Alberta Water Council

Drought Simulation Literature Review

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Submitted on:
March 12, 2021

Executive Summary

The Alberta Water Council (AWC) launched a project to improve community resiliency and stakeholder understanding of multi-year drought in Alberta. One aspect of this project is the development of a drought simulation exercise to assist stakeholders understanding and planning for drought preparation and response in Alberta. The AWC engaged WaterSMART Solutions Ltd. (WaterSMART) to conduct a literature review as the first step towards development of the simulation exercise. The literature review is comprised of three tasks:

1. A drought management review to understand the regulatory framework, historical drought response and drought management approach within Alberta and external jurisdictions of interest.
2. A review of drought simulation exercises conducted in other jurisdictions to identify and assess exercise types, goals and outcomes.
3. A review of interactive decision support tools that can be used to potentially support the AWC simulation exercise.

In addition to Alberta drought management, approaches were reviewed in Saskatchewan, California and South Carolina. All four jurisdictions use some form of permitting system which gives priority to specific users during water shortage periods. However, in the United States jurisdictions, the permits were found to be less prescriptive and were not necessarily required for smaller water users. By contrast, the regulatory system in Alberta is highly structured and the licencing framework in place provides some degree of drought management. To overcome regulatory challenges, California and South Carolina engage stakeholders in the development of highly detailed drought plans. There is an opportunity for Alberta to benefit from stakeholder engagement in the development of local and provincial drought plans as they create buy-in from all groups and stakeholders through understanding their roles and responsibilities.

Five drought simulation exercises were reviewed that took place in Alberta, South Carolina, Saskatchewan, Colorado and Chesapeake Bay. Some exercises like the Saskatchewan Invitational Drought Tournament used competitive games to engage participants while others such as the South Carolina Tabletop exercise used fixed paper-based scenarios. Common outcomes across all exercises included increased awareness of drought risks and stakeholder roles in drought response.

Eleven tools were reviewed, ranging from game-style educational tools to highly complex drought planning tools. It is recommended that when choosing a supporting tool, the AWC first clearly define the desired outcomes of the simulation exercises and focus on tools which will best support the selected exercise style. When considering tools for the AWC Drought Simulation exercise, it is recommended that a stepwise process is implemented in which the desired exercise outcomes are identified, that the exercise type and style is selected based upon the desired outcomes and finally, that the tool is selected by considering how it can support the desired outcomes and how it fits within the boundary conditions of the project. This approach is more likely to lead to beneficial outcomes of the AWC Drought Simulation exercise that will effectively support improvements to drought resiliency and response in Alberta.

Contents

1.0 Introduction

Drought management sits at the complicated interface of policy, society, technology, and the physical world. The management of drought involves complex monitoring, collaboration across diverse entities, communal decision making and coordinated communication.

It is difficult to prepare for the complexity of the required management efforts and collaboration needed before a drought takes place. Drought is a natural phenomenon that can have very serious negative impacts. However droughts occur over a long period of time, making it easy for planning to be postponed. One way to overcome this barrier is to engage the diverse actors and decision makers in drought management in thinking about and planning for drought through simulation exercises.

Drought simulation exercises can also support adaptive planning because successive droughts are rarely the same in terms of length, regionality, severity, and impacts. Being able to test multiple drought scenarios through a simulation is advantageous.

The Alberta Water Council (AWC) launched a project to improve community resiliency and stakeholder understanding of multi-year drought in Alberta. The effort is multi-pronged and includes developing and conducting a drought simulation exercise to improve drought resiliency.

This report compiles the results of a literature review and analysis that was conducted to support the drought resilience work of the AWC. The report is split into two separate sections, each with a different focus. This first section provides the results from examining drought management systems in the jurisdictions of interest. The second area (Section 4) examines relevant tools and case study examples of drought simulation exercises.

1.1 Project background and approach

The intent of this literature review is to compile information that will support the AWC Drought Simulation Project Team's decisions by defining the key outcomes, the geographic scope, and the ideal tools for the simulation exercise. The AWC Drought Simulation Project Team will decide to move forward in developing and executing an appropriate drought simulation exercise following the conclusion of this literature review.

The literature review was completed by WaterSMART using the following process:

1. Confirmed the expectations and requirements, including selection of jurisdictions of interest and preferred characteristics for the tools and case studies. A shortlist of tools and case studies was identified and provided to the AWC Project Team.
2. Completed the research and review.
3. Submitted three tables with compiled literature review results. The tables detail drought planning and management in three jurisdictions of interest, five relevant case studies, and eleven tools that

could potentially be used for drought simulation.

4. Presented the results to the AWC through a workshop style meeting.
5. Compiled the final report (this document) and submitted it to the AWC Project Team.

1.2 Definitions

For this analysis and through this report, the following words and definitions are used.

Drought: Natural occurrences resulting from a lack of precipitation over a prolonged period of time, as well as depletion of natural water sources, human-made storage, and soil moisture. Includes agricultural, hydrological, meteorological, and socio-economic droughts.

Drought Exercise: An exercise undertaken individually or as part of a group to educate, validate, or drive a decision-making process for some aspect of drought management.

Game: A tool that encourages users to meet a goal or objective by manipulating certain elements or components of a simulation. Games typically involve cooperation and/or competition, as well as a challenge, rules and scoring.

General public: Refers to people with no technical background in watershed management and who are not members of a broader group or organization connected to watershed management or operations.

Scenario: A plausible story that describes an event or situation. In this case, a drought scenario provides the description, details and context of a plausible drought.

Simulation: An imitation of a system, event, or process.

Stakeholder: A person who is a member of a broader group or organization connected to drought management, water management operations, or who makes decisions that affect other water users in the event of a drought.

Tool: A virtual or paper-based instrument or device that can be used to support a drought exercise.

1.3 Assumptions

This literature review focuses on tools, case studies, and governance models for drought management. Although there are numerous 'how to' documents for planning and running drought simulation exercises, these have not been specifically reviewed for this work. The AWC has already reviewed many of the most relevant 'how to' documents and provided them to WaterSMART; where appropriate, WaterSMART has referenced those documents in this report.

It is assumed that this report will support the AWC Drought Simulation Project Team's decisions. The report does not provide a recommendation regarding which simulation tool to use or how to conduct a drought simulation exercise.

The WaterSMART research team understands that a game-style simulation exercise is of most interest to the AWC Project Team. Therefore, the case study literature and tools selected for review are games or adaptable to game-style exercises. In addition, it is understood that the AWC Project Team expects drought exercise participants to include both stakeholders and the general public. Therefore, the tools selected for review represent a range of technicality and complexity.

Jurisdictions of interest were selected and confirmed by the AWC Project Team to be Alberta, Saskatchewan, South Carolina, and California. These informed, but did not limit, the selection of case studies and tools for review.

2.0 Drought Management Review

The purpose of this section is to compile information from each jurisdiction on drought management regulations and regulatory systems, existing resources and plans, identified roles and responsibilities, and metrics and indicators. Where available, information on historical drought response is reviewed and included. The jurisdictions of interest for this study are Alberta, Saskatchewan, South Carolina, and California.

2.1 Drought management - Alberta

2.1.1 Drought planning and existing resources

Alberta Agriculture and Forestry (AAF) created a drought management framework titled "*Alberta's Agriculture Drought and Excess Moisture Risk Management Plan*" (ADEMRMP). The document was first published in 2001, superseded in 2010, and then published once again in 2016. This document provides a framework for a coordinated, proactive approach to reduce the short and long-term effects of drought and excess moisture on Alberta farmers and ranchers. It is also a guide for government agencies in assisting producers to more effectively reduce the impacts before, during, and after an adverse event, and will help the agriculture industry be more prepared. The framework is broken down into three sections: preparedness, monitoring, and reporting and response.

Key metrics used in AAF's framework to monitor drought include:

- Soil moisture monitoring program
- Precipitation monitoring
- Snowfall accumulations
- Temperature and humidity monitoring
- Release rates from reservoirs and stream flows
- Wildfire risk
- Grasshopper levels
- Duration of drought (relative to historical conditions)

Additionally, Alberta Environment and Parks (AEP) created a response procedures manual in 2009 for managing water shortage conditions in the South Saskatchewan River Basin (SSRB) (Alberta Environment, 2009). The procedure details AEP's responsibilities with respect to the Water Act and is set out in four stages. Each stage is dependent on the severity of the water shortage.

AEP defines water shortage as a period of time when it is appropriate for the department to be comprehensive and responsible in administering priorities for water licences and registrations to protect the aquatic environment and integrity of the water management system.

In the SSRB, four response stages are noted depending on severity:

- **Stage 1** – Normal operations: monitoring for water shortage potential in water management areas and preparing for water shortages.
- **Stage 2** – Priority call assessment and administration of priority.
- **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.
- **Stage 4** – Due to unforeseen circumstances that could not be mitigated, the Lieutenant Governor in council may consider a declaration of an emergency under the *Water Act*.

Note: AEP has developed a more recent version of this document that includes procedures for the Milk River Basin; however it is not yet available for public release.

2.1.2 Regulatory system specific to drought management

The *Water Act (1999)*, and associated regulations made under it, is the overarching legislation governing water in Alberta. The *Water Act* supports and promotes the conservation and management of water through the use and allocation of water in Alberta (*Water Act,* 1999). It requires the establishment of a water management framework and sets out requirements for the preparation of water management plans (*Water Act*, 2000). The *Water Act* is also the primary legislative mechanism for managing water withdrawals during a drought. The *Water Act* also addresses the following:

- A licence holder's right to divert water and the priority of water rights among users.
- The types of legislative instruments available for diversion and use of water and the associated processes for decision-making. This includes statutory rights to divert water without a licence for household use and traditional agriculture use.
- The range of enforcement measures available to ensure the goals of the *Water Act* are met (*Water Act*, 2000).

AEP delivers the *Water Act* mandate, manages provincially-owned reservoirs, and regulates impacts to water quality under the *Environmental Protection and Enhancement Act* (EPEA) for all water matters not associated with oil, gas, coal, and pipelines. For these energy related matters, the *Water Act* and EPEA mandate is delivered by the Alberta Energy Regulator (AER) under the *Responsible Energy Development Act* (REDA).

Under section 30 of the *Water Act*, water allocations (water licences) have a priority number based on when the application was originally submitted. This system of priority is the basis for management of water under water shortage situations. Priority numbers indicate seniority, and in times of water shortage, the most senior licence has the right to withdraw their full allocation, provided all conditions on the licences are met, including stream flow. Under this system, the more junior the licence (i.e., licences that were applied for more recently), the greater the risk of not receiving all or part of the allocated water in low flow years. However, during emergency situations, the GoA has the power to suspend a water licence and reassign the water for other uses, with compensation.

There is no legislated priority for specific water uses. However, in 2011, the 13 irrigation districts in Alberta, all licence holders that include senior licences, approved a declaration committing that in times of water shortage, the water needs of humans and livestock would be met. This is a commitment by those with senior licences and with the greatest allocated water volume (in the southern half of the province) to ensure essential human and livestock water needs are met, even if they are junior licences, in times of water shortage.

The Province of Alberta has a strong regulatory framework for water management that includes dynamic management and operations aimed at adapting to constantly changing water availability. The tools made available by the *Water Act* include assignments, temporary transfers, and transfers, as well as normal operating agreements made during the weekly meetings of large water-volume licence holders during irrigation season. There are priorities and adjustments to priorities that have been made within this framework at a basin-wide scale.

Section 33 of the *Water Act,* "Agreements to assign water", includes the formal process for sharing water which can be undertaken as a way to manage impacts from a water shortage or drought. It allows water sharing between higher and lower priority licensees, and the formal agreement and oversight by the AEP supports water users abiding by the terms of their agreements.

Another significant piece of water-related legislation is the *Approved Water Management Plan for the South Saskatchewan River Basin (2006)*, which is designed to guide water management decisions and protect both the aquatic environment and water allocation licensees. The *Approved Water Management Plan for the SSRB* was approved by Lieutenant Governor in Council in 2006. It makes various recommendations, including to close the Bow, Oldman, and South Saskatchewan River sub-basins to new applications for water licences and to designate Water Conservation Objectives (WCOs) on the mainstem rivers and their tributaries. *The Bow, Oldman and South Saskatchewan River Water Allocation Order* was subsequently issued in 2007 as a regulation under the *Water Act.* The order formally implements the recommendation of the *Approved Water Management Plan for the South Saskatchewan River Basin* to close specific sub-basins. Since the *Order* was issued, all unallocated surface water in the Bow, Oldman, and South Saskatchewan River sub-basins has been reserved; however, the Director may allocate reserved water for limited and specific licences for each basin. Please see the *Order* for details on these specific uses.

The *Oldman River Basin Water Allocation Order (2010)* is a regulation issued under Section 35 of the *Water Act* that reserves 11,000 acre-feet per year to the projects within the area meeting criteria in the *Order*, and can be issued by the Director for agricultural, municipal, commercial, industrial, recreational or rural water supply uses. This *Order* governs water allocation in the basin and does not directly contribute to drought management or response.

Apportionment for downstream provinces

Commitments for cooperation on the management of transboundary waters are recorded in three documents: the Mackenzie River Basin Transboundary Waters Master Agreement for the north, the 1969 *Master Agreement on Apportionment (MAA)* for east-central, and the Boundary Waters Treaty 1909 to the south. *The MAA* outlines how waters are to be shared between the three Prairie Provinces (Alberta, Saskatchewan and Manitoba) and includes water quality objectives at the borders. All water management decisions that are made within each province's jurisdiction should be done in the context of variability in the annual water supply from year to year, and the monitoring data on *MAA* commitments throughout a particular year, which is particularly relevant in drought years.

