning on page 17).

Education and Awareness

This is a suggested action after you have completed a risk assessment and impact analysis related to drought.

- Raise awareness of projected water insufficiencies
- Incent low-water-use technology
- Raise local awareness of issues and options facing agriculture
- Promote conversions to less water-intensive agriculture
- Promote water-moderate products and businesses

Ecological/Environmental

- Natural feature protection (visit [ALSA Tools Webinars](#))
- Use available wetland planning tools to protect complexes of importance in your municipality*
- Construct wetlands where appropriate*
- Stream channel naturalization/restoration*
- Implement large woody debris on banks*
- Implement riparian buffer zones (see [Stepping Back from the Water](#) *)
- Promote beaver reintroduction and retention*

Low Impact Development

Improve water retention capability through the utilization of low impact development practices that either store water or reduce water consumption.

- Rainwater harvesting*
- Increased soil depths and reduced compaction*
- Downspout redirection*
- Rain gardens*
- Biofiltration (sometimes called bioretention)*
- Stormwater capture and reuse*
- Plant native turf (fescue) and other landscaping, which is drought tolerate (xeriscape) and hardy to our climate
- Bioswales*
- Tree canopy retention*



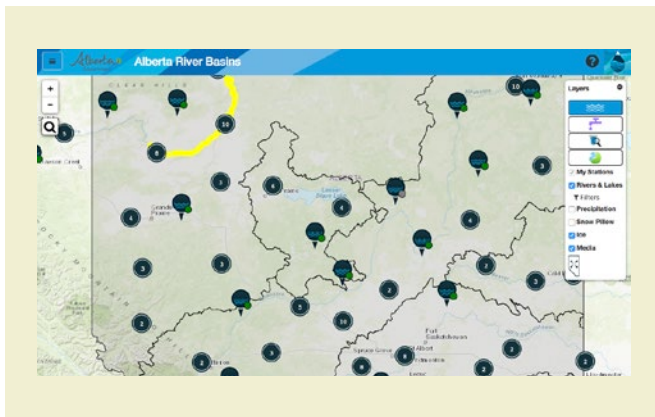
10

What data is used to monitor for flood and drought?

The following Government of Alberta websites provide monitoring and data on local water resources and assets. For municipalities that do not have a system in place to monitor water resources in their area, it is recommended they become familiar with these sites and contact the departments responsible for monitoring if they have questions. During severe weather events such as flooding, public warnings will be issued.

Alberta River Basins

rivers.alberta.ca



The Government of Alberta has created an interactive map that provides real-time records for:

- low flow, water shortage and flood warnings;
- monthly water supply forecasts;
- data for flood forecasting.

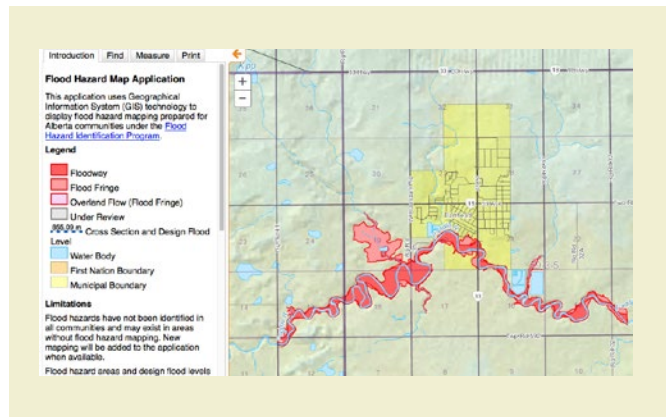
The menu (top left corner of page) shows further information and is linked to other recent data.

Data is monitored daily and on a real-time basis from weather monitoring stations and stream gauges throughout the province.

A smartphone version of this website is available as well. Search for Alberta Rivers: Data and Advisories, available for iOS and Android. This site will provide valuable information for those municipalities that require water supply data in and around their area (especially upstream).

Flood Hazard Mapping

maps.srd.alberta.ca/FloodHazard/

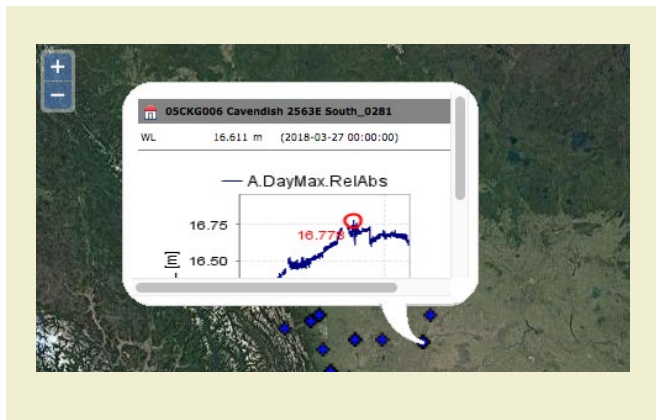


Flood hazard mapping delineates flood hazard areas along streams and lakes using design flood levels (100-year flood) established as part of flood hazard studies. The maps completed to date show the floodway, flood fringe and overland flow area.

Flood hazards have not been identified in all communities and may exist in areas without flood hazard studies or mapping.

Alberta Well Monitoring

www.environment.alberta.ca/apps/GOWN/



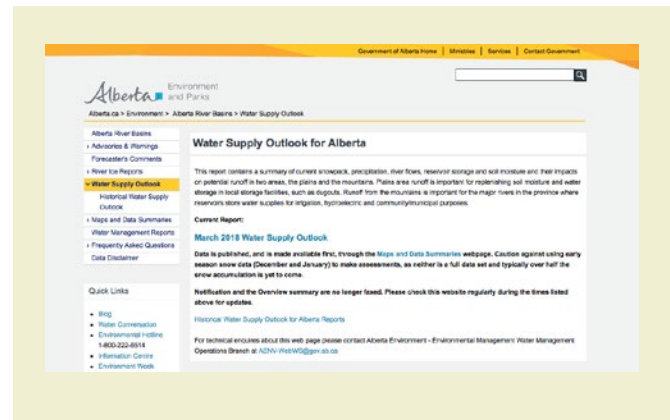
Provides current and historical water and additional geographic data for monitoring stations across the province of Alberta.

Data is provided from the date the station was set up, to the current date. Data is available in a table format or as a map and includes:

- Well depth
- Water level elevation
- River basin name
- Aquifer name
- Formation
- Lithology
- Aquifer type
- Equipment installation and drill dates
- Station location information including imagery
- Well elevation
- Production interval
- Data type
- Station status
- Relative Elevation
- Geodetic Elevation

Water Supply Outlook for Alberta

www.environment.alberta.ca/forecasting/WaterSupply



Plains area runoff is important for replenishing soil moisture and water storage in local storage facilities, such as dugouts. Runoff from the mountains is important for the major rivers in the province where reservoirs store water supplies for irrigation, hydroelectric and community/municipal purposes.

This webpage contains a summary of current:

- mountain runoff forecasts (natural volumes by river basin)
- mountain snowpack (accumulation by river basin)
- plains snowpack (estimate of plains snow water equivalent, maps of accumulations and compared to normal)
- precipitation (percent of normal for the past month, current and recent seasons, amounts for the most recent day, week and month, as well as long lead precipitation outlooks)
- reservoir storage (Provincial reservoir storage summary)
- soil moisture (for non-mountainous regions)

Historical water supply reports dating back to 2000 can be found on the [Alberta Environment and Parks website](http://www.alberta.ca/Alberta-Environment-and-Parks-website).