Under the *MAA*, Alberta is entitled to a minimum of 2,590,000,000 m^3 annually even if this is more than 50% of the annual natural flow, but cannot do this if it reduces the flow to less than 1,500 cubic-feet per second (42.5 m^3/s) in the South Saskatchewan River downstream of the confluence with the Red Deer River, near the Alberta-Saskatchewan border. If 1500 cubic-feet per second cannot be maintained then 50% of the annual flow must be passed downstream.

Water Conservation Objectives (WCOs) and Instream Objectives (IOs)

WCOs and IOs are the instruments used in Alberta that ensure there is a minimum amount of water to support basic ecosystem needs. WCOs are established under the *Water Act* as a regulatory tool for balancing human, environmental and ecosystem needs for water flows. WCOs can be implemented in several different ways, including by specifying the volume of release from a public reservoir or by specifying when a water allocation licence holder can divert water. Water allocations may be held for WCOs in licences with priority either by the government applying for a licence to protect instream flows, or by transfer from existing licences.

Water allocation licences include conditions that determine minimum flows that must be present before water can be diverted in order to protect the aquatic environment. WCOs guide government officials on decisions about when water can be allocated and the amount of water needed for flow restoration.

WCOs do not guarantee that the designated WCO volume of water remains in the water course, as some licensees are not subject to a WCO condition and may withdraw water when a WCO threshold is surpassed (GoA, n.d.).

In the absence of an established WCO, IOs are flows that are included in the conditions of some water licences. Licences are not permitted to withdraw water when river flows fall below the specified IO. In areas where WCOs are identified they are not backdated to apply to licences that existed when the WCO was established, and the IOs that may have conditioned licences before that time remain in force. AEP provincial infrastructure licences have IO conditions but are often operated to meet WCO objectives when sufficient water is available.

IOs were historically set on a river reach by reach basis. Since the first minimum flows were developed and applied to licences in the mid-1970s, gradually evolving to IOs in the 1990s, there have been many updated versions used, resulting in an uneven application of restrictions to licences issued since that time. In the period 1891 to 1967 licences were limited by time periods, such as different permitted diversion rates at flood, high and low flows.

2.1.3 Roles and responsibilities relating to drought management

There are diverse entities that have both direct and indirect roles and responsibilities in drought management and resilience. Both water supply management and demand management are important roles in drought management, and they must be coordinated. Additionally, the roles and responsibilities should cover a wide range of methods for drought management, including providing accurate and current information to all water users regarding water availability and forecasting drought, creating public awareness and offering recommendations and guidelines for responsible water use, and legislated authority to reduce water use where necessary.

Supply Management

In Alberta, most direct roles are played by provincial government departments, municipal governments, and entities that manage water control structures. Monitoring of available surface water and groundwater and forecasting of water supply is the responsibility of AEP through the River Forecast Centre and the Groundwater Observation Well Network. Surface water data is sourced primarily through the Water Survey of Canada system. AEP and the AER have programs that are responsible for notifying water licensees of approaching water shortage and below-minimum flow conditions in source water bodies, as well as monitoring to ensure water licensees are abiding by the conditions of their licences, and that water use is reported where required. As well, several water reservoirs and water control structures are managed by AEP as part of delivering water licence allocations and regulating flow in the several rivers.

AAF has several direct roles in drought management, including providing the online Alberta Climate Information Services (GoA, 2020) and issuing monthly Farm Gate Allocation Forecasts for irrigators from the Southern Tributaries of the Oldman River. AAF is also responsible for facilitating the Drought and Excessive Moisture Advisory Group and for publishing and updating the *Agriculture Drought and Excessive Moisture Risk Management Plan* (AAF, 2016).

Irrigation districts have responsibilities to their irrigators as well as to the other water needs in the province and, due to the volume and seniority of their water licence allocations, they play key roles in water sharing agreements (as seen in the 2001 drought, see section 2.1.4) under section 33 of the Water Act. Irrigation districts own and operate many water storage and management structures in the province, and some irrigation districts deliver water to certain municipalities through their water conveyance infrastructure. These both translate into roles and responsibilities during a drought.

Certain corporations also play various roles. For example, TransAlta managing its hydropower facilities on the Bow River plays a direct role in flood and drought management.

Demand Management

There are also direct roles and responsibilities held by the municipal governments, particularly in municipal demand management through bylaws and in communications to the public.

Watershed Planning and Advisory Councils, watershed stewardship groups, community organizations, and other stakeholder collaboration and planning entities also play important roles in drought management and mitigation, although their roles are more often indirect. They contribute particularly to awareness-raising, building community resilience before a drought, and initiatives to mitigate drought impacts. Drought planning and guidance manuals are also created by these types of organizations; for example, the Miistakis Institute published a Municipal Flood and Drought Action Planner in 2018 (Miistakis Institute, 2018).

Corporate initiatives to increase water use efficiency in connection to public image during a drought is an aspect of drought mitigation that is indirectly related to demand management. Aside from any legislated requirements for water efficiency or water licence restrictions, some corporations take on responsibility for their water stewardship and water use. A corporation that voluntarily implements a series of water saving and water reuse measures that reduces their overall water demand by 30% may be promoting this achievement explicitly during a water shortage as part of improving their public image. This leading by example is effective at reducing overall water demand.

Drought Impact Mitigation

The economic and social impacts caused by drought are another area of roles and responsibilities related to drought. There are many government responsibilities in these areas, including through crown corporations like the Agriculture Finance Services Corporation (AFSC) to provide financial incentives for producers to build on-farm drought resilience as well as loans, and supports including insurance and income stabilization.

Research and experience in many countries has found that preparation is one of the best ways to reduce losses and negative impacts from drought (Bathke et al., 2019). Because building community resilience and adaptive capacity is a cross-sectoral effort, no one entity is solely responsible for drought planning and preparation. Initiatives and projects by groups like the AWC and the Miistakis Institute, which support building drought resilience and understanding across a wide range of stakeholder and community groups, are very important for building a body of support resources. Implementing a drought risk management plan can be a very valuable tool, and planning documents, manuals, and stakeholder engagement efforts of many kinds can be key to developing a sound drought risk management plan (Bathke et al., 2019).

Further detail on roles and responsibilities can be found in Module 3 of the document "*Building Resiliency to Multi-Year Drought in Alberta*" (AWC, 2021).

2.1.4 Historical drought response (2001 drought in southern Alberta)

The period from 2000 through 2002 is widely considered the most recent, significant multiyear drought experienced in Alberta (AWC, 2021). This is referred to as the 2001 drought. The greatest water supply shortage was seen in the Oldman River Basin, but a variety of drought effects were experienced in many other parts of the province and in Saskatchewan.

Snowfall over the winter between 1999 and 2000 was below normal. Following that, recorded precipitation from April to November 2000 was below normal in much of the province and ranged between 36% to 56% of the normal precipitation in the headwaters areas of the Oldman River (Alberta Environment, 2000). The snowpack conditions in the spring of 2001 were also below normal across the entire province except the Red Deer River headwaters, and the volumes forecast for the Oldman River were 59% of average (Alberta Environment, 2001). These conditions caused Alberta Environment (at the time) to forecast that there would be insufficient water in the system to supply all water licences and still meet in-stream flow needs on the Southern Tributaries of the Oldman River (Albert Environment, 2002). In addition, the summers during this time were hot and dry, leading to higher-than-normal water demand. By the end of the 2000 irrigation operation season, storage reservoirs in the Southern Tributaries were drawn down to historically low levels (Alberta Environment, 2001).

The St. Mary River, Taber and Raymond irrigation districts share a common irrigation canal ("main canal"), operations on the main canal were managed via regular meetings of the Main Canal Advisory Committee which comprised of water managers from the irrigation districts. In November 2000, the existing Main Canal Advisory Committee invited other large water users to join their regular meetings and called themselves the Expanded Main Canal Advisory Committee (EMCAC) to prepare for the possibility of drought conditions in 2001. The EMCAC included eight irrigation districts as wells as some private irrigator associations.

At a meeting on April 19, 2001, the Regional Water Manager who was the decision-maker from Alberta Environment presented a comprehensive list of all water licences (excluding stockwater licences with storage) in the St. Mary, Belly, and Waterton basins by priority. This list included 388 licences. Based on the water forecast, 336 junior licensees were at risk of having their licences suspended for the year. The alternative discussed during the meeting was to create a water sharing agreement, as provided for under section 33 of the *Water Act*. Any licences whose priority was junior to 1950 would be suspended until water availability improved if water sharing measures were not agreed to. The scale of the needed water sharing agreement was in the order of a total demand of approximately 1.1 million acre feet (1.3 billion cubic metres), and a supply of approximately 600 thousand acre feet (740 million cubic metres) representing a regional population of about 200,000.

A water sharing agreement was drafted by the EMCAC and submitted to Alberta Environment on May 9th, 2001. The agreement included an offer to all licensees in the basin including mainstems, tributaries to mainstems, and private licenses supplied through the works of the respective districts to join the agreement. Letters were sent to licensees in the Southern Tributaries basins containing information on the sharing agreement as well as the water supply forecast, the priority system and the potential consequences of not joining the water sharing agreement based on the available forecast data. Due to data systems at the time, it was hard to easily access the address of all licence holders and some letters were returned due to wrong addresses.

Some private water sharing agreements were made between water users who chose not to participate in the basin-wide agreement. Private agreements were permitted among licensees providing they did not conflict with the overall water sharing agreement.

A deadline of June 27, 2001 was set for water users in the Southern Tributaries to sign up to the sharing agreement, after which those who had not signed were subject to administration of priorities. Enforcement of priorities was conducted through the issuing of Water Management Orders which defined a licence cut-off date. Water users with licences junior to the date specified that were not part of a water sharing agreement were subject to the restrictions outlined in the Water Management Order. The Regional Water Manager reviewed the merit of each order. By July 21, 2001, 63 Water Management Orders had been signed.

Weekly inspections were done to ensure licence holders were following the rules of the private water sharing agreements, Water Management Orders and the water sharing agreement. The water sharing agreement allowed junior licensees to continue diversion, provided irrigators reduced use to 10 inches of water over their project area and other users (municipal, industrial, commercial) reduced their usage to 60 percent of their licenced water allocation. Additional initiatives by Alberta Agriculture supported stockwatering projects, and water pumping and equipment rentals, which facilitated reduced agricultural water withdrawals and improved efficiencies.

In general, the water sharing agreement was considered to have worked effectively. Despite some challenges experienced with the administration of a sharing agreement on such a wide scale, this implementation of water sharing under section 33 of the *Water Act* as a drought management tool was effective and successful. Generally, feedback from users was positive and most participants abided by the spirit of the agreement.

The Alberta government identified the following key lessons from the 2001 drought in southern Alberta:

- Data monitoring tools and ease of access to data has changed the way droughts can be managed.
- Initial information for a water sharing agreement should be sent out sooner (possibly mid-April).
- Agreement should be finalized prior to the irrigation season.
- All licensees should be required to record the dates and times of diversions during a sharing agreement.
- The installation of water meters on all licenced water diversions should be encouraged.

See Appendix A – Drought Management Literature Review Summary Table for further details and discussion of impacts in other parts of the province from the 2001 drought.

Relevant literature:

Alberta Agriculture and Forestry. (2016). *Alberta's Agriculture Drought and Excess Moisture Risk Management Plan*. https://open.alberta.ca/dataset/19be574e-8a12-41f3-9880-403f93747655/resource/9c4ba961-016c-42f2-ac51-f49d41de8b01/download/2016-albertas-agriculture-drought-excess-moisture-risk-management-plan-2016-06-16.pdf

Alberta Environment. (2000). *Water Supply Outlook for Alberta December 2000*. http://environment.alberta.ca/forecasting/watersupply/historical/dec00.PDF

Alberta Environment. (2002). 2001 Water Administration Summary Report – Southern Tributaries: St. Mary, Belly, Waterton Rivers.

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Alberta Environment. (2009). AENV Water Shortage Procedures for the South Saskatchewan River Basin – for internal use by the staff of Alberta Environment. https://open.alberta.ca/dataset/74ed2c40-7022-4e2d-bec4-1db32f5f4708/resource/f367e876-5fa9-4b07-b741-38ed78c67092/download/2009-watershortageprocedures-ssrb-apr2009.pdf

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Government of Alberta. (2020). Alberta Climate Information Service, access from http://agriculture.alberta.ca/acis/about.jsp

Miistakis Institute. (2018). Municipal Flood and Drought Action Planner, access from https://www.rockies.ca/miradm/uploads/1c6f89bf3c419806ff8791b2e11b5128f2b6717c.pdf

Water Act (2000), (AB)(Can.) https://open.alberta.ca/publications/w03

2.2 Drought management – California

Water rights in California are governed by the California State Water Resources Control Board. Three types of water rights exist in the state: riparian, prescriptive, and appropriative. Permits are issued for prescriptive and appropriative rights issued after 1914, and permit priority for water rights is based on seniority of right. Appropriative water rights issued pre-1914 and riparian rights do not require a permit (California State Water Resources Control Board, 2020).

Water rights permits are granted to individuals to develop a project, which is assessed by the State Water Resources Control board to determine the user's eligibility for a license. A permit is only issued once the board assesses the environmental risk, whether the project is in the public interest and if there are any conflicting appropriative rights.

In California, drought management policy is determined by the *California Drought Contingency Plan* (*The Plan*), developed by the California Department of Water Resources (California Department of Water Resources, 2010). *The Plan* is a drought plan developed to assist state governance in preparation, response, and recovery from drought. Within *The Plan,* a framework for agency coordination to respond to and manage drought is detailed, including the development of an Interagency Drought Task Force that provides direction for implementing drought management between agencies. Within *The Plan*, roles and responsibilities regarding drought response are outlined for various local, regional, state, tribal, and federal agencies. The Interagency Drought Task Force plays a key role in coordinating drought response from all levels of government within the state and works to provide policy recommendations for drought response and recovery. Though more of a government response framework, *The Plan* documents some metrics used to monitor and forecast drought: water supply data (snowpack, precipitation, runoff, reservoir storage), hydrologic data collection (snow reporting gauges, precipitation and river stage sensors), and water year precipitation.

Water storage and delivery system entities such as the California State Water Project or the California Central Valley Project are permitted to develop their own drought contingency plans (California Department of Water Resources, 2015, 2016). These contingency plans are developed for the California State Water Resources Control Board by a variety of agencies within the federal and state government including the U.S. Bureau of Reclamation, California Department of Water Resources, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and California Department of Fish and Wildlife. These drought contingency plans are developed to provide an alternative framework for water operations within the state based on modeled hydrological scenarios for that year. The plan may also propose possible requests for changes to legislation for operational standards for water based on potential hydrologic scenarios. Metrics used in such plans can include water quality (salinity), hydrology (precipitation to date, runoff, reservoir storage, snowpack) and biology (local fish and wildlife populations). Development of a state contingency plan is required by law under Division 6 of the *California Water Code*. Urban water providers are required by law to create contingency plans under the *California Water Code* Section 10632. Other water users such as irrigation districts are not required to create contingency plans but may choose to implement them to manage drought effectively (California State Legislature, 2019).

See Appendix A – Drought Management Literature Review Summary Table for further details.

Relevant links and sources:

California Department of Water Resources. (2010). *California Drought Contingency Plan* (State of California, Natural Resources Agency, California Department of Water Resources). Sacramento, CA: California Department of Water Resources. Retrieved from https://drought.unl.edu/archive/plans/Drought/state/CA_2010.pdf

California Department of Water Resources. (2015). *Central Valley Project and State Water Project Drought Contingency Plan* (State of California, Natural Resources Agency, California Department of Water Resources). Retrieved from https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/2015_drought_contingency_plan.pdf

California Department of Water Resources. (2016). *Central Valley Project and State Water Project 2016 Drought Contingency Plan For Water Project Operations* (State of California, Natural Resources Agency, California Department of Water Resources). Retrieved from https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/tucp/docs/febnov_2016plan.pdf

California State Legislature. (2019). *Water Code Division 6: Conservation, Development and Utilization of State Water Resources*. California Legislature Information. https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=WAT§ionNum=10632#:%7E:text=10632.,each%20of%20the%20following%20elements%3A&text=The%20annual%20supply%20and%20demand,of%20the%20urban%20water%20supplier.

California State Water Resources Control Board. (2020, August 20). Water Rights. Retrieved January 20, 2021, from https://www.waterboards.ca.gov/waterrights/board_info/faqs.html#toc178761097

2.3 Drought management – South Carolina

Surface water withdrawals in South Carolina are issued under the *South Carolina Surface Water Withdrawal, Permitting, Use and Reporting Act (SC Withdrawal Act)* administered by the South Carolina Department of Health and Environmental Control (SCDHEC). The *SC Withdrawal Act* requires users withdrawing more than three million gallons per month (11,356 m^3 per month) to obtain a permit from the SCDHEC. Permitted users can withdraw up to their monthly volumetric limit and must abide by any conditions placed upon their permit (South Carolina Legislature, 2010). There is no priority system that governs permitted users, however, permits specify minimum instream flow limits that will trigger below which the user will have to introduce specified reductions in water withdrawal (South Carolina Legislature, 2010).

Users withdrawing less than three million gallons per month are not required to obtain a permit but must register their use with the SCDHEC. This process requires the user to notify the SCDHEC of their intended water use, withdrawal rate, and monthly withdrawal volume. Registered users are not placed under any conditions that may restrict their withdrawals. There is no priority system for registered users so it is possible that small users may not have enough water to meet their demands during low flow periods.

Groundwater withdrawals are regulated under the *Groundwater Use and Reporting Act* under which those withdrawing more than three million gallons per month must apply for a permit. Similar to surface water withdrawals, smaller water users are not required to obtain a permit for groundwater withdrawals (South Carolina Legislature, 2000).

The *South Carolina Drought Response Act (SC Drought Response Act)* was implemented to outline the responsibilities of the South Carolina Department of Natural Resources (SCDNR) and other bodies to prepare for and in the event of drought. Drought forecasting is the responsibility of the SCDNR, and the severity and type of drought governs the response under the *SC Drought Response Act.* Figure 1 shows the responsibilities denoted by the *SC Drought Response Act* during successive phases of drought.

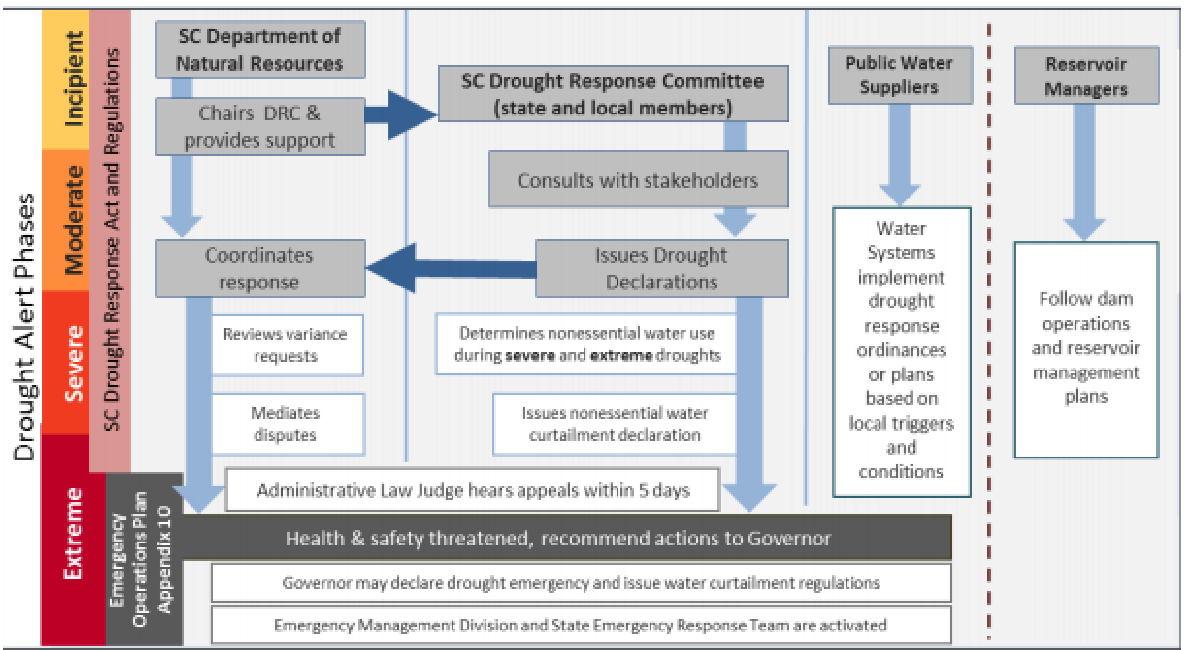

Figure 1 Components of South Carolina's drought response process (CISA, 2019)

The *SC Drought Response Act* mandates the SCDNR to establish localized drought response committees which are responsible for the creation and implementation of localized drought response plans. Under the *SC Drought Response Act*, the drought response committees must contain members representing the following interests:

- Counties, municipalities and public service districts
- Private water suppliers
- Agriculture
- Domestic water users
- Regional councils

- Commissions of public works
- Power generation facilities
- Special purpose districts
- Soil and Water Conservation Districts

The drought response plans created by the localized committees detail responsibilities and procedures at the local level including reservoir operations, municipal restrictions, and agricultural withdrawal limitations during each phase of drought. South Carolina uses the U.S. Drought Monitor to define each stage of drought. In total there are five stages of drought severity:

- **D0 Abnormally dry** – Irrigation may begin early, row crop growth is stunted and the risk of brush fires increase.
- **D1 Moderate drought** – Tree pests increase, water levels are low and water use is higher than normal.
- **D2 Severe drought** – Number and intensity of fires increases, fisheries are impacted, and recreational boating is impacted by water levels.
- **D3 Extreme drought** – Soil moisture is low, small aquatic species are stressed, and winter crops are slow to germinate.
- **D4 Exceptional drought** – Trees are stressed, daily life is compromised, and wells are contaminated or running dry.

Engaging stakeholders in the development of drought response plans and within local committees ensures that all water users buy into the response plan. Engagement also helps prevent non-permitted water users being cutoff during drought through negotiations and compromise from permitted water users. In recent years, the SCDNR has sought to test and optimize the drought response plans through stakeholder engagement exercises such as the South Carolina Tabletop exercise held in 2017 and 2019. See section 4.1.2 for further discussion of this simulation exercise.

See Appendix A – Drought Management Literature Review Summary Table for further information on South Carolina's drought management system.

Relevant links and sources:

South Carolina Legislature. (2010). *South Carolina Surface Water Withdrawal, Permitting Use, and Reporting Act*. South Carolina Code of Laws Unannotated. https://www.scstatehouse.gov/code/t49c004.php

South Carolina Legislature. (2000). *Groundwater Use and Reporting Act*. South Carolina Code of Laws Unannotated. https://www.scstatehouse.gov/code/t49c005.php

Santee Cooper. (2020, July 29). *5 LEADING INDUSTRIES IN SC*. https://www.santeecooper.com/news/2020/072920-Leading-Industries-in-SC.aspx

CISA. (2019, July). *South Carolina Drought Tabletop Exercise*. Carolinas Integrated Sciences and Assessments. http://www.scdrought.com/pdf/2019_SC-DroughtTTX_FinalReport.pdf

National Drought Mitigation Center. (n.d.). *United States Drought Monitor > Current Map > State Drought Monitor*. United States Drought Monitor. Retrieved November 27, 2020, from https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?SC#:%7E:text=D1%20(Moderate%20Drought),D4%20(Exceptional%20Drought)

2.4 Drought management – Saskatchewan

Historical drought management in Saskatchewan was largely handled by the Prairie Farm Rehabilitation Administration (PFRA). This administration was established in 1935 after a long series of droughts in Alberta and Saskatchewan necessitated management action that would aid farmers in restoring their landscapes.

Although multiple periods of drought were experienced throughout the prairie provinces in the early 20th century, Saskatchewan farmers suffered severe drought between 1928-1939. This period of extreme agricultural hardship in the province spurred the establishment of the PFRA by the federal government and headquartered in Saskatchewan. The PFRA was designed to rehabilitate once-productive farmland that had desertified, and particularly addressed issues such as soil erosion and water shortages.

Marchildon et al. (2008) detail the conditions of the southern regions of both provinces most prone to drought (the Dry Belt, and later the Palliser Triangle), drought exposure in these areas, agricultural drought, and institutional adaptation through establishment of bodies such as the Special Areas Board in Alberta. Marchildon et al. (2008) utilize the drought index as a metric of drought measurement, which is a "climate moisture index that expresses the moisture deficit in terms of mean crop year precipitation minus potential evapotranspiration (P-PET)."

See Appendix A – Drought Management Literature Review Summary Table for further information.

In modern-day Saskatchewan, the *Water Security Agency Act* (Government of Saskatchewan, 2005) is the primary piece of legislation concerning the management of water rights within the province. The Water Security Agency (WSA), a crown corporation, is responsible for the majority of the provincial government's water management tasks (Saskatchewan Water Security Agency, n.d.). Responsibilities include issuing water licenses for both surface water and groundwater, owning and operating dams and works, monitoring water quality and quantity, and managing transboundary water issues. The WSA also leads the implementation of the *25 Year Saskatchewan Water Security Plan*, developed in 2012, which includes discussion of water shortage. The *25 Year Saskatchewan Water Security Plan* was developed to provide the province with a vision, principles, and action items to meet water security goals (Saskatchewan Water Security Agency, 2012).

The water license system in Saskatchewan is based on the principal of priority of purpose although this is not formalized through the legislation. The WSA develops and directs water sharing strategies based on prevailing conditions, which includes the authority to manage water licensees’ withdrawals. Irrigation is generally lowest priority while municipal and domestic use is generally given highest priority. The Ministry of Agriculture has become the de-facto drought planning and response entity as historically water shortages have most severely impacted the agricultural sector.

In the past, drought management in Saskatchewan was largely reactive rather than proactive and most mitigation was aimed towards protecting agricultural losses. In 2012, the province of Saskatchewan began developing the *25 Year Saskatchewan Water Security Plan* (Saskatchewan Water Security Agency, 2012) to proactively manage water security throughout the province. Within this plan, drought is identified as a potential risk and identifies areas requiring improvements such as water allocation systems, climate change adaptation, dam operations, ecosystem health and biodiversity protection, and drought response. Goals set within this plan to adapt to and / or mitigate drought include ensuring dams safely meet water supply and management needs, ensuring measures are in place to effectively respond to flood and drought, and ensuring adequate data, information, and knowledge are available to support decision making.

Drought management is also an area that is addressed within Saskatchewan's *Climate Resilience Measurement Framework* (Saskatchewan Ministry of Environment, 2018). This framework provides structure and clarity on provincial climate change resilience initiatives. The framework defines a pathway to climate resilience comprising of several focus areas including Natural Systems, Physical Infrastructure, Human Well-Being and Community Preparedness. Drought mitigation is identified as a priority under the Natural Systems and Human Well-Being focus areas and as a key outcome of Saskatchewan's agricultural water management framework. Resilience to drought and improved drought response are identified as key outcomes of these two focus areas.

3.0 Metrics, Indicators and Thresholds for Assessing Drought Management

In the table below, drought indicators and metrics for Alberta, Saskatchewan, California, and South Carolina were identified by reviewing the regulatory framework, drought plans, and relevant reports. The purpose of this review is to understand which metrics are used in each jurisdiction and how these metrics inform drought resiliency and drought planning. Indicators of drought impact such as economic implications of droughts were not reviewed as part of this project (AWC, 2021).