The information provided on this webpage will be helpful for municipalities beginning to plan for flood and drought as a historical impact analysis is a step in that process.

For information about weather and climate data visit [Alberta Climate and Atlas Maps](#) at the Alberta Climate Information Service (ACIS) website.

11

How does the Province monitor for flood and drought?

The Provincial Government has monitoring systems in place for high and prolonged low water events. There are systems in place to notify the public of emergency flood events and a notification process in place for when a water shortage has been forecast.

Flood

www.emergencyalert.alberta.ca

Alberta's river forecasting system has three main alert levels that are broadcast through Alberta Emergency Alerts, local municipal websites, radio stations and twitter. For each level, municipalities will be expected to monitor areas and keep public informed and potentially recommend steps to minimize damage and ensure public safety. The flood alert levels include:

High Streamflow Advisories

Stream levels are rising and are expected to rise rapidly. Minor flooding in low-lying areas is expected.

Flood Watches

Stream levels are rising and will approach or exceed river, lake or stream banks. Flooding of the adjacent areas may occur.

Flood Warnings

Rising stream levels will result in flooding of adjacent areas. There is a likelihood that overland flooding will occur.



The Alberta Emergency Alert provides critical information about an immediate disaster, where it is occurring and what action you need to take. You can subscribe through the website or download the app to your mobile device at www.emergencyalert.alberta.ca

Drought

According to AENV Water Shortage Procedures for the South Saskatchewan River Basin, 2009 (Alberta Environment, 2009) once a water shortage has been forecast and the information made available, a determination on whether the water shortage will effect household users, licensees, traditional agriculture users, or other provincial responsibilities will be made. The assessment considers reservoir storage, snow pack, predicted precipitation and anticipated demand by all users.

Once the data has been analyzed, and a water shortage of sufficient severity is determined, water shortage management procedures will be activated. These include the following stages:

Stage 1

Normal operations; monitoring for water shortage potentials in water management areas, preparing for water shortages. At this stage, municipalities may be contacted and the following issues considered:

- information on their short term (5 day) forecasted water requirements
- opportunities for water conservation measures may be discussed
- water shortage response plans may be implemented
- a media release to the public may be issued

Stage 2

Priority called in a Water Management Area, water shortage response in Water Management Area. A priority call is when a water users (household user, licensees or traditional agriculture users) are not able to receive their full allocation of water. The District Approvals Manager will assess and respond to the call accordingly.

Stage 3

Large scale water shortage with risk to the majority of household users/ licensees/traditional agricultural users across multiple water management areas of the SSRB or the entire SSRB. Municipalities (and other stakeholders) may be engaged to discuss issues, information on water availability, water conservation practices and consider water sharing possibilities.

Stage 4

Due to unforeseen circumstances that could not be mitigated, the Lieutenant Governor in Council may consider declaring an emergency. The emergency declaration would involve recommendations to the Minister to manage the emergency as needed.

Municipalities with flood and drought mitigation plans in place will have already taken actions to mitigate potential impacts of these events. Having a mitigation plan in place will enable the municipality and community members to be better prepared to address the various levels of response as per the processes shown above.

12

Are there resources available to support local mitigation work?

For municipalities with limited resources interested in developing a drought and/or flood mitigation plan, there is assistance available to help develop your strategies.

Funding

Most of the Provincial funding opportunities for municipalities support capital infrastructure development. However, in a few cases, flood and drought risk assessments are part of the process to gain the capital funding support.

Alberta Community Resilience Program (ACRP)

www.aep.alberta.ca

This is a multi-year grant program supporting the development of long-term resilience to flood and drought events while supporting integrated planning and healthy functioning watersheds. The ACRP program is aimed at the implementation of projects that minimize risks and impacts to municipal infrastructure and help ensure public safety.

The application process requires municipalities to complete a high-level community-wide resilience and mitigation assessment.

Watershed Resiliency and Restoration Program (WRRP)

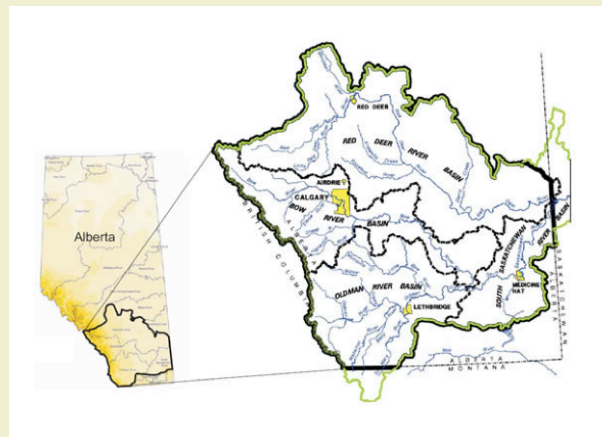
www.aep.alberta.ca

The WRRP is a grant managed by Alberta Environment and Parks. The key goal is to improve natural watershed functions in order to build greater long-term resiliency to flood and droughts. The program supports conservation, education and stewardship, research and data, and restoration and enhancement initiatives. Municipalities interested in developing flood and drought mitigation plans with their community should investigate whether mitigation planning is eligible for funding support under this grant program.

WRRP also promotes [Stepping Back from the Water](#), a guidebook municipalities can use to make decisions about new developments near water bodies.

SOUTH SASKATCHEWAN RIVER BASIN

SOURCE: (ALBERTA ENVIRONMENT AND PARKS, 2015)



Information Resources

Check in with your local Watershed Planning and Advisory Committee (WPAC) to see what resources they have available specific to your watershed. Some WPACs have developed Watershed Management Plans that identify specific actions municipalities can take to plan for flood and drought and improve water quality. South Saskatchewan River Basin WPACs include:

- [Bow River Basin Council](#)
- [Oldman Watershed Council](#)
- [Red Deer River Watershed Alliance](#)
- [South East Alberta Watershed Alliance](#)

To find out about watershed stewardship groups in your area visit www.stewardshipdirectory.com

Numerous additional flood and drought resources collected during this project's research stage are provided in Appendix B.

13

What's Next?

The Miistakis Institute is in the process of creating a guide for municipalities to develop their own local flood and drought mitigation plans.

The guide will consider strategies to:

- make sure the right people are brought together to develop a purpose and set of objectives for the plan;
- complete a risk assessment to construct a vulnerability profile for today and into the future;
- assess potential mitigation strategies;
- establish criteria for determining event triggers and responses to flood and drought; and
- plan development, monitoring, review and updates.

One of the most important aspects of flood and drought mitigation planning is the discussions with community stakeholders so they are informed of the risks, vulnerabilities and actions that may be required to reduce the impacts of flood or drought events.