Table 1 summarizes the metrics, thresholds and indicators identified in each jurisdiction, a more detailed version of the table is included in Appendix A. It was found in most jurisdictions, drought response is not governed by individual indicators, but all indicators will be assessed holistically by decision makers to understand the severity of water shortage. When considering individual water users, most jurisdictions that have a licencing or permitting system identify certain thresholds, such as instream flow, below which water withdrawals are reduced or restricted. These thresholds are typically determined by the regulatory body and identified on each permit or licence.

Table 1 Metrics, thresholds and indicators for drought monitoring and response identified in Alberta, Saskatchewan, California, and South Carolina.

Jurisdiction	Documentation containing metrics, indicators, or thresholds	Metrics, indicators, and thresholds
Alberta	Alberta's Agriculture Drought and Excess Moisture Risk Management Plan (ADEMRMP)	• Soil moisture monitoring program • Precipitation monitoring • Snowfall accumulations • Temperature and humidity monitoring • Release rates from reservoirs and streamflow • Wildfire risk • Grasshopper levels • Duration of drought (relative to historical conditions) • Groundwater levels
	City of Calgary Climate Resilience Strategy	• Reduction of per-capita water use

Jurisdiction	Documentation containing metrics, indicators, or thresholds	Metrics, indicators, and thresholds
Saskatchewan	Synthesis Report: Agricultural Adaptation to Drought (ADA) in Canada: The Case of 2001 to 2002	• Standard Precipitation Index (SPI) • Palmer Drought Severity Index (PDSI) • Drought Index - A climate moisture index that expresses the moisture deficit in terms of mean crop year precipitation minus potential evapotranspiration (P-PET)
California	California Drought Contingency Plan	• Water supply data (snowpack, precipitation, runoff, reservoir storage) • Hydrologic data collection (snow reporting gauges, precipitation and river stage sensors) • Water year precipitation
	Central Valley Project and State Water Project 2015 and 2016 Drought Contingency Plan	• Water quality (salinity) • Hydrology (precipitation to date, runoff, reservoir storage, snowpack) • Biology (local fish and wildlife populations)
South Carolina	South Carolina Drought Response Plan	• Soil moisture • Stream flow • Well levels • Precipitation
	South Carolina Drought and Water Shortage Tabletop Exercise Summary Report	• Palmer Drought Severity Index • Crop Moisture Index • Standardized Precipitation Index • Keetch-Byram Drought Index • U.S. Drought Monitor • Average daily streamflow • Groundwater static level in an aquifer

All jurisdictions seek to monitor water availability by measuring streamflow and precipitation at multiple locations. California and Alberta both use snowpack as an indicator of the potential for drought to occur.

Both Saskatchewan and South Carolina make use of the Palmer Drought Severity Index (PDSI) which was developed in the 1960s to estimate relative drought conditions using precipitation and temperature. The PDSI is best suited to measuring hydrological drought (Alley, 1984), so Saskatchewan and South Carolina have each used supplementary methods for assessing crop health. Saskatchewan assesses crop health using the Drought Index, while South Carolina has opted for the Crop Moisture Index.

All jurisdictions use continuous monitoring at multiple locations to capture data so they can understand where droughts may occur. Data collected within a jurisdiction is monitored and analyzed by state or provincial regulators and used to implement restrictions and controls. In U.S. jurisdictions, drought is usually declared by the state based on the indicators, and state and local drought response plans are implemented based on drought severity.

In Alberta, drought indicators are monitored by AEP and water users are obligated to abide by the conditions of their licences which include no withdrawal when the source water body is below a certain threshold. AEP also monitors drought indicators that are used to predict imminent water shortages and monitors ongoing local, regional and multi-basin water shortages. In the event of regional and multi-basin droughts, AEP will implement drought response procedures in basins that have these procedures established. As part of the drought assessment, AEP determines whether implementation of priority-based water restrictions is necessary. In Saskatchewan, the WSA has a similar mandate and can also cut off users as a last resort; however, there are not currently any basin scale drought response procedures in place to be implemented in the event of regional droughts.

In the U.S., data is also collected by federal entities such as the National Drought Mitigation Center (NDMC) and National Oceanic and Atmospheric Administration (NOAA). This data is collated into a tool called the U.S. Drought Monitor which is made available to all states as well as the public (NDMC, n.d.). South Carolina uses this map to supplement their own data and to understand when to implement their drought response plans.

Relevant literature and links:

Alberta Agriculture and Forestry. (2016). *Alberta's Agriculture Drought and Excess Moisture Risk Management Plan*. https://open.alberta.ca/dataset/19be574e-8a12-41f3-9880-403f93747655/resource/9c4ba961-016c-42f2-ac51-f49d41de8b01/download/2016-albertas-agriculture-drought-excess-moisture-risk-management-plan-2016-06-16.pdf

Alberta Water Council. (2021). Building Resiliency to Multi-Year Drought in Alberta.

Alley, William. (1984). The Palmer Drought Severity Index: Limitations and Assumptions. Journal of Climate and Applied Meteorology. 23. 1100-1109. 10.1175/1520-0450(1984)023<1100:TPDSIL>2.0.CO;2.

California Department of Water Resources. (2015). *Central Valley Project and State Water*

Project Drought Contingency Plan (State of California, Natural Resources Agency, California Department of Water Resources). Retrieved from https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/2015_drought_contingency_plan.pdf

California Department of Water Resources. (2016). *Central Valley Project and State Water Project 2016 Drought Contingency Plan For Water Project Operations* (State of California, Natural Resources Agency, California Department of Water Resources). Retrieved from https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/tucp/docs/febnov_2016plan.pdf

City of Calgary. (2019). *Climate Resiliency Strategy 2019 Update*. https://www.calgary.ca/content/dam/www/uep/esm/documents/esm-documents/climate-strategy-report-2019.pdf

CISA. (2019, July). *South Carolina Drought Tabletop Exercise*. Carolinas Integrated Sciences and Assessments. http://www.scdrought.com/pdf/2019_SC-DroughtTTX_FinalReport.pdf

National Drought Mitigation Center. (n.d.-b). *What is the U.S. Drought Monitor?* United States Drought Monitor. Retrieved November 27, 2020, from https://droughtmonitor.unl.edu/About/WhatistheUSDM.aspx

Natural Resources Agency, State of California, & California Department of Water Resources. (2010). *California Drought Contingency Plan*. California Department of Water Resources. https://drought.unl.edu/archive/plans/Drought/state/CA_2010.pdf

Saskatchewan Research Council. (2007). *Agricultural Adaptation to Drought in Canada: The case of 2001 to 2002*. https://cariboo-agricultural-research.ca/documents/CARA_lib_Wheaton_et_al_2007_Agricultural_Adaptation_to_Drought_ADA_in_Canada_The_Case_of_2001_to_2002.pdf

4.0 Simulation Tools and Case Studies

This section of the literature review summarizes the reviews of drought simulation exercise methods and supporting tools. All of the case studies reviewed use some form of exercise to explore or improve drought management. To the extent possible, case studies were selected from the jurisdictions of interest identified in section 2.0.

There are many more tools available than could be reviewed in the scope of this project. The tools selected for review are games or adaptable to game-style exercises and are capable of simulating drought. The tools were also selected to represent a variety of technicality and complexity, and to align with one of the case studies where possible. The shortlist of tools and case studies were provided to AWC before the review work was conducted.

4.1 Case studies

Each of the case studies below includes a description, objectives, outcomes, key lessons learned, budget, and the simulation tool used (if any). For further information, including the organization that conducted the exercise, see Appendix B – Simulation Case Study Research Summary Table.

4.1.1 Bow River Live Simulation

This case study is relevant to the Alberta Water Council Drought Simulation project because the study used a simulation tool, involved stakeholders gathering and making decisions together, focused on a watershed in Alberta, and focused on water management during a drought year.

Key considerations for AWC:

- Technical capabilities of the tool and good data were essential to the success of the exercise.
- Participants were expert stakeholders and familiar with the simulation tool.
- Outcomes were concrete and implementable with direct drought management implications.
- The tool and the exercise were specific to a single basin.

The information about the Bow River Live Simulation comes from the "*Bow River Live Simulation Summary Report,"* prepared by Alberta WaterSMART and Alberta Innovates – Energy and Environment Solutions, or from proposal documentation and personal communications from the project team members.

<u>Description</u>

In 2011, a group of key stakeholders and people who make decisions about the Bow River operations came together to run a simulation of collaborative drought management decisions for the Bow River watershed. This group were the same people who worked together to develop and refine the *Bow River Operational Model (BROM)* in a prior project. The Bow River Live Simulation built directly off the work done to initially develop the *BROM* tool which was part of the Bow River Project (BRP). The BRP resulted in a series of recommendations for integrated Bow River management operating rules and a specific 'preferred scenario'. The *"Bow River Live Simulation Study"* was intended to compare the current operations of the river system, the preferred scenario developed through the BRP, and the live operation from the simulation exercise.

This simulation exercise took place over one half-day workshop in which the management decisions (operations) for the Bow River were made week by week, progressing through the simulated spring and summer months. In order to make management decisions, participants were provided the current conditions for each week (including decisions from previous weeks), the forecasted inflows, and various other data produced from the *BROM*. Running the whole final sequence of decisions on the BROM took approximately 10 minutes. The simulation included the perspective of the public perception and media coverage of decisions.

The participants were all key stakeholders and decision-makers in their professional lives, with very strong familiarity with the river system and with the *BROM* tool. The weather and river flow data used was from the year 1941, which was one of the five worst drought years on record in Alberta. Participants did not know in advance that this was the source of the data used for the simulation.

<u>Objectives</u>

1. Revisit and validate the *BROM* and the preferred scenario recommendations.
2. Test and improve the proposed integrated river management operating rules.
3. Identify and address the consequences of the proposed integrated river management operating rules.

<u>Outcomes</u>

Model Outcomes

In comparing the performance measures, the live simulation outperformed the current management approach to the river (that is, the current operations) and in most cases, also outperformed the preferred scenario developed in the BRP. Performance measures used included Bow River flow below Bassano Dam, water shortages in the system, Kananaskis River flow below Pocaterra hydroelectric plant, Kananaskis River Flow, and water bank storage.

The simulation study identified possible recommendations for integrated river management operations. It also identified several needed improvements or adjustments to the BROM tool.

Participant Outcomes

Participants concluded that the *BROM* is a realistic and valuable tool for understanding the Bow River system and for exploring potential opportunities to manage the system for broader benefits for various water users.

<u>Key lessons learned</u>

The simulation study confirmed that the Bow River system can and should be managed differently to achieve many economic, environmental, and social goals throughout the Bow basin.

Given the participants represented subject matter experts and key stakeholders, their conclusion that the *BROM* is a is a realistic and valuable tool speaks strongly for it being useful for actual governance and drought management decision making.

The simulation confirmed the value and effectiveness of various key recommended operational changes from the BRP.

Budget

The budget for planning, coordination with attendees, running the event, and drafting the summary report was $87,250. The total does not include development of the tool or data compilation.

Simulation tool/exercise used

Bow River Operational Model (BROM) - built using *OASIS* (*Options Analysis in Irrigation Systems*) (see section 4.2.11).

Relevant literature and links:

> Alberta WaterSMART and Alberta Innovates – Energy and Environment Solutions. (2011). *Bow River Live Simulation Summary Report*.

4.1.2 South Carolina Drought and Water Supply Shortage Tabletop Exercise

This case study is relevant to the Alberta Water Council Drought Simulation project because it is a good example of stakeholder-based engagement with drought response plans to identify gaps and pathways for improving drought resiliency. South Carolina was selected as one of the jurisdictions of interest for comparison with Alberta.

Key considerations for AWC:

- Paper-based scenarios were developed specifically for this event.
- Existing drought response plans provided the response options.
- Participants were from entities that have decision-making roles in a drought event.
- It functioned as a 'dry run' for actual drought event management.
- Multiple real river basins were used, and outcomes applied to the whole state.

All the information about the South Carolina Drought and Water Supply Shortage Tabletop Exercise came from the "*South Carolina Drought and Water Shortage Tabletop Exercise Summary Report"*, or from personal communication with Tom Walker, Research coordinator at Clemson University.

Description

This tabletop exercise engaged drought response stakeholders at local, state, and federal levels to practice responding to drought by simulating a moderate, severe, and extreme drought scenario. Scenarios were paper-based, and each group worked through their drought response plans to identify gaps in response and legislative challenges.

Objectives

- Test the South Carolina drought monitoring and response processes.
- Identify gaps in existing processes and prioritize follow-up actions.
- Increase awareness of participant roles and responsibilities for drought response planning within their agencies and organizations.

Outcomes

Model Outcomes

N/A

Participant Outcomes

Engaging stakeholders in a "dry run" drought scenario identified gaps in the legislative process and helped identify additional key people who needed to be involved in drought response (e.g., media representatives for dispersal of information).

Key lessons learned

Although legislative gaps were not resolved as a result of the simulation, stakeholders became aware of the challenges, know who to contact, and have introduced their own best practices for drought response.

Engaging stakeholders from all basins allowed information sharing and networking, which improves drought response.

Budget

The budget for planning the scenarios and running the event was under $10,000. The budget did not include catering, venue, or any tool costs (as no tool was used).

Simulation tool/exercise used

The tabletop exercise consisted of four paper-based scenarios:

- Incipient drought – based on U.S. Drought Monitor rating of D0.
- Moderate drought – based on U.S. Drought Monitor rating of D1.
- Severe drought – based on U.S. Drought Monitor rating of D2.
- Extreme drought – based on U.S. Drought Monitor rating of D3.

Each scenario was located in real world basins within South Carolina. Groups were tasked with developing and / or using existing drought response plans for each specific area.

During the 2019 exercise, Mentimeter was used to engage participants and encourage discussion. Mentimeter is an interactive presentation software that uses live polls, word clouds and Q&As to allow participant engagement and real time feedback.

Relevant literature and links:

Altman, E. and Lackstrom, K. (2018). *South Carolina Drought and Water Shortage Tabletop Exercise Summary Report*. Accessed from https://www.cisa.sc.edu/PDFs/2017%20SC%20Drought%20Tabletop%20Exercise/SC%20Drought-Water%20Shortage%20Tabletop%20Report%20FINAL%204-18.pdf

4.1.3 Saskatoon Invitation Drought Tournament (IDT)

This case study is relevant to the Alberta Water Council Drought Simulation project because it specifically focused on drought adaptation and management, used a tool that can be adapted to other jurisdictions, and used either a specific watershed or a fictional one. Participants were from a variety of backgrounds where technical expertise was not necessary. This exercise was conducted with participants from throughout the South Saskatchewan River Basin, including both Alberta and Saskatchewan stakeholders.

Key considerations for AWC:

- The scenario was adapted from an existing framework.
- This framework could be adapted for a specific basin or outcomes, or it could be adopted directly.
- A computer model was a support tool for participants to understand the consequences of drought management actions.
- Game qualities included competition, cooperation, strategies, rules, players, and referees.

The information contained in this section about the IDT is directly from "*The Invitational Drought Tournament: What is it and why is it a useful tool for drought preparedness and adaptation?"* by Harvey Hill et al., (2014), "*A water resources simulation gaming model for the Invitational Drought Tournament"* by Wang and Davies (2015), and personal communication with Harvey Hill.

<u>Description</u>

The IDT combined a workshop with features of a game, including competition, cooperation, strategies, rules, players, and referees. The IDT game was developed by Agriculture and Agri-Food Canada in 2010 to support discussions between stakeholders from different specialties on different proactive drought management policies. The IDT is a day-long workshop in which multidisciplinary teams compete against each other to develop the best drought management plan. Constraints on team options were in the form of an annual budget (for each round), the physical realities of the drought as presented in the scenario, and the technical expertise of the game referees.

Participants were provided with a workbook in advance of the tournament which included background information on the simulation and on the watershed. The IDT can be run based on a real or fictitious watershed. There are two fictional watersheds already developed.

The game consists of three or four rounds, each representing one year. Each team must decide which drought management or adaptation options to choose from, within the annual budget they have. A system dynamics-based simulation gaming model called the IDT Model was developed to support the IDT game. It was designed to quantify and communicate the effects of IDT teams' drought management decisions both in the short-term and over several years of drought conditions. The IDT event held in Saskatoon in 2013 included use of the *IDT Model*.

Objectives

Since 2011, multiple IDT events have been held in Canada and the US with objectives that include:

1. Improving participants' understanding of drought management.
2. Sharing experiences in dealing with drought.
3. Improving collaborative decision-making and consensus-building approaches.

Outcomes

Participant Outcomes

The IDT supports interactive learning and creativity in drought management. Participants found the IDT engaging and effective at bringing together stakeholders with different perspectives to engage in meaningful dialogue to achieve consensus decisions around drought preparedness.

The *IDT Model* clearly illustrated the effects of team policy choices, based on different policy combinations and their cumulative effects on both physical and socio-economic variables, with results that sometimes surprised participants and contributed to learning about both drought and drought management.

Model Outcomes

The use of the *IDT Model* enabled the Saskatchewan IDT event to be more technical and to have information feedback mechanisms so that participants understood the impacts of the decisions, and the consequences carried forward through each round.

Key lessons learned

The IDT framework was tested and improved over a series of years and events with different participants. The *IDT Model* was developed and added later to address some of the responses from participants to have better mechanisms for in-game learning.

For government institutions, the *IDT Model* framework could be used experimentally to explore policy combinations and motivate creative thinking about drought management. In this capacity, the model could aid regional and local levels of government in developing and accessing plans, soliciting public support for drought management, and contributing to proactive drought management efforts.

Budget

Unknown as it varies significantly based on the IDT event.

Simulation tool/exercise used

The Invitational Drought Tournament framework and the *IDT Model* (see section 4.2.2).

Relevant literature and links:

Hill, H., Hadarits, M., Rieger, R., Strickert, G., Davies, E., and Strobbe, K. (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, pp 107-116.

Wang, K. and Davies, E. (2015). *A water resources simulation gaming model for the Invitational Drought Tournament*. Journal of Environmental Management, 160 pp 167-183.

4.1.4 Colorado Drought Tournament

This case study is relevant to the Alberta Water Council Drought Simulation project because it used a gaming forum to specifically engage stakeholders and communities on drought preparedness for the whole state of Colorado.

Key considerations for AWC:

- The scenario was adapted from an existing framework for predetermined objectives and the regional context.
- Drought management for the whole state was tested in this event.
- Participants were selected from across the state and had real-world roles in drought mitigation and management.

The information about the Colorado Drought Tournament is taken from "*Summary Report: Colorado Drought Tournament*" (2012) prepared by AMEC Environment and Infrastructure, or from personal communication with Courtney Black.

Description

A drought tournament was held on September 18, 2012 in Denver, Colorado, as a precursor to the two-day State Drought Conference. The tournament was adapted from the Canadian Integrated Drought Tournament (IDT) framework to the context for the State of Colorado by AMEC specifically for this event.

The drought tournament was designed over the prior summer through a series of meetings and included a simulation day when it was tested before the actual tournament. The simulation day provided valuable points for game refinement, definition of referee roles, round timing, and familiarity for the facilitators and referees.

Approximately forty people were involved in playing and running the tournament. The game was based on a fictional basin developed to characteristically represent watersheds in Colorado. Each of the teams developed a drought response plan and competed against each other for the best one. Teams were constrained by an annual budget, the river administration rules that are legislated in Colorado, and a list of specific drought mitigation or response options. The final scoring combined individual, team and referee perspectives.

Objectives

- Educate participants on multidisciplinary and multi-sector implications of drought.
- Encourage collaboration among stakeholders with various backgrounds.
- Introduce the concept of a game as a way to engage stakeholders and develop relationships.
- Provide a forum to develop contacts and information useful for future local, regional, and statewide drought planning purposes.
- Create an environment that was engaging, competitive, fun, and worthwhile to attend for education and networking.

Outcomes

Model Outcomes

N/A

Participant Outcomes

In the response survey following the tournament, 88% of participants strongly or moderately agreed that it was effective in achieving the objectives of educating participants, encouraging collaboration, and was an effective tool for a fun environment for engaging stakeholders. 65% of participants agreed strongly or moderately that it was an effective tool to collect information for planning purposes.

The tournament was effective at engaging participants in the game, provided an excellent forum for discussion and critical thinking about drought, facilitated connections between stakeholders from sectors that normally would not interact, and created an effective collaboration environment.

Key lessons learned

Specific learnings provided by participants identified that there was an overwhelming amount of information and too much to read during the session time, specifically in the short time for each round. Various suggestions for how to improve this are noted in the "*Summary Report: Colorado Drought Tournament.*" There was interest from participants in having economic impacts, agriculture, and water storage level information provided at greater detail, and in having a way to track trade-offs.

Overall, the "*Summary Report: Colorado Drought Tournament*" concludes that a drought tournament framework must be customized to the predetermined objectives for that session and to the local region context. Technical components were important for developing the drought tournament framework; however, the selection of stakeholders to invite and the formation of teams was critical to the success of the tournament. The Colorado Drought Tournament was successful at engaging stakeholders in a competitive and fun environment by fostering multidisciplinary collaboration on drought issues and solutions. It is suggested that this exercise could be used for a variety of real-life planning efforts (e.g., for water supply and management or for drought management planning), and it could be a tool to build trust among stakeholders throughout the State.

Budget

Unknown, sponsored by the Colorado Water Conservation Board (CWCB) and the National Integrated Drought Information System (NIDIS).

Simulation tool/exercise used

The paper-based exercise was built on the IDT framework (see section 4.2.2). There was very detailed planning, but no modelling tool was used during the simulation exercise.

Relevant literature and links:

AMEC Environment and Infrastructure. (2012). *Summary Report: Colorado Drought Tournament*, prepared for Colorado Water Conservation Board and National Integrated Drought Information System. Accessed from https://cpaess.ucar.edu/sites/default/files/meetings/2016/documents/2012DroughtTournament.pdf

4.1.5 Basin-Wide Framework for Drought Forecasting and Planning in the Chesapeake Bay Region

This case study is relevant to the Alberta Water Council Drought Simulation project because it was specifically aimed at practical application of drought planning and management, and it included stakeholders modelling in workshop settings. This project used the tool in a series of localized water supply utility 'case studies' throughout the Chesapeake Bay Region.

Key considerations for AWC:

- The technical capabilities of the tool and good data are essential to the success of the exercise.
- The objectives required a significant amount of communication before and after the in-person events.
- The tool and the exercise were specific to a single basin.

All the information about the Basin-Wide Framework for Drought Forecasting and Planning in the Chesapeake Bay Region is directly from “*Sectoral Applications Research Program (SARP) Final Report: Developing A Basin-Wide Framework for Drought Forecasting and Planning in the Chesapeake Bay Region”,* on the Hazen and Sawyer website (Hazen Sawyer, 2021).

Description

National Oceanic Atmospheric Administration (NOAA) and Susquehanna River Basin Commission (SRBC), along with several partner organizations, ran this project with the primary goals of developing a *Drought Planning Tool (DPT)* for the Susquehanna River Basin to inform stakeholder planning and drought coordination activities and to evaluate the tool for use in drought planning and operations.

The *Drought Planning Tool* consists of a system simulation model (*OASIS*); time series of climatological/meteorological drought indices and forecasts; model code for water supply drought operations; and a post-processing dashboard for the evaluation of tradeoffs among cost, water supply reliability, and other performance metrics of interest for alternative drought scenarios.

This project used the *DPT* in a series of localized water supply utility 'case studies.' For each case study, two sets of *DPT* simulations were carried out: (1) one set to compare responses of drought indices and reforecasts to dry periods and severe droughts within the historical simulation period under baseline (current) water supply operations; and (2) one set to compare alternative operating strategies specific to each case study, triggered by a subset of drought indices and reforecasts.

This project included extensive outreach efforts, including project-specific and basin-wide stakeholder workshops, numerous conference presentations, and a planned nationwide webinar to be facilitated by Water Research Foundation.

Two sets of workshops were conducted for the project case studies, one set with staff from the City of Baltimore's Department of Public Works and a second set with case study participants from the Lower Susquehanna River Basin. Initial project workshops were conducted in the first half of the project during design of the case study analyses. These workshops focused on introducing the project and the Drought Planning Tool; discussing drought indices and forecasts; reviewing baseline operating policies; and soliciting input from utility staff on potential alternatives to evaluate. These workshops were followed by informal phone calls with utility staff to discuss follow up questions. A second set of workshops was held near the end of the project to review case study results and to solicit input on any additional refinements or alternatives to evaluate.

In addition to the case study workshops, the project team conducted outreach via several local and regional stakeholder groups including: the Baltimore Metropolitan Council's Reservoir Watershed Management Program; the Lower Susquehanna River Source Water Protection Partnership; the Maryland Water Monitoring Council; the Conowingo Pond Management Workgroup; and the Pennsylvania Section of the American Water Works Association. This outreach focused on briefing regional stakeholders on NOAA drought products and development of the *DPT*. Finally, project members gave presentations on this project at several national conferences.

Objectives

Project objectives included:

1. Developing a quantitative *Drought Planning Tool* for the Susquehanna River Basin based on the OASIS system simulation model and other tools.

2. Evaluating the use of the *Tool* to support water utility drought planning and operations.
3. Developing a set of methodologies for near-and medium-term predictions of drought likelihood.
4. Identifying key climate, other climate and other drought index parameters of importance in the Chesapeake Bay Region.
5. Developing practical guidance for NOAA drought products and a framework for implementation.

Outcomes

Model Outcomes

Various outcomes were found for each case study. This project work resulted in several concrete and technical outcomes, including specific operational changes for reservoirs, agreed-upon demand cutbacks, and how forecasting changes or supports decisions.

For Baltimore DPW (one case study), this project has already enabled changes to the allocation management for the Susquehanna River and has supported negotiations between the City and the Susquehanna River Basin Commission.

Participant Outcomes

The outreach and communication activities met the objectives by:

- Raising awareness of the *DPT* within the basin stakeholder community.
- Raising awareness of the NOAA early warning drought and forecast products within the Chesapeake Bay region.
- Soliciting peer review and guidance on *DPT* applications from the broader research and water resources communities.

Key lessons learned

This project was initiated to address a critical need for water resources planning in the Chesapeake Bay Region, and more specifically in the Susquehanna River Basin. Much of the drought planning in the region is done in silos with various divisions based on state and local requirements, industry, and individual objectives. The *DPT* works successfully to address these shortcomings because the platform provides a quantitative, simulation-based tool to evaluate alternative drought policies across multiple scales. It allows alternative planning or operations scenarios for individual entities that are then simulated in the overall basin, which allows recognition of the bigger impacts, and facilitates coordination of decision-making across the basin.

Inclusion of these products in the *DPT* enables evaluation of alternative drought mitigation policies triggered by index and forecast-informed measures of weather and basin conditions. The inclusion of existing drought indices and forecasts in the tool helps stakeholders emphasize proactive and "no regrets" policies for which performance can be predicted in a quantitative manner through DPT simulations.

Budget

Unknown. Funded by NOAA, matching funds noted to include $52,000 USD (in-kind labour) by the SRBC. There is no information on what the total budget was or the total matching amount.

Simulation tool/exercise used

This project included the development of *a Drought Planning Tool based* on the *OASIS* system simulation model (see section 4.2.11). The streamflow and precipitation are in daily timestep and allows for a climate change scenario to be represented in the data. The geographic scale is a basin/watershed, but crosses state boundaries.