Please stay tuned to progress on this phase of the **Flood and Drought Action Planning** project by signing up to the Miistakis Miinute newsletter at www.rockies.ca/newsletter

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References

- Alberta Agriculture and Forestry.** (2016a). Agriculture Drought and Excess Moisture Risk Management Plan for Alberta. Retrieved October 24, 2017, from [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/ppe3883](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/ppe3883)
- Alberta Agriculture and Forestry.** (2016b). *Alberta's Agriculture Drought and Excess Moisture Risk Management Plan*. Retrieved from [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/ppe3883/\\$file/2016_06_16_ADEMP_Extreme_Weather_Events.pdf?OpenElement](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/ppe3883/$file/2016_06_16_ADEMP_Extreme_Weather_Events.pdf?OpenElement)
- Alberta Environment.** (2009). *AENV Water Shortage Procedures for the South Saskatchewan River Basin: for Internal Use by Staff of Alberta Environment*. Retrieved from <http://aep.alberta.ca/water/programs-and-services/south-saskatchewan-river-basin-water-information/documents/WaterShortageProcedures-SSRB-Apr2009.pdf>
- Alberta Environment: Water Management Operations - River Forecast Section.** (2011). *Flood Hazard Identification Program Guidelines*. Retrieved from <https://www.alberta.ca/albertacode/images/Flood-Hazard-Identification-Program-Guidelines.pdf>
- Alberta Environment and Parks.** (2015). South Saskatchewan River Basin Water Information. Retrieved February 27, 2018, from <http://aep.alberta.ca/water/programs-and-services/south-saskatchewan-river-basin-water-information/default.aspx>
- Alberta Environment and Sustainable Resource Development.** (2012). *Stepping Back from the Water: A Beneficial Management Practices Guide for New Development Near Water Bodies in Alberta's Settled Region*. Calgary, AB: Her Majesty the Queen in right of the Province of Alberta. Retrieved from <http://aep.alberta.ca/water/education-guidelines/documents/SteppingBackFromWater-Guide-2012.pdf>
- Alberta Low Impact Development Partnership.** (2018a). Natural Feature Protection. Retrieved January 3, 2017, from <http://www.alidp.org/events-and-education/the-lid-toolbox/tools-for-achieving-lower-impact/natural-feature-protection>
- Alberta Low Impact Development Partnership.** (2018b). Tools for Achieving Lower Impact. Retrieved January 3, 2018, from <http://www.alidp.org/resources/the-lid-toolbox/tools-for-achieving-lower-impact>
- Alberta North American Waterfowl Management Plan Partnership.** (2016). *Your Guide to Making Wetlands Work in Your Municipality*. Retrieved from http://www.abnawmp.ca/media/uploads/NAWMP_MunicipalWetlandGuide_Final.pdf
- Alberta WaterPortal.** (2017a). Drought Mitigation Methods. Retrieved November 24, 2017, from <https://albertawater.com/drought-mitigation>
- Alberta WaterPortal.** (2017b). Flood Mitigation Methods. Retrieved November 24, 2017, from <https://albertawater.com/flood-mitigation>
- Alberta WaterPortal.** (2017c). The History of Climate in Alberta and Effects of Climate Change on Alberta's Watersheds. Retrieved December 13, 2017, from <https://albertawater.com/history-and-effects-of-climate-change-on-alberta-s-watersheds>

- Alberta WaterPortal. (2017d). What is Drought? Retrieved November 24, 2017, from <https://albertawater.com/what-is-drought>
- All One Sky Foundation, Alberta Biodiversity Monitoring Institute, Municipal Climate Change Action Centre, & Miistakis Institute. (n.d.). Climate Resilience Express. Retrieved October 31, 2017, from <http://allonesky.ca/climate-resilience-express-project/>
- AMEC Earth & Environmental. (2010). *Municipal Drought Management Plan Guidance Document*. Denver, CO.
- Astorino, R. P. (2010). *Flooding and Land Use Planning: A Guidance Document for Municipal Officials and Planners*. White Plains, NY. Retrieved from <http://www.schohariecounty-ny.gov/CountyWebSite/OES/EMO/FloodingandLandUsePlanningAGuidanceDocumentforMunicipalOfficialsandPlanners.pdf>
- Bentrup, G. (2008). *Conservation Buffers: Design Guidelines for Buffers, Corridors, and Greenways*. Gen. Tech. Rep. SRS-109. Asheville, NC.
- Colorado Water Conservation Board. (2013). *Colorado Drought Mitigation and Response Plan*.
- Government of Canada. (2014). Water Quantity: Droughts. Retrieved November 24, 2017, from <https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/droughts.html>
- Miistakis Institute. (2014). Adapt-action. Retrieved October 24, 2017, from <http://www.adaptaction.ca/>
- National Drought Mitigation Center. (2017). What is Drought? Retrieved October 24, 2017, from <http://drought.unl.edu/DroughtBasics/WhatisDrought.aspx>
- National Weather Service. (n.d.). Understanding Drought. *National Weather Service Development Series in Climate Services on Climate Variability*. Retrieved from <http://www.drought.gov/media/imageserver/NIDIS/content/education/comet/climate/drought/player.html>