Relevant literature and links:

National Oceanic Atmospheric Administration. (2017). Sectoral Applications Research Program (SARP) Final Report: Developing A Basin-Wide Framework for Drought Forecasting and Planning in the Chesapeake Bay Region. Accessed from https://www.srbc.net/our-work/programs/planning-operations/docs/drought-forecasting-planning-chesapeake.pdf

Hazen and Sawyer. (2021) Basin-Wide Framework for Drought Forecasting and Planning in the Chesapeake Bay Region, under "All Projects." Accessed from https://www.hazenandsawyer.com/work/projects/basin-wide-framework-for-drought-forecasting-and-planning-in-the-chesapeake/%20%20%20https://www.srbc.net/our-work/programs/planning-operations/docs/drought-forecasting-planning-chesapeake.pdf

4.2 Simulation tools

The eleven tools described through this section are games or can be adapted to a game-style exercise. For a table breakdown of the tools for easy comparison, see Appendix C – Tools Summary Table.

4.2.1 Bow River Sim

Bow River Sim is a single-player desktop game developed by AEP and BGC Engineering. It has a user-friendly interface and fun visual elements that allow players to navigate the Bow River Basin (Figure 2) based on the *Water Resources Management Model (WRMM),* developed by AEP. The *WRMM* is a computer program that simulates water uses, priorities, and flows with a water allocation model using naturalized streamflow data from the South Saskatchewan River Basin from 1928-2009. It is a valuable decision-support tool due to its ability to allocate water resources according to the Alberta *Water Act* and has been used for numerous water studies at a local, regional, inter-provincial, and international scale. *Bow River Sim* runs on a simplified *WRMM* model with only 50 key water management components, allowing it to run quickly and provide players with more instant results. Through three different modes (tutorial, *WRMM*, and challenge), players are engaged in the water management planning process to improve their understanding of parameter constraints and influences on the Bow River basin. In the challenge mode, players aim to distribute water to stakeholders so that they all receive 100% of the requested amount.

Adjustable parameters include reservoir capacity, maximum reservoir levels for wet and dry seasons, City of Calgary water demand, return flows from different irrigation districts, inflows from the three tributaries (Bow, Elbow, and Highwood Rivers), percentage and volume of minimum flow apportionment, and priority of water licences. Data needed to run the tool are already built into it.

The game is not currently available for public distribution, however the AWC can likely gain access by contacting AEP or the current owner. Multiple participants can play *Bow River Sim* on separate computers simultaneously, allowing it to be used in a workshop setting. It has been tested at two workshops in Alberta, one in Calgary and one in Edmonton. Workshops were four hours in length to allow participants to explore the three different modes. The minimum number of participants is one, and the maximum is conceivably only limited by the number of computers available. The game could be played by individuals at home with discussion held by video-conference, allowing an exercise to align with COVID-19 health guidelines.

Figure 2 Screenshot from the *Bow River Sim* game.

Relevant literature and links:

Bow River Sim – A Serious Game for Water Management in the Bow River Basin. (2018, May 3). [Video]. YouTube. https://www.youtube.com/watch?v=pSEhUNqSFVo

Akhtar, M., C. Chevrotière, S. Tanzeeba, T. Tang, & P. Grover. 2020. A serious gaming tool: Bow River Sim for communicating integrated water resources management. Journal of Hydroinformatics. 22 (3): 491–509.

4.2.2 Invitational Drought Tournament

The *Invitational Drought Tournament* (*IDT*) is a multiplayer, in-person game developed by Agriculture and Agri-Food Canada where teams of players work competitively to develop solutions to a drought scenario (Figure 3). Teams must manage water resources with competing budgetary, cultural, regulatory, and institutional constraints. Teams are provided with background information regarding the watershed and work through three to four rounds with site-specific scenario drought data to develop a management plan that is environmentally, economically, and socially sustainable. The *IDT* framework was originally developed for two semi-fictitious basins, one based on a prairie watershed and the other on a sub-watershed in the Okanagan, British Columbia. The *IDT* framework can be adapted to create different iterations of the game based on different river basins. The amount of data required will depend on the detail and complexity of the basin setting and the drought scenario. Using one of the scenarios that was previously developed for a fictional basin may require less new data.

To provide players with more instantaneous feedback, the *IDT Model* was developed to accompany the *IDT*. The model simulates short-term and long-term effects that various policy combinations have on land use and water balances within the basin. The game is designed to be run through a one-day workshop and should be coordinated with technical personnel. Cost of the workshop is unknown and likely to be highly variable. The *IDT* was originally tested in Calgary, Alberta, in 2011 with 46 participants, and has also been tested since, with and without the *IDT Model*, in Saskatoon, Saskatchewan (2012; 49 participants), Kelowna, British Columbia (2012; 53 participants), Colorado (2012; 40 participants), and Lincoln, Nebraska (2015; 32 participants).

The *IDT* framework can be used to create a single game scenario that can be run at multiple events across the province. It can also be used to develop one technical and one non-technical version of the same scenario, aimed for different objectives and participants. A tournament game held based on the *IDT* framework is best suited to 12 to 60 participants per event. It would not be possible to host a tournament entirely virtually; however previous examples have had some attendees participate virtually.

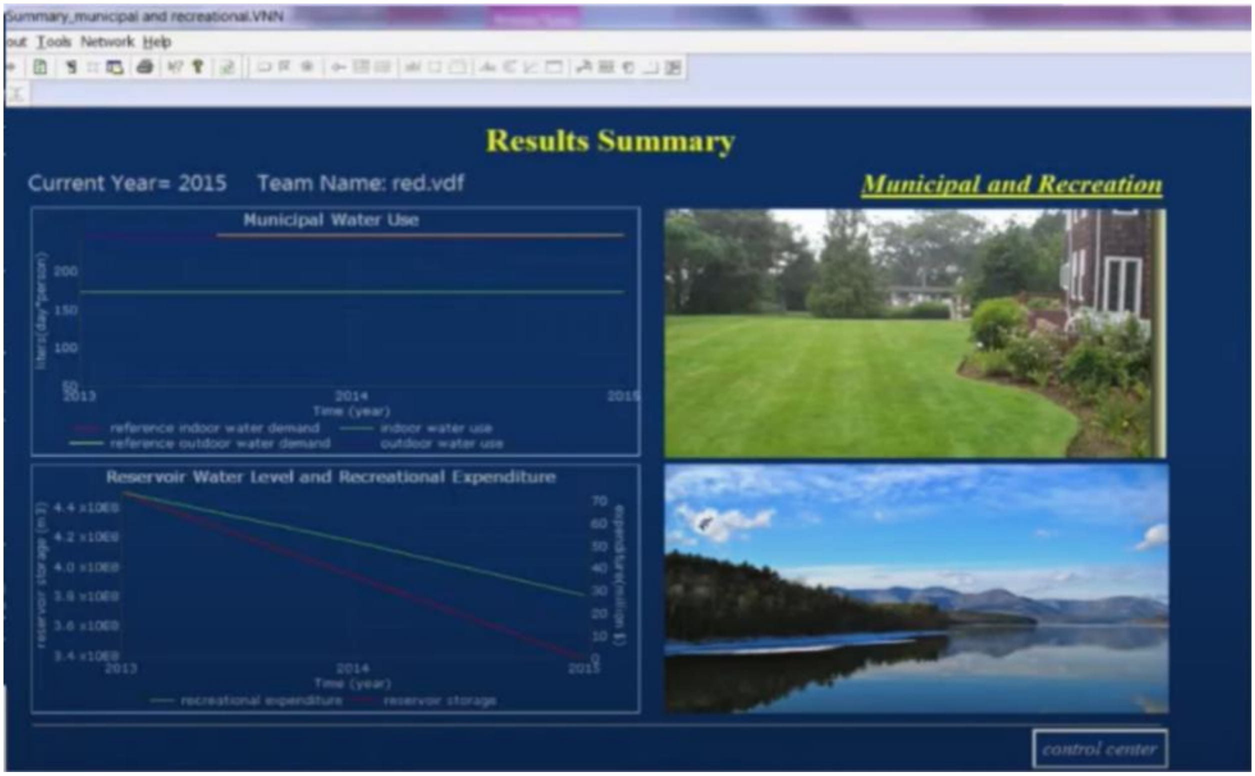

Figure 3 Screenshot from the Invitational Drought Tournament accompanying IDT Model.

Relevant literature and links:

Hill, Harvey, M. Hadarits, R. Rieger, G. Strickert, E. Davies, & K. Strobbe. 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.

Wang, K. & E. Davies. 2015. A water resources simulation gaming model for the Invitational Drought Tournament. Journal of environmental management. 160: 167 – 183.

Drought Policy Modelling: The Invitational Drought Tournament Model. (2013, July 11). [Video]. YouTube. https://www.youtube.com/watch?v=JJUvkFGzRc4

Okanagan Basin Water Board ,2012. Okanagan Invitational Drought Tournament. https://www.obwb.ca/workshops/okanagan-invitational-drought-tournament/

4.2.3 Aqua Republica

Aqua Republica is an online, single-player game created by DHI and the UNEP-DHI Centre for Water and Environment. *Aqua Republica* takes place in a fictitious world created with real-world data where players compete to manage limited water resources and a growing demand (Figure 4). Players must manage population increases, social pressures and competing water demands, as well as environmental and economic impacts in response to decisions made. Players learn water management best practices, integrated water resources management, and ecosystem-based approaches. The developer, DHI, can customize the game to different geographical locations, water data, scenarios, and learning objectives.

The original version should be available for free, although at the time of writing the website was no longer operational. The game was developed based on MIKE BASIN software, a map-based tool that supports water resource decision making processes. The game has been played in numerous countries and was part of the Eco Challenge where students compete to have the highest score in creating a prosperous basin. There is no evidence that the game has been played in Alberta in a formal workshop setting.

The game is designed for a single player on a single computer, however multiple participants can group around a table to discuss and play the game on a single computer. Multiple tables of participants could also play in a workshop setting. The game could be played by individuals at home, with discussion held by video-conference, allowing an exercise to align with COVID-19 health guidelines. The minimum number of participants is one, and the maximum is conceivably only limited by the space and number of computers available.

Aqua Republica is designed to facilitate players' understanding of how integrated and complex decision-making is with social, economic, environmental and political factors at play. The pre-built versions do not require any data inputs. A version with Alberta context and more specific types of drought-scenario objectives could be developed with the support of the developers, which would require the provision of significant amounts of data.

Figure 4 Screenshot from the Aqua Republica game.

Relevant literature and links:

CWR, 2013, Aqua Republica: Water Strategems. China Water Risk. https://www.chinawaterrisk.org/opinions/aqua-republica-water-strategems/

DHI, 2013,. Our Aqua Republica uses serious gaming to improve water resource management. https://www.dhigroup.com/global/news/imported/2013/10/4/ouraquarepublicausesseriousgamingtoimprovewaterresourcemanagement

DHI., 2013a,. Aqua Republica [Slides]. Australian Water Association. http://www.awa.asn.au/documents/WA_Conference_June2016/02_PBhautoo_Innovative_teaching_of_sustainable_water_management.pdf

Games4Sustainability., 2018,. Aqua Republica. https://games4sustainability.org/gamepedia/aqua-republica/

4.2.4 Ready for Drought?

"Ready for Drought?" is an in-person role-playing game based on the game *Extreme Event.* Players work collaboratively to solve community problems during a drought in order to build community resilience. Players learn to assess and respond to droughts by prioritizing resources and building coalitions. *Ready for Drought?* was created by the National Drought Mitigation Center and can be played in as little as 90 minutes and accommodates 12-24 players. The game can be downloaded for free and includes instructions (Figure 5).

The game takes place in the Missouri River basin and parameters of the game cannot be changed easily to another basin. The game is based on the drought planning decision-support model *THIRA (Threat and Hazard Identification and Risk Assessment)*. It has been tested at University of Nebraska-Lincoln and drought-related meetings, including the Natural Resource District drought planning meeting, the Federal Emergency Management Agency (FEMA) Region 8 drought workshop, and the North Central Agricultural and Natural Resources Academy. It is not believed that the game has been played in Alberta in a formal workshop setting.

If this style of in-person, role-playing game is appealing to the AWC, it may be possible to create a very similar version of the game based on a real or fictitious watershed of Alberta.

"Ready for Drought?" is a pre-build game and does not require any data inputs. It is designed to be played around a table in person and does not seem to be adaptable to video-conference to align with COVID-19 health guidelines.

Figure 5 Screenshot of some of the materials provided with the Ready for Drought? download.

Relevant literature and links:

Podebradska, M., M. Noel, D. Bathke, T. Haigh, & M. Hayes. 2020. Ready for Drought? A Community Resilience Role-Playing Game. Water. 12. 2490. 10.3390/w12092490.

NDMC, n.d., Ready for Drought? A community resilience role-playing game. National Drought Mitigation Center. https://drought.unl.edu/Education/DroughtGame.aspx#:%7E:text=About%20the%20Game,drought%20%2D%20building%20a%20community%20resilience.

4.2.5 Water Wars

Water Wars is a 3D desktop, multiplayer role-playing strategy game developed by Intel that takes place in New Mexico along the Rio Grande (Figure 6). Players manage land parcels in several different roles, including farmers, developers, and policymakers, and must manage their water allocations accordingly. As players are presented with different water scenarios with unique problems, players must make hard decisions and negotiate with each other for water resources. Existing policies that are based on real-world policy scenarios detail how water resources are allocated and governed and can be altered by the policy maker during the game. *Water Wars* provides an opportunity for players to think critically and to negotiate policy under various water scenarios; however, the game does not appear to be available currently. There is no evidence that the game has been played in Alberta in a formal workshop setting.

There is limited information regarding the access to, or availability of this game, but the AWC may be able to gain access by contacting the developer or current owner. The game is pre-built, does not require data, and parameters cannot be changed. It is not clear what the minimum number of players required is, or if this game can be played in a way that aligns with COVID-19 health guidelines.