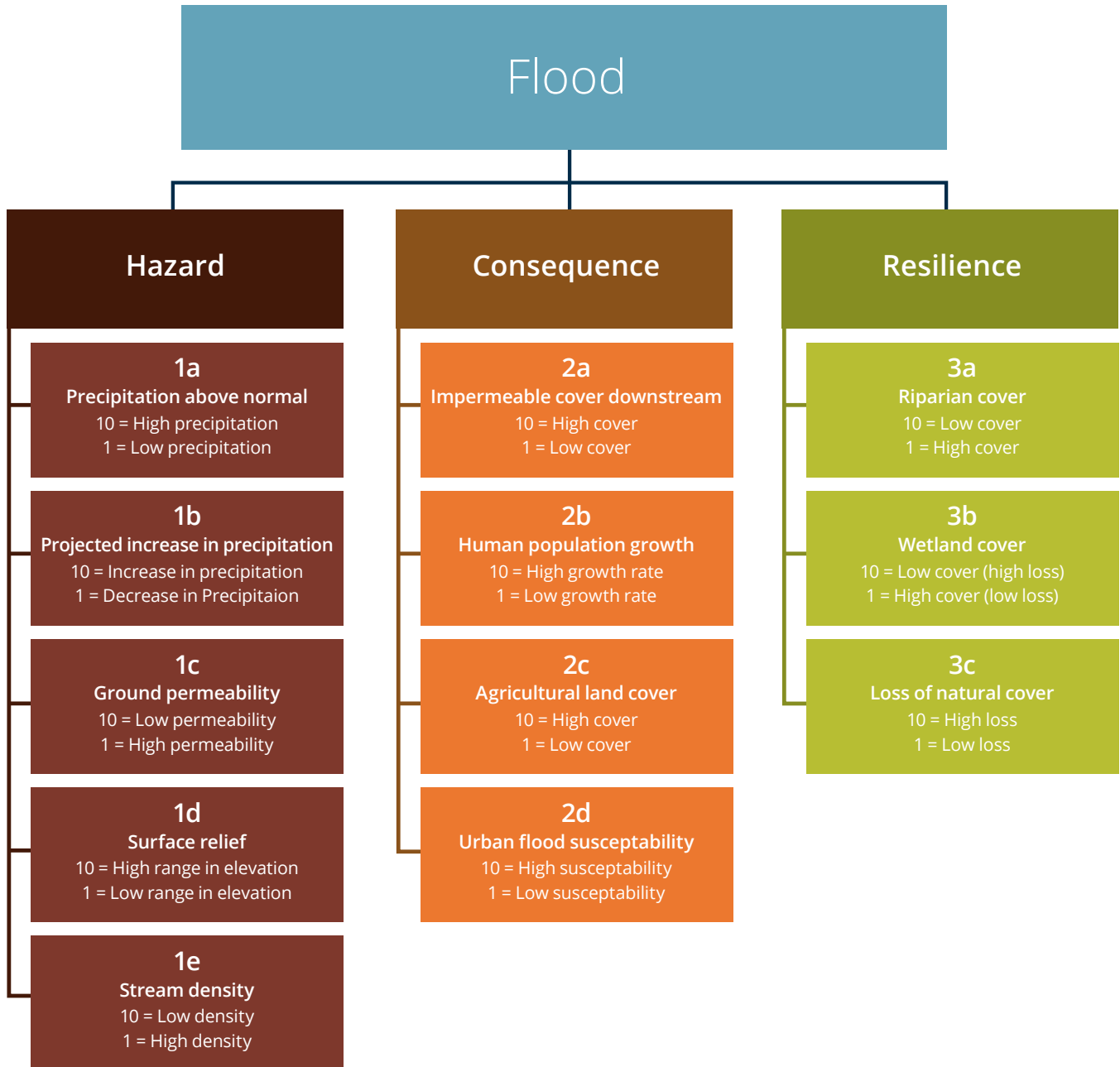


- Summit Environmental Consultants Inc., Fiera Biological Consulting, & Associated Engineering.** (2015). Summary Report: Environment and Sustainable Resource Development: Watershed Resiliency and Restoration Program Prioritization. Retrieved from <http://aep.alberta.ca/water/programs-and-services/watershed-resiliency-and-restoration-program/documents/WatershedResiliencyRestoration-Jan-2015A.pdf>
- United Nations World Water Assessment Programme/UN-Water.** (2018). The United Nations World Water Development Report 2018: Nature-Based Solutions for Water. Paris, France. Retrieved from <http://unesdoc.unesco.org/images/0026/002614/261424e.pdf>
- WaterSMART Solutions Ltd.** (2013). *The 2013 Great Alberta Flood: Actions to Mitigate, Manage, and Control Future Floods*. Retrieved from <http://www.albertawatersmart.com/alberta-flood-2013.html>
- Weber, B.** (2018, January 22). "Definite Trends": New Extreme Weather Index Shows Canada is Getting Hotter and Wetter. *National Post*, p. 1. Retrieved from <http://nationalpost.com/news/canada/insurers-say-canadian-weather-getting-hotter-wetter-and-weirder>
- Wilhite, D. A.** (1991). Drought Planning: a Process for State Government. *JAWRA Journal of the American Water Resources Association*, 27(1), 29–38. <https://doi.org/10.1111/j.1752-1688.1991.tb03110.x>
- Wilhite, D. A.** (2009). *Defining Drought: The Challenge for Early Warning Systems*. Lincoln, NE: University of Nebraska-Lincoln. Retrieved from <http://www.wamis.org/agm/meetings/wies09/S21-Wilhite.pdf>
- Wilhite, D. A., Hayes, M. J., & Knutson, C. L.** (2005). Drought Preparedness Planning: Building Institutional Capacity. In D. A. Wilhite (Ed.), *Drought and Water Crises: Science, Technology, and Management Issues* (pp. 93–136). Boca Raton, FL: CRC Press.
- World Wildlife Fund, & United States Agency for International Development.** (2016). *Natural & Nature-based Flood Management: A Green Guide*. Retrieved December 12, 2017, from <http://envirodm.org/flood-management>

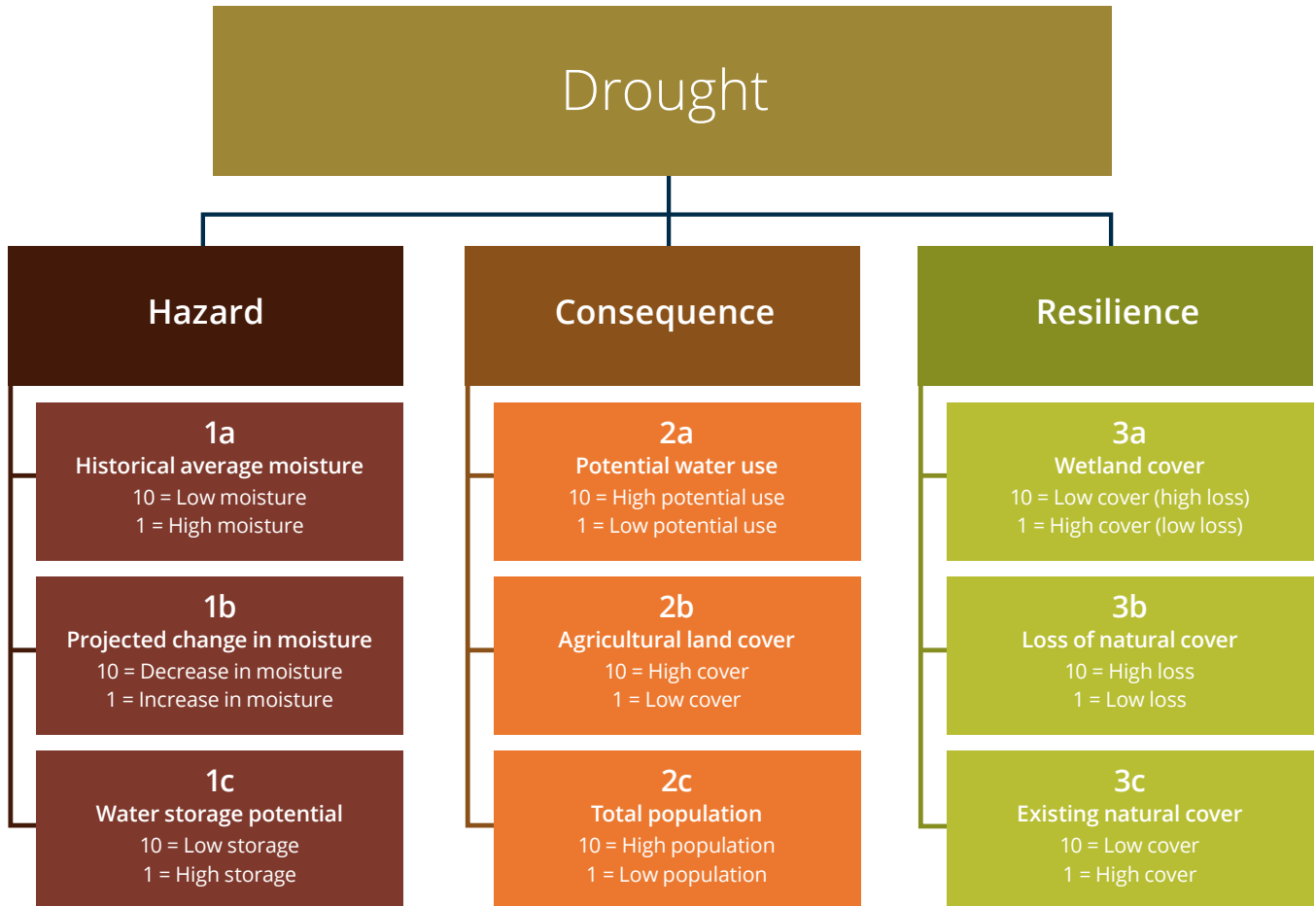


Appendix A

Criteria and indicators used by WRRP to develop the flood priority map shown on page 4:



Criteria and indicators used by WRRP to develop the drought priority map shown on page 5:



Appendix B

Municipal Flood and Drought Action Planning: Background Research Resource List

The following documents, reports and webpages were collected during Phase 1 background research as part of the Municipal Flood and Drought Action Planning project. The information found was reviewed and synthesized into the Flood and Drought Primer, April 2018.

Agriculture and Agri-Food Canada. (2017). Drought Watch. Retrieved January 10, 2018, from <http://www.agr.gc.ca/eng/programs-and-services/list-of-programs-and-services/drought-watch/?id=1461263317515>

Agriculture and Agri-Food Canada. (2018). Canadian Drought Monitor. Retrieved January 10, 2018, from <http://www.agr.gc.ca/eng/programs-and-services/list-of-programs-and-services/drought-watch/canadian-drought-monitor/?id=1463575104513>

Alberta Agriculture and Forestry. (2016a). Agriculture Drought and Excess Moisture Risk Management Plan for Alberta. Retrieved October 24, 2017, from [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/ppe3883](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/ppe3883)

Alberta Agriculture and Forestry. (2016b). *Alberta's Agriculture Drought and Excess Moisture Risk Management Plan*. Retrieved from [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/ppe3883/\\$file/2016_06_16_ADEMP_Extreme_Weather_Events.pdf?OpenElement](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/ppe3883/$file/2016_06_16_ADEMP_Extreme_Weather_Events.pdf?OpenElement)

Alberta Agriculture and Forestry. (2016c). Monitoring and Reporting Precipitation and Soil Moisture Conditions. Retrieved January 8, 2018, from [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/ppe9019](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/ppe9019)

Alberta Agriculture and Forestry. (2017a). Agricultural Moisture Situation Updates. Retrieved January 10, 2018, from [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/ppe9917](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/ppe9917)

Alberta Agriculture and Forestry. (2017b). Alberta Climate and Atlas Maps. Retrieved January 10, 2018, from <https://agriculture.alberta.ca/acis/climate-maps.jsp>

Alberta Agriculture and Forestry. (2017c). Alberta Climate Information Service (ACIS). Retrieved December 13, 2017, from <http://www.agriculture.alberta.ca/acis/>

Alberta Agriculture and Forestry. (2017d). Alberta Crop Report. Retrieved January 10, 2018, from [http://www1.agric.gov.ab.ca/\\$Department/deptdocs.nsf/All/sdd4191](http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/All/sdd4191)

Alberta Association of Municipal Districts and Counties. (n.d.). Integrated Community Sustainability Plan (ICSP) Toolkit. Retrieved October 31, 2017, from <http://aamdc.com/advocacy/toolkits-initiatives/209-integrated-community-sustainability-plan-icsp-toolkit>

Alberta Association of Municipal Districts and Counties. (2017a). *AAMDC Climate Change Advisory Committee - Overview Report*. Retrieved from <http://aamdc.com/archive/aamdc-reports/public-reports/1849-aamdc-climate-change-advisory-committee-final-report/file>

Alberta Association of Municipal Districts and Counties. (2017b). Climate Change Advocacy Position Statements. Alberta Association of Municipal Districts and Counties. Retrieved from <http://aamdc.com/archive/position-statements/may-2017/1851-climate-change-position-statements/file>

- Alberta Environment. (2009a). *AENV Water Shortage Procedures for the South Saskatchewan River Basin: for Internal Use by Staff of Alberta Environment*. Retrieved from <http://aep.alberta.ca/water/programs-and-services/south-saskatchewan-river-basin-water-information/documents/WaterShortageProcedures-SSRB-Apr2009.pdf>
- Alberta Environment. (2009b). *Water Measurement Guidebook*.
- Alberta Environment: Water Management Operations - River Forecast Section. (2011). *Flood Hazard Identification Program Guidelines*. Retrieved from <https://www.alberta.ca/albertacode/images/Flood-Hazard-Identification-Program-Guidelines.pdf>
- Alberta Environment and Parks. (2017). *Riparian Areas and Wetlands Municipal Engagement Needs Assessment Survey Summary*. Retrieved from <http://aep.alberta.ca/water/programs-and-services/watershed-resiliency-and-restoration-program/documents/MunicipalNeedsSurveySummary-Jan2017.pdf>
- Alberta Environment and Parks. (2015a). Snow Data. Retrieved November 28, 2017, from <http://www.environment.alberta.ca/apps/basins/Map.aspx?Basin=8&DataType=4>
- Alberta Environment and Parks. (2015b). South Saskatchewan River Basin Water Information. Retrieved February 27, 2018, from <http://aep.alberta.ca/water/programs-and-services/south-saskatchewan-river-basin-water-information/default.aspx>
- Alberta Environment and Parks. (2016). Flood Hazard Map Application. Retrieved January 8, 2018, from <http://maps.srd.alberta.ca/FloodHazard/>
- Alberta Environment and Parks. (2017a). Alberta Community Resilience Program. Retrieved November 27, 2017, from <http://aep.alberta.ca/water/programs-and-services/alberta-community-resilience-program/default.aspx>
- Alberta Environment and Parks. (2017b). Flood Hazard Mapping. Retrieved December 11, 2017, from <http://aep.alberta.ca/water/programs-and-services/flood-hazard-identification-program/flood-hazard-mapping.aspx>
- Alberta Environment and Parks. (2017c). Flood Mitigation Studies. Retrieved December 13, 2017, from <http://aep.alberta.ca/water/programs-and-services/flood-mitigation/flood-mitigation-studies.aspx>
- Alberta Environment and Parks. (2017d). Legislation/Guidelines. Retrieved January 4, 2018, from <http://aep.alberta.ca/water/legislation-guidelines/default.aspx>
- Alberta Environment and Parks. (2017e). *River Flow Basics*. Canada: YouTube. Retrieved from <https://youtu.be/l2i4BmurcyA>
- Alberta Environment and Parks. (2017f). Watershed Planning and Advisory Councils. Retrieved January 8, 2018, from <http://aep.alberta.ca/water/programs-and-services/water-for-life/partnerships/watershed-planning-and-advisory-councils/default.aspx>
- Alberta Environment and Parks. (2017g). Watershed Resiliency and Restoration Program. Retrieved October 24, 2017, from <http://aep.alberta.ca/water/programs-and-services/watershed-resiliency-and-restoration-program/default.aspx>
- Alberta Environment and Parks. (2018). Water Supply Outlook for Alberta. Retrieved January 10, 2018, from <http://www.environment.alberta.ca/forecasting/WaterSupply/index.html>
- Alberta Environment and Sustainable Resource Development. (2012). *Stepping Back from the Water: A Beneficial Management Practices Guide for New Development Near Water Bodies in Alberta's Settled Region*. Calgary, AB: Her Majesty the Queen in right of the Province of Alberta. Retrieved from <http://aep.alberta.ca/water/education-guidelines/documents/SteppingBackFromWater-Guide-2012.pdf>
- Alberta Innovates Energy and Environment Solutions, & WaterSMART Solutions Ltd. (2014). *Final Report to the Climate Change Emissions Management Corporation. Report prepared for the South Saskatchewan River Basin Adaptation to Climate Variability Project*.