Figure 6 Screenshot from the Water Wars game, taken from Hirsch (2010).

Relevant literature and links:

Hirsch, T., 2010. Water wars: designing a civic game about water scarcity. In: Proceedings of the 8th ACM Conference on Designing Interactive Systems. ACM, Aarhus, Denmark, pp. 340-343.

United Nations. (n.d.). Water Wars. UN Framework on Climate Change. https://www4.unfccc.int/sites/NWPStaging/Pages/item.aspx?ListItemId=24053&ListUrl=/sites/NWPStaging/Lists/MainDB

4.2.6 Catchment Detox

Catchment Detox is an online single-person game where the player manages a fictitious watershed while simultaneously trying to create a strong economy (Figure 7). The game was developed by the Australian Broadcasting Corporation and is available online for free to help educate players about the challenges of balancing catchment-scale environmental issues, economic impacts, and population growth. Players are given 100 turns and are scored based on their ability to balance development with environmental demands. The game is based on a model developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Division of Land and Water and e-water Co-operative Research Centre and parameters cannot easily be changed by players. It is not believed that the game has been played in Alberta in a formal workshop setting.

The game is designed for a single player on a single computer; however multiple participants can group around a table to discuss and play the game on a single computer, and multiple tables of participants could play in a workshop setting. The game could also be played by individuals at home with discussion held by video-conference, allowing an exercise to align with COVID-19 health guidelines. The minimum number of participants is one, and the maximum is conceivably only limited by the space and number of computers available.

Catchment Detox is a pre-build game and does not require any data inputs. The parameters of the game cannot be changed.

Figure 7 Screenshot from the Catchment Detox game.

Relevant literature and links:

> Alhadeff, E., 2010, Online Water Conservation Serious Game. Serious Game Market. https://www.seriousgamemarket.com/2010/02/online-water-conservation-serious-game.html
> Australian Broadcasting Corporation, 2008, ABC Catchment Detox - FAQs. ABC Science. https://www.abc.net.au/science/catchmentdetox/files/faq.htm#faq

4.2.7 WAT-a-GAME

WAT-a-GAME is a multiplayer, in-person game where players manage land plots in a watershed and must make decisions on how to utilize their land and water resources. The game consists of spatial structures such as river segments, land plots, pipes, aquifers, and cards, all of which can be printed or drawn, or purchased in the "all-in-one" kit for €50. There are several versions of the game currently available. The *"Self-WAG"* version of the game (short for *Self-WAT-a-GAM*E; Figure 8) has been designed to be flexible in nature and allow the game to be adapted to suit local situations. The game is designed to run for approximately a half day, and courses and instructions are available online to help set up and run the game. The game has been used in a number of countries but there is no indication that the game has been played in Alberta in a formal workshop setting.

This is a pre-build game and does not require any data inputs. Depending on which version is being played, the minimum number of players is one and the maximum number is 150. It is designed to be played around a table in person and does not seem to be adaptable to video-conference to align with COVID-19 health guidelines.

Figure 8 Photo of some of the spatial structures that can be purchased in the "All-in-one" kit version of WAT-a-GAME.

Relevant literature and links:

Ferrand, N. S. Farolfi, G. Abrami, D. Du Toit. WAT-A-GAME: sharing water and policies in your own basin. 40th Annual Conference, Int. Simulation and Gaming Association, Jun 2009, Singapour, France. 17 p. ffhal-01355501

WAT-A-GAME, n.d., WATaGAME. https://sites.google.com/site/waghistory/

4.2.8 Run the River

Run the River is a single player game created by Unity and the Australian Government (Murray-Darling Basin Authority) for use on a desktop or smartphone and is free to download. Players allocate river water to different water uses in a basin, such as agriculture, ecosystem health, or human use, and try to keep the connection between the river and the ocean (Figure 9). At each level of the game, the difficulty increases with challenges in the form of natural disasters, seasonal changes, and increased water demand. The game was developed based on historic and modelled data from the Murray–Darling Basin from 1905 to 2006. The game parameters are not adjustable, and it is unknown if the game has been played in Alberta in a formal workshop setting, though it is unlikely given that it is a simplified game and is more ideal as an educational tool for a younger audience.

This game is pre-built, no data input is required, and parameters cannot be changed. The game is designed for a single player, but likely could be conducted in a workshop discussion setting. It could be played by individuals at home with discussion held by video-conference, allowing an exercise to align with COVID-19 health guidelines.

Figure 9 Screenshot from the *Run the River* game.

Relevant literature and links:

Games4Sustainability., 2018b, Run the River. https://games4sustainability.org/gamepedia/run-the-river/

Murray-Darling Basin Authority, 2018, Teacher supplement: Run the river. https://www.mdba.gov.au/education/apps/run-the-river/teacher-guide

4.2.9 CAULDRON (Climate Attribution Under Loss & Damage: Risking, Observing, Negotiating)

CAULDRON is an in-person game developed by the Environmental Change Institute, University of Oxford, AfClix (the Africa Climate Exchange), and the University of Reading in partnership with the Red Cross Climate Centre. The purpose of *CAULDRON* is to create discussion around extreme weather events and how they may impact policy development. Players begin as farmers that need to make decisions and roll dice to determine their success in response to various climate challenges, then become climate scientists, and finally policy makers that need to negotiate a climate change treaty for their region. Designed to be played in 90 minutes and accommodate between 24 – 80 players, the game is free though parts need to be constructed in advance. Three variations are currently available with online facilitation guides. It is not believed that the game has been played in Alberta in a formal workshop setting.

This is a pre-build game, does not require any data inputs, and game parameters cannot be changed. It is designed to be played around a table in person and does not seem to be adaptable to video-conference to align with COVID-19 health guidelines.

Figure 10 Screenshot of some of the materials available online to support the CAULDRON game.

Relevant literature and links:

Walker Institute, n.d., The CAULDRON Game is a free, Climate Change game. http://www.walker.ac.uk/research/projects/the-cauldron-game

University of Reading, AfClix, EQUIP, ECI, University of Oxford, & Red Cross/ Red Crescent Climate Centre, n.d., The CAULDRON Game Climate Attribution Under Loss & Damage: Risking, Observing, Negotiating [Slides]. Walker Institute. http://www.walker.ac.uk/media/1093/2-cauldronslides_version1.pdf

University of Reading, 2015, The CAULDRON Game Climate Attribution Under Loss & Damage: Risking, Observing, Negotiating. Walker Institute. http://www.walker.ac.uk/media/1092/1-cauldronrules-main-document.pdf

4.2.10 SeGWADE (Serious Game for WDS Analysis, Design & Evaluation)

SeGWADE is an online, web-based game developed by the University of Exeter, Centre for Water Systems. It is driven by a hydraulic simulation engine based on EPANET, a water-distribution system modelling software, and was developed to help players learn to optimize water distribution systems. The goal of the game is to change the diameter of pipes along a water distribution system to find the most cost-effective configuration that meets pressure requirements. Multiple versions are available for free, custom versions can be created by changing input files, and the game can be set up as single- or multi-player. There is no evidence that the game has been played in Alberta in a formal workshop setting.

The game is designed for a single player on a single computer; however multiple participants can group around a table to discuss and play the game on a single computer, and multiple tables of participants could play in a workshop setting. The game could be played by individuals at home, with discussion held by video-conference, allowing an exercise to align with COVID-19 health guidelines. The minimum number of participants is one, and the maximum is conceivably only limited by the space and number of computers available.

SeGWADE is designed to facilitate a player's understanding of water distribution systems. The pre-built versions do not require any data inputs. Custom versions require data.

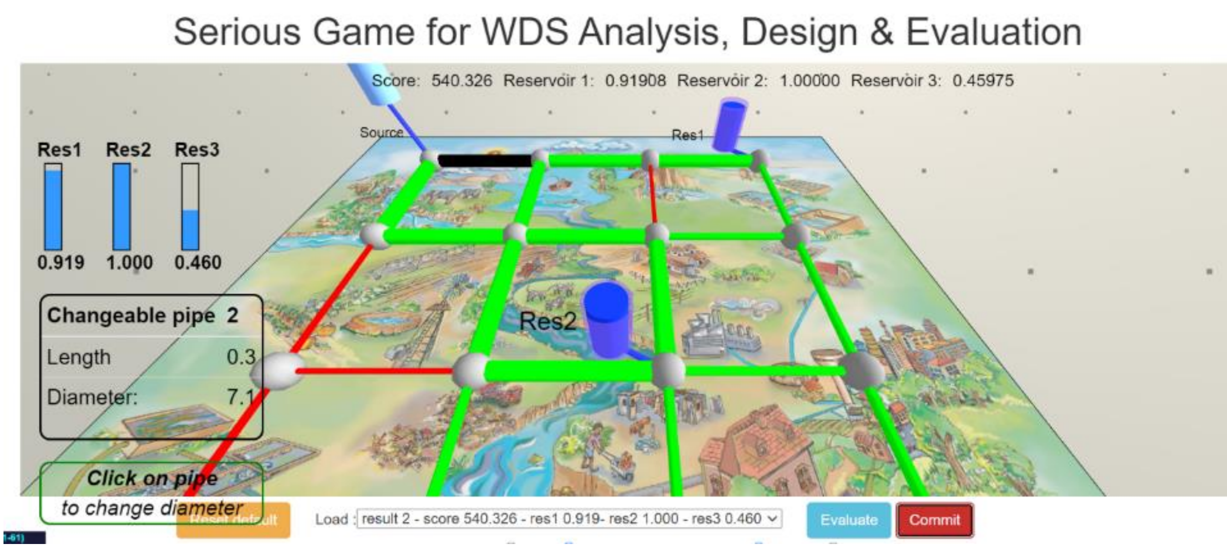

Figure 11 Screenshot from the SeGWADE game.

Relevant literature and links:

Khoury, M., M. Morley, & D. Savic. 2016. Serious Game Approach to Water Distribution System Design and Rehabilitation Problems. Procedia Engineering 186: 76 – 83.

University of Exeter, n.d., Serious Game for WDS Analysis, Design & Evaluation. Water Serious Games. http://waterseriousgames.org/

4.2.11 *OASIS (Options Analysis in Irrigation Systems)*

The *OASIS (Options Analysis in Irrigation Systems)* model was developed by Hydrologics Inc. in 2009. It is an arc and node type model which simulates the flow of water through a multi-user watershed. *OASIS* allows the user to define water management systems in a watershed by setting up an arc-node system and by defining a set of operating goals, constraints, and performance measures. User defined inflows can be entered into the model as well.

OASIS typically functions at hourly to monthly time steps and can be applied to variably sized basins from small and simple to large and complex. Generally, the model runs quickly (in a matter of minutes) and is designed to be very flexible. Multiple scenarios can be created which allow for simulation of different operating rules and implementation of alternative management scenarios.

Past examples of *OASIS'* real world application extends to its use in the Bow River Project, the South Saskatchewan Adaptation Project, and the Athabasca River Basin Initiative. *OASIS* has also been applied to investigate how climate change will affect water storage in the New York City Water Supply System. Although *OASIS* has been deemed a good example of a computer-aided negotiation tool, it is not necessarily set up as a game and therefore may not be as intuitive or engaging to use. The tool can be used by an individual or to support large groups in a workshop style.

The *OASIS* tool is a versatile building block and can be used to create a simulation of one or multiple watersheds with whatever level of detail is appropriate to gain the desired objectives from an exercise. Potentially one of the models already developed for an Alberta watershed could be simplified and adapted for the AWC's purposes. A collaborative or competitive game-style drought exercise could be designed with a simple *OASIS* model as the supporting tool.

This tool requires data inputs including flow data. It may be possible to design an exercise that participants could attend via video-conference. This would allow some networking and cross-sectoral collaboration, which is currently being done for more specific watershed projects; however, this exercise is more compelling when in person networking and cross-sectoral collaboration is possible.

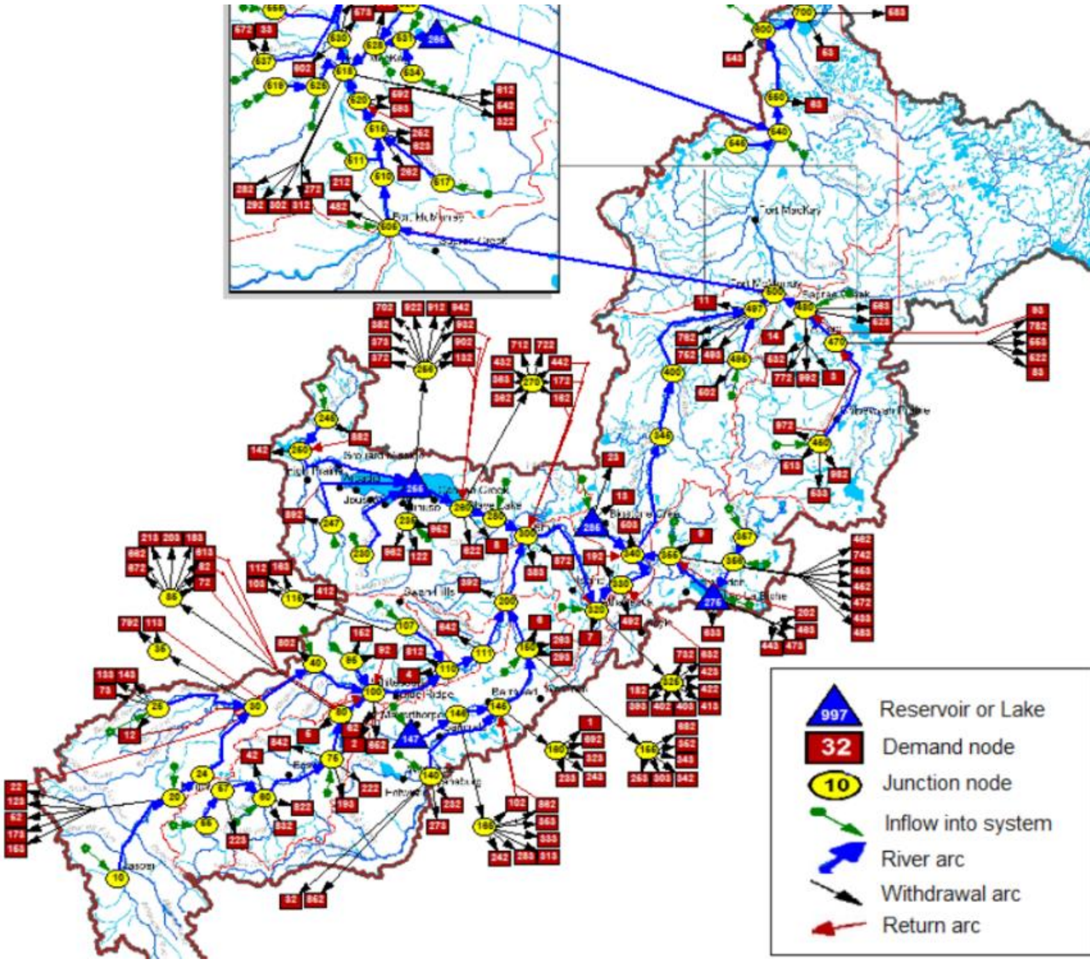

Figure 12 Screenshot of the graphical user interface for a version of the OASIS model

Relevant literature and links:

Kelly, M. 2012. The Bow River Project: An Exercise in Water Management, Resource Protection, and Collaborative Decision Making. http://www.hydrologics.net/documents/TheBowRiverProject.pdf

University of Lethbridge. 2014. The History of OASIS use in Alberta. http://www.uleth.ca/research-services/node/432/#history

WaterSMART. 2014. South Saskatchewan River Basin Adaptation to Climate Variability Project. Phase III: Oldman and South Saskatchewan (OSSK) River Basins Summary Report. 113 pp.