- Alberta Low Impact Development Partnership. (2013). *Low Impact Development Research in Alberta: Background, Partners and Proposed Activities*. Retrieved from http://www.alidp.org/assets/pdfs/occi_alidp_lid_research_-_backgrounder.pdf
- Alberta Low Impact Development Partnership. (2017). Root Systems of Prairie Plants & Plant Zone Schematic. Retrieved January 2, 2018, from <http://www.alidp.org/projects/root-systems-of-prairie-plants-plant-zone-schematic>
- Alberta Low Impact Development Partnership. (2018a). Alberta Low Impact Development Partnership. Retrieved January 2, 2018, from <http://www.alidp.org/>
- Alberta Low Impact Development Partnership. (2018b). Natural Feature Protection. Retrieved January 3, 2017, from <http://www.alidp.org/events-and-education/the-lid-toolbox/tools-for-achieving-lower-impact/natural-feature-protection>
- Alberta Low Impact Development Partnership. (2018c). Tools for Achieving Lower Impact. Retrieved January 3, 2018, from <http://www.alidp.org/resources/the-lid-toolbox/tools-for-achieving-lower-impact>
- Alberta North American Waterfowl Management Plan Partnership. (2016). *Your Guide to Making Wetlands Work in Your Municipality*. Retrieved from http://www.abnawmp.ca/media/uploads/NAWMP_MunicipalWetlandGuide_Final.pdf
- Alberta Urban Municipalities Association, & Alberta Municipal Services Corporation. (n.d.). Achieving Environmental Objectives. Retrieved October 27, 2017, from <https://auma.ca/advocacy-services/programs-initiatives/municipal-planning-hub/how-we-plan/achieving-environmental-objectives>
- Alberta Urban Municipalities Association, & Alberta Municipal Services Corporation. (2014a). 2014 *Municipal Water Policy on Stormwater: Convention Policy Paper*. Retrieved from http://www.auma.ca/sites/default/files/Advocacy/Document_library/80676_stormwater_policy_paper.pdf
- Alberta Urban Municipalities Association, & Alberta Municipal Services Corporation. (2014b). 2014 *Urban Municipal Water Conservation, Efficiency and Productivity Plan – Targets and Actions for the Urban Municipal Sector*. Retrieved from http://www.auma.ca/live/digitalAssets/80/80674_2014_CEP_Plan.pdf
- Alberta WaterPortal. (2017a). Alberta WaterPortal Society. Retrieved November 24, 2017, from <https://albertawater.com/>
- Alberta WaterPortal. (2017b). Drought Forecasting and Monitoring. Retrieved December 13, 2017, from <https://albertawater.com/drought-mitigation/drought-forecasting-and-monitoring>
- Alberta WaterPortal. (2017c). Drought Mitigation Methods. Retrieved November 24, 2017, from <https://albertawater.com/drought-mitigation>
- Alberta WaterPortal. (2017d). Flood Mitigation: Improved Flood Forecasting. Retrieved December 13, 2017, from <https://albertawater.com/flood-mitigation/improved-flood-forecasting#footnote2>
- Alberta WaterPortal. (2017e). Flood Mitigation Methods. Retrieved November 24, 2017, from <https://albertawater.com/flood-mitigation>
- Alberta WaterPortal. (2017f). The History of Climate in Alberta and Effects of Climate Change on Alberta's Watersheds. Retrieved December 13, 2017, from <https://albertawater.com/history-and-effects-of-climate-change-on-alberta-s-watersheds>
- Alberta WaterPortal. (2017g). The History of Climate in Alberta and Effects of Climate Change on Alberta's Watersheds. Retrieved November 6, 2017, from <https://albertawater.com/history-and-effects-of-climate-change-on-alberta-s-watersheds>

- Alberta WaterPortal. (2017h). What is Drought? Retrieved November 24, 2017, from <https://albertawater.com/what-is-drought>
- Alberta WaterPortal. (2017i). What is Flooding. Retrieved November 24, 2017, from <https://albertawater.com/what-is-flooding>
- All One Sky Foundation, Alberta Biodiversity Monitoring Institute, Municipal Climate Change Action Centre, & Miistakis Institute. (n.d.). Climate Resilience Express. Retrieved October 31, 2017, from <http://allonesky.ca/climate-resilience-express-project/>
- AMEC Earth & Environmental. (2010). *Municipal Drought Management Plan Guidance Document*. Denver, CO.
- Astorino, R. P. (2010). *Flooding and Land Use Planning: A Guidance Document for Municipal Officials and Planners*. White Plains, NY. Retrieved from <http://www.schohariecounty-ny.gov/CountyWebSite/OES/EMO/FloodingandLandUsePlanningAGuidanceDocumentforMunicipalOfficialsandPlanners.pdf>
- Bentrup, G. (2008). *Conservation Buffers: Design Guidelines for Buffers, Corridors, and Greenways*. Gen. Tech. Rep. SRS-109. Asheville, NC.
- Bizikova, L., Neale, T., & Burton, I. (2008). *Canadian Communities' Guidebook for Adaptation to Climate Change: Including an Approach to Generate Mitigation Co-Benefits in the Context of Sustainable Development. First Edition*. Retrieved from https://fcm.ca/Documents/tools/PCP/canadian_communities_guidebook_for_adaptation_to_climate_change_EN.pdf
- Bow River Project. (2002). *Protecting Riparian Areas: Creative Approaches to Subdivision Development in the Bow River Basin: A Guide for Municipalities, Developers, and Landowners*. Airdrie, AB.
- British Columbia Ministry of Environment Land and Parks. (1997). Cottonwood Riparian Ecosystems of the Southern Interior. *Ecosystems in British Columbia At Risk*. Government of British Columbia. Retrieved from <http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Ministry+of+Environment,+Lands+and+Parks#7>
- Brown, B., & Davidson, G. (2011). *Climate Change Adaptation Planning: a Handbook for Small Canadian Communities*.
- California Department of Water Resources. (2008). *Urban Drought Guidebook: 2008 Updated Edition*. Retrieved from http://www.water.ca.gov/pubs/planning/urban_drought_guidebook/urban_drought_guidebook_2008.pdf
- California Department of Water Resources. (2016a). *Draft: Central Valley Flood Protection Plan Conservation Strategy*.
- California Department of Water Resources. (2016b). *Draft Central Valley Flood Protection Plan: 2017 Update*. Sacramento, CA.
- Colorado Water Conservation Board. (2013). *Colorado Drought Mitigation and Response Plan*.
- Daniell, K. A., Máñez Costa, M. A., Ferrand, N., Kingsborough, A. B., Coad, P., & Ribarova, I. S. (2011). Aiding multi-level decision-making processes for climate change mitigation and adaptation. *Regional Environmental Change*, 11(2), 243–258. <https://doi.org/10.1007/s10113-010-0162-0>
- Davis, G., Bardini, G. B., & California Department of Water Resources. (2017). *Central Valley Flood Protection Plan: 2017 Update*. Retrieved from <http://www.water.ca.gov/cvfmpl/docs/2017/2017CVFPPUpdate-Final-20170828.pdf>
- DRI: Drought Research Initiative. (n.d.). Data. Retrieved November 28, 2017, from <http://www.meteo.mcgill.ca/dri/data.php>

- Drought Research Initiative Network. (2011). *The 1999-2005 Canadian Prairies Drought: Science, Impacts, and Lessons*. (R. Stewart, R. Lawford, & A.-A. (Technical E. . Boisvert, Eds.). Winnipeg, MB: Drought Research Initiative. Retrieved from [http://www.meteo.mcgill.ca/dri/The 1999-2005 Canadian Prairies Drought - Science, Impacts, and Lessons.pdf](http://www.meteo.mcgill.ca/dri/The%201999-2005%20Canadian%20Prairies%20Drought%20-%20Science,%20Impacts,%20and%20Lessons.pdf)
- Environment and Sustainable Resource Development. (2013). *Alberta Wetland Policy*. Retrieved from [http://aep.alberta.ca/water/programs-and-services/wetlands/documents/ AlbertaWetlandPolicy-Sep2013.pdf](http://aep.alberta.ca/water/programs-and-services/wetlands/documents/AlbertaWetlandPolicy-Sep2013.pdf)
- Environment and Sustainable Resource Development. (2014). *Preparing Water Shortage Response Plans*. Retrieved from [http://aep.alberta.ca/forms-maps-services/directives/ documents/PreparingWaterShortageResponse-Apr23-2014A.pdf](http://aep.alberta.ca/forms-maps-services/directives/documents/PreparingWaterShortageResponse-Apr23-2014A.pdf)
- Global Water Futures. (n.d.). *Global Water Futures: Solutions to Water Threats in an Era of Global Change*. University of Saskatchewan. Retrieved from [https://gwf.usask.ca/ documents/outreach/GWF-four-page-Nov-24.pdf](https://gwf.usask.ca/documents/outreach/GWF-four-page-Nov-24.pdf)
- Government of British Columbia: Deputy Ministers' Committee on Drought. (2016). *Dealing with Drought: A Handbook for Water Suppliers in British Columbia*. Retrieved from [http:// www2.gov.bc.ca/assets/gov/environment/air-land-water/water/drought-info/suppliers_drought_handbook_2009.pdf](http://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/drought-info/suppliers_drought_handbook_2009.pdf)
- Government of Alberta. (2014). *South Saskatchewan Regional Plan 2014-2024*. An Alberta Land-use Framework Integrated Plan.
- Government of Alberta. (2016a). *Alberta Rivers: Data and Advisories App*. Version 3.0.5. Retrieved December 1, 2017, from <https://itunes.apple.com/ca/app/alberta-rivers-data-and-advisories/id888325071?mt=8>
- Government of Alberta. (2016b). *Community Resilience and Mitigation Assessment: Community Resilience Program*. Government of Alberta. Retrieved from [http://aep.alberta.ca/water/programs-and-services/alberta-community-resilience-program/ documents/ResilienceMitigationAssessment-Jul19-2016.pdf](http://aep.alberta.ca/water/programs-and-services/alberta-community-resilience-program/documents/ResilienceMitigationAssessment-Jul19-2016.pdf)
- Government of Alberta. (2016c). *Priority Areas Maps*. Retrieved from [http://aep.alberta.ca/water/programs-and-services/watershed-resiliency-and-restoration-program/ documents/WRRP-PriorityMaps-Jul29-2016.pdf](http://aep.alberta.ca/water/programs-and-services/watershed-resiliency-and-restoration-program/documents/WRRP-PriorityMaps-Jul29-2016.pdf)
- Government of Alberta. (2017a). *Alberta Monitoring Site*. Retrieved December 1, 2017, from <http://environment.alberta.ca/apps/GOWN/>
- Government of Alberta. (2017b). *Alberta River Basins*. Retrieved December 1, 2017, from <https://rivers.alberta.ca/>
- Government of Alberta. (2018). *Alberta Water Wells*. Retrieved January 10, 2018, from [http:// groundwater.alberta.ca/WaterWells/d/](http://groundwater.alberta.ca/WaterWells/d/)
- Government of Canada. (2014). *Water Quantity: Droughts*. Retrieved November 24, 2017, from [https://www.canada.ca/en/environment-climate-change/services/water-overview/ quantity/droughts.html](https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/droughts.html)
- Government of Canada. (2016). *Pan-Canadian Framework on Clean Growth and Climate Change*. Retrieved from [https://www.canada.ca/content/dam/themes/environment/ documents/weather1/20170113-1-en.pdf](https://www.canada.ca/content/dam/themes/environment/documents/weather1/20170113-1-en.pdf)
- Government of Canada. (2017a). *Canada's Top 10 Weather Stories 2017*. Retrieved February 27, 2018, from [https://www.canada.ca/en/environment-climate-change/services/top-ten- weather-stories/2017.html](https://www.canada.ca/en/environment-climate-change/services/top-ten-weather-stories/2017.html)
- Government of Canada. (2017b). *Making Communities Flood Ready*. Retrieved July 20, 2007, from <https://www.canada.ca/en/campaign/flood-ready/communities.html>
- Government of Canada. (2017c). *Real-Time Hydrometric Data*. Retrieved January 10, 2018, from https://wateroffice.ec.gc.ca/mainmenu/real_time_data_index_e.html

- Government of Canada. (2017d). Seasonal Forecasts. Retrieved January 10, 2018, from https://weather.gc.ca/saisons/index_e.html
- Government of Canada. (2017e). Weather Information. Retrieved December 13, 2017, from http://www.wateroffice.ec.gc.ca/index_e.html
- Government of Canada. (2018). Canada's Top Ten Weather Stories. Retrieved from <https://www.canada.ca/en/environment-climate-change/services/top-ten-weather-stories.html>
- Hill, H., Hadarits, M., Rieger, R., Strickert, G., Davies, E. G. R., & Strobbe, K. M. (2014). The Invitational Drought Tournament: What is it and why is it a useful tool for drought preparedness and adaptation? *Weather and Climate Extremes*, 3, 107–116. <https://doi.org/10.1016/j.wace.2014.03.002>
- IBI Group, & Golder Associates Ltd. (2015). *Provincial Flood Damage Assessment Study Report*. Retrieved from <https://open.alberta.ca/dataset/807b9710-0867-453e-8fa7-50c239bcd7d0/resource/f2d0a88c-b04b-4a39-af76-0aa8cd1e880b/download/pfdas-alberta-main.pdf>
- ICLEI Local Governments for Sustainability. (2010). *Changing Climate, Changing Communities: A Guide and Workbook for Municipal Climate Adaptation*. ICLEI - Local Governments for Sustainability. Toronto, ON. Retrieved from <http://www.iclei.org/index.php?id=8708>
- Institute for Sustainable Infrastructure. (2016). Join the Institute for Sustainable Infrastructure. Washington, D.C.: Institute for Sustainable Infrastructure. Retrieved from <https://sustainableinfrastructure.org/brochure/isi-corporate-membership-brochure/>
- ISL Engineering and Land Services Ltd. (2014). *Town of Okotoks: Final Report: Stormwater Management Master Plan and Flood Mitigation Plan*. Okotoks, AB. Retrieved from http://www.okotoks.ca/sites/default/files/pdfs/publications/25476_PDF_for_submission_Final_Stamped.pdf
- James C. Schwab (Ed.). (2013). *Planning and Drought*. American Planning Association: Planning Advisory Service. Chicago, IL. Retrieved from <http://drought.unl.edu/Planning/PlanningProcesses/PlanningandDrought.aspx>
- Johnson, C. W., & Buffler, S. (2008). *Riparian Buffer Design Guidelines for Water Quality and Wildlife Habitat Functions on Agricultural Landscapes in the Intermountain West*. Gen. Tech. Rep. RMRS-GTR-203. Fort Collins, CO. [https://doi.org/Technical Report RMRS-GTR-203](https://doi.org/Technical%20Report%20RMRS-GTR-203)
- Joyce, L. A., Briske, D. D., Brown, J. R., Polley, H. W., McCarl, B. A., & Bailey, D. W. (2013). Climate Change and North American Rangelands: Assessment of Mitigation and Adaptation Strategies. *Rangeland Ecology & Management*, 66(5), 512–528. <https://doi.org/10.2111/REM-D-12-00142.1>
- Larson, R. P., Byrne, J. M., Johnson, D. L., Kienzie, S. W., & Letts, M. G. (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*, 36(1), 35–52. <https://doi.org/10.4296/cwrj3601035>
- Lenarduzzi, A., Zimmer, C., Waterfiel, A., James, P., & Schembri, C. (n.d.). *Grey to Green Enhanced Stormwater Management Master Planning: Guide to Optimizing Municipal Infrastructure Assets and Reducing Risk*. Mississauga, Ontario. Retrieved from <http://www.creditvalleyca.ca/wp-content/uploads/2016/01/ORGuide.pdf>
- Miistakis Institute. (2014a). Adapt-action. Retrieved October 24, 2017, from <http://www.adaptaction.ca/>
- Miistakis Institute. (2014b). Adapt-action: Adapting to Floods. Retrieved February 24, 2018, from <http://www.adaptaction.ca/page2.php?nar=1>
- Miistakis Institute. (2014c). Adapt-action: Adapting to Water Scarcity. Retrieved February 24, 2018, from <http://www.adaptaction.ca/page2.php?nar=1>

- Moudrak, N., & Feltmate, B. (2017). *Preventing Disaster Before it Strikes: Developing a Canadian Standard for New Flood-Resilient Residential Communities*.
- Moudrak, N., Hutter, A., & Feltmate, B. (2017). *When the Big Storms Hit: the Role of Wetlands to Limit Urban and Rural Flood Damage*. Waterloo, ON. Retrieved from <http://www.intactcentreclimateadaptation.ca/wp-content/uploads/2017/07/When-the-Big-Storms-Hit.pdf>
- National Drought Mitigation Center. (2017a). Types of Drought. Retrieved December 11, 2017, from <http://drought.unl.edu/DroughtBasics/TypesofDrought.aspx>
- National Drought Mitigation Center. (2017b). Types of State Drought Plans. Retrieved September 27, 2017, from <http://drought.unl.edu/Planning/DroughtPlans/StateDroughtPlans/Types.aspx>
- National Drought Mitigation Center. (2017c). What is Drought? Retrieved October 24, 2017, from <http://drought.unl.edu/DroughtBasics/WhatisDrought.aspx>
- National Drought Mitigation Center, Oklahoma Climatological Survey, Illinois State Water Survey, & Lower Platte River Corridor Alliance. (2011). *Drought-Ready Communities: A Guide to Community Drought Preparedness*. Lincoln, NE. Retrieved from http://drought.unl.edu/portals/0/docs/DRC_Guide.pdf
- National Weather Service. (n.d.). Understanding Drought. *National Weather Service Development Series in Climate Services on Climate Variability*. Retrieved from <http://www.drought.gov/media/imageserver/NIDIS/content/education/comet/climate/drought/player.html>
- Natural Resources Canada. (2016). Adaptation Planning. Retrieved October 31, 2017, from <http://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/tools-guides/11080>
- Otonabee Region Conservation Authority (ORCA). (2012). *Watershed Planning & Regulation Policy Manual*. Retrieved from <http://www.otonabee.com/wp-content/uploads/2014/04/ORCA-Watershed-Planning-Regulation-Policy-Manual-April-2014-DFO-Strikethroughs.pdf>
- Province of Alberta: Office Consolidation. (2014). *Water Act: Revised Statutes of Alberta 2000 Chapter W-3*. Edmonton, AB. Retrieved from <http://www.qp.alberta.ca/documents/Acts/w03.pdf>
- Public Safety Canada. (2017). National Drought Mitigation Program (NDMP). Retrieved November 27, 2017, from <https://www.publicsafety.gc.ca/cnt/mrgnc-mngmnt/dsstr-prvntn-mtgtn/ndmp/index-en.aspx>
- Richardson, G. R. A., & Otero, J. (2012). *Land Use Planning Tools for Local Adaptation to Climate Change*. Ottawa, ON. Retrieved from <http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/files/landuse-e.pdf>
- Sauchyn, D. (2017). Climate Variability and Change in the Athabasca River Basin. Retrieved from <http://albertawatersmart.com/featured-projects/collaborative-watershed-management.html>
- Summit Environmental Consultants Inc., Fiera Biological Consulting, & Associated Engineering. (2015). *Summary Report: Environment and Sustainable Resource Development: Watershed Resiliency and Restoration Program Prioritization*. Retrieved from <http://aep.alberta.ca/water/programs-and-services/watershed-resiliency-and-restoration-program/documents/WatershedResiliencyRestoration-Jan-2015A.pdf>
- SurveyMonkey Inc. (2017). SurveyMonkey Inc. Retrieved March 4, 2018, from www.surveymonkey.com

- Tehrani, M. R. M. Z. (2014). *Vulnerability Measures for Flood and Drought and the Application in Hydrometric Network Design*. University of Waterloo. Retrieved from https://uwspace.uwaterloo.ca/bitstream/handle/10012/8559/Moazezi_Zadeh_Tehrani_Mohammad.pdf?sequence=1&isAllowed=y
- UBC Master of Land and Water Systems program. (2014). Innovative Stormwater Management at the Watershed Scale. Retrieved January 3, 2018, from <http://www.alidp.org/projects/innovative-stormwater-management-at-the-watershed-scale>
- United States Environmental Protection Agency. (n.d.). National Stormwater Calculator. Retrieved January 16, 2018, from <https://www.epa.gov/water-research/national-stormwater-calculator>
- University of Saskatchewan: Global Water Futures. (n.d.). Major Facilities. Retrieved November 27, 2017, from <https://gwf.usask.ca/science/research-facilities/major-facilities.php#CentreforHydrology>
- WaterSMART Solutions Ltd. (2013). *The 2013 Great Alberta Flood: Actions to Mitigate, Manage, and Control Future Floods*. Retrieved from <http://www.albertawatersmart.com/alberta-flood-2013.html>
- WaterSMART Solutions Ltd., & Alberta Innovates: Energy and Environment Solutions. (2014). *Bow Basin Flood Mitigation and Watershed Management Project*. Retrieved from <http://www.albertawatersmart.com/bow-basin-flood-mitigation-and-watershed-management-project.html>
- Weber, B. (2018, January 22). "Definite Trends": New Extreme Weather Index Shows Canada is Getting Hotter and Wetter. *National Post*, p. 1. Retrieved from <http://nationalpost.com/news/canada/insurers-say-canadian-weather-getting-hotter-wetter-and-weirder>
- Wilhite, D. A. (1991). Drought Planning: a Process for State Government. *JAWRA Journal of the American Water Resources Association*, 27(1), 29–38. <https://doi.org/10.1111/j.1752-1688.1991.tb03110.x>
- Wilhite, D. A. (2009). *Defining Drought: The Challenge for Early Warning Systems*. Lincoln, NE: University of Nebraska-Lincoln. Retrieved from <http://www.wamis.org/agm/meetings/wies09/S21-Wilhite.pdf>
- Wilhite, D. A., Hayes, M. J., & Knutson, C. L. (2005). Drought Preparedness Planning: Building Institutional Capacity. In D. A. Wilhite (Ed.), *Drought and Water Crises: Science, Technology, and Management Issues* (pp. 93–136). Boca Raton, FL: CRC Press.
- Wilson Okamoto Corporation. (2005). *Hawaii Drought Plan: 2005 Update*. Retrieved from http://drought.unl.edu/portals/0/docs/DRC_Guide.pdf
- World Meteorological Organization, & Global Water Partnership. (2016). *Handbook of Drought Indicators and Indices*. Geneva. <https://doi.org/10.1007/s00704-016-1984-6>
- World Wildlife Fund. (2016). *Natural and Nature-based Flood Management: A Green Guide*. Washington, DC. Retrieved from https://c402277.ssl.cf1.rackcdn.com/publications/1058/files/original/WWF_Flood_Green_Guide_FINAL.pdf?1495628174
- World Wildlife Fund, & United States Agency for International Development. (2016). *Natural & Nature-based Flood Management: A Green Guide*. Retrieved December 12, 2017, from <http://envirodm.org/flood-management>



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