WaterSMART Solutions Ltd. 2018. A Roadmap for Sustainable Water Management in the Athabasca River Basin. Produced by WaterSMART Solutions Ltd. for Alberta Innovates, Calgary, Alberta, Canada. 247 pages. http://www.albertawatersmart.com/

Matonse, A.H., Pierson, D.C., Frei, A., Zion, M.S., Schneiderman, E.M., Anandhi, A., Mukundan, R., and Pradhanang, S.M. 2011. Effects of changes in snow pattern and the timing of runoff on NYC water supply system. *Hydrol. Process*. 25, 3278–3288. DOI: 10.1002/hyp.8121

Rivera, M.W. and Sheer, D. 2013. Computer Aided Negotiation and River Basin Management in the Delaware. Chapter 7 p 66 in Water Resources Systems Analysis through Case Studies; Data and Models for Decision Making. Prepared by Task Committee on Environmental and Water Resources Systems Education. Edited by David W. Watkins Jr., Ph.D. Sponsored by Environmental and Water Resources Institute American Society of Civil Engineers.

5.0 Summary and Observations

5.1 Drought management review

The regulatory framework and approach to drought management was reviewed in four jurisdictions. The review noted that Alberta and Saskatchewan have a more prescriptive regulatory framework than in the two U.S. jurisdictions reviewed. Both provinces use a priority-based system allowing government some control over total water withdrawals during low flow periods. This type of regulatory framework, with certain conditions on water licences, can support sharing water between users during a shortage. This approach can also be supplemented by voluntary agreements between water users such as those seen in Alberta on the Southern Tributaries during the 2001 drought.

Historically, in both Alberta and Saskatchewan, drought planning and response has been the basis for decisions about infrastructure and the design of regulatory systems for water management, as both provinces are drought prone. However, neither Alberta nor Saskatchewan has implemented a formal, provincial drought response plan. Alberta has implemented water shortage procedures and water management plans in basins impacted by severe historical droughts. In both provinces, the agriculture sectors have been most seriously impacted by droughts. As a result, in Saskatchewan historical drought response has focused on mitigating the impact of drought to agriculture through various methods including the development of irrigation infrastructure.

In both South Carolina and California, the regulatory framework is less prescriptive than Alberta or Saskatchewan. In these states, certain high volume water users or industries do not require permits to access surface or groundwater resources, meaning, historically, there was no regulatory instrument to reduce water consumption during periods of water shortage. During droughts, this type of regulatory framework has the potential to result in water conflicts that must be resolved through the courts. In addition, regulators cannot apply conditions to the withdrawals of smaller water users which has the potential to lead to excessive withdrawals and result in environmental damage. To mitigate conflict and the potential for excessive withdrawals, both states require stakeholders to be actively involved in the development and implementation of drought response plans. This collaborative approach allows discussion and compromise between stakeholders so that water can be shared in times of drought. The resulting drought plans are localized and highly detailed, and prescribe communication and reporting pathways as well as operational responsibilities at different stages of drought.

The review of historical drought simulation exercises showed that a simulation exercise can be an effective way to increase drought awareness and preparation when a drought is currently not being experienced. Keeping drought awareness front of mind in non-drought times may be beneficial to drought mitigation and response.

Relevant literature:

Government of Saskatchewan. (2005). *The Water Security Agency Act*. Regina, Saskatchewan.

Marchildon, G. P., Kulshreshtha, S., Wheaton, E., & Sauchyn, D. (2008). Drought and institutional adaptation in the Great Plains of Alberta and Saskatchewan, 1914–1939. *Natural Hazards, 45*, 391-411. doi:10.1007/s11069-007-9175-5

Saskatchewan Ministry of Environment. (2018). *Saskatchewan's Climate Resilience Measurement Framework* (Government of Saskatchewan, Saskatchewan Ministry of Environment). Regina, Saskatchewan.

Saskatchewan Water Security Agency. (2012). *25 Year Saskatchewan Water Security Plan* (Government of Saskatchewan, Saskatchewan Water Security Agency). Moose Jaw, Saskatchewan: Saskatchewan Water Security Agency.

Saskatchewan Water Security Agency. (n.d.). Retrieved January 25, 2021, from https://www.wsask.ca/About-WSA/About/

5.2 Case study and simulation tool review

The most successful simulation exercises had focused agendas that aimed to achieve only one or two specific outcomes from the exercise. Centering the objectives this way encouraged participants to ask specific questions pertinent to the exercise goals and for participants and organizers to manipulate the exercise tools effectively to answer those questions. This approach encourages discussion amongst participants and may result in other secondary beneficial outcomes. A good example of this was reported with the South Carolina Tabletop Exercise where the primary outcome was for stakeholders to understand how to implement their drought response plan, but participants reported secondary outcomes including an improved knowledge of other stakeholder roles and responsibilities in the context of drought response.

Simulation exercises using game-style tools such as *AquaRepublica* are well suited to collaborative learning and education. Game-style tools are often very visual with user friendly interfaces that allow the user to change certain parameters to achieve simple objectives. These game-style tools are frequently tailored to cater to participants who have limited technical knowledge of watershed operations and drought management and are useful for increasing awareness and understanding amongst non-technical people. Game-style tools are often simplified so only certain parameters can be changed by the user. This approach has the advantage that scenarios can be run quickly using a web-based interface or even on portable devices; however, scenarios are less realistic as they do not pull from an extensive background dataset.

More complex tools such as the *IDT* and *OASIS* are highly adaptable for use in different workshop types. They are also well suited to use in workshop style exercises that require realistic basin operations to be understood by participants, for example when testing basin operations during a drought or during development of basin drought plans. In exercises where there is a requirement for realistic simulations, there may be many parameters within the tool that can be changed, and a large background dataset may be required to simulate realistic basin operations. Simulations of multiple basins or at the provincial scale may require greater computer processing power meaning it may not be possible to run live scenarios during a workshop. In this case, the simulation developer would need to run the scenarios ahead of the exercise and graphical scenario outputs would form part of the workshop discussion.

The themes that are identified in the AWC report "*Building Resiliency to Multi-Year Drought in Alberta*" align with what could be determined to be the objectives for the simulation exercise. For example, Theme I – Public Education and Theme J – Collaboration, align very well with most game-type exercises. Theme B – Planning for Drought, Theme C – Supply Management, and Theme D – Demand Management may be partially addressed through a simulation exercise; however, they likely cannot be achieved with the same game-style tools as Themes I or J.

'Education' or 'raising awareness' are common objectives for drought simulation exercises. These are easily achievable objectives; however, for the outcomes of the simulation exercise to be measurable and valuable, it is important to specify the type of education or awareness desired and who the audience is that is learning. The tools themselves may all be deemed educational in one way or another, but they vary widely in what is being learned by the players.

The educational tools assessed in this project point to two very different types of educational tools. The first type are 'general drought understanding' educational tools. These tools help players or participants gain a general appreciation for the complexity of drought and water management, and they may understand some aspects of who makes decisions or what factors must be considered in drought management. The 'general drought understanding' tools can support understanding, but generally not action or direct engagement in drought management systems. The second group of tools might be called 'Alberta-specific drought understanding' tools. These tools support the player or participant learning specific parts of the water management system in Alberta and understanding concrete roles, actions and options for drought mitigation. These types of educational tools may support a wide range of engagement and practical action. One major difference between these two types of tools is cost; a 'general drought understanding' tool can be adopted from another developer, but a tool or game that is for 'Alberta-specific drought understanding' will require adjustments to the game at minimum. The tool may need to be essentially redeveloped to facilitate the type of education desired, and if additional outcomes from the overall simulation exercise are desired, this will need to be included in the tool re-design.

6.0 Recommendations

6.1 General approach to exercise development

The simulation tool that will be used to engage participants will be the foundation of the AWC simulation exercise. Selection of an appropriate tool should support the desired outcomes from the exercise and provide a valuable step towards the strategic intent of improving drought response within Alberta.

Figure 13 outlines the recommended approach to selecting an appropriate tool to support the AWC simulation exercise.

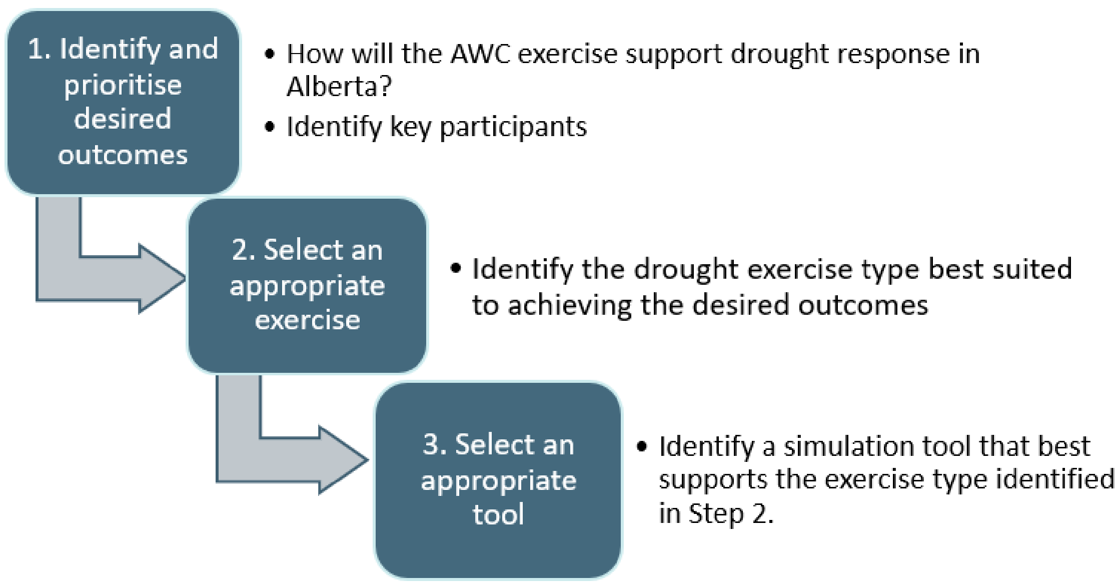

Figure 13 Recommended approach for selecting an appropriate simulation tool to support the AWC Simulation Exercise

The first step in the tool selection approach is identifying the desired outcomes from the AWC project. In the workshop held with the AWC Simulation Project Team on January 15th, 2021, the AWC Project Team identified that the broad desired outcome was to support the development of the provincial drought response plan currently being developed by the AEP. In addition, the following potential outcomes were highlighted as being of interest to the project team:

- Identifying strengths and weaknesses (costs and benefits) of various strategies for solving problems.
- Increasing awareness (e.g., informing, education) around water resources management and

drought management procedures.

- Building relationships, partnerships, collaboration, and coordination.
- Engaging stakeholders in planning and decision-making.
- Improving cross-sectoral communication and collaboration.
- Generating innovative mitigation and response strategies.

It is recommended that the project team select up to two of these outcomes as high priority, primary desired outcomes for the AWC Simulation Exercise. Selection of only two primary desired outcomes will allow for the optimal design of the simulation exercise and the creation of game scenarios that will focus discussion and make it much easier to achieve the outcomes as well as measure the success of the exercise. Selection of two high priority, primary outcomes is not to restrict the number of beneficial outcomes from the exercise, but to keep focused. Additional and overlapping secondary outcomes may also be achieved from the exercise. These secondary outcomes can also be considered as part of the selection process but are assigned a lower priority.

After selecting the primary desired outcomes, it is recommended that AWC consider which groups of participants should attend the exercise to best support the desired outcomes. While planning the simulation exercise, it is important to consider who the participants will be and their level of technical knowledge to ensure there is adequate time for participants to effectively engage and to avoid overloading them with information. For exercises based on the *IDT* framework (case studies in 4.1.3 and 4.1.4), the selection of participants and game team makeup were important elements of designing the exercise and achieving the desired outcomes.

It is understood that the AWC Simulation Exercise will engage stakeholders who have some technical watershed background; however, if a more technical outcome is desired there may be a need to provide an informational package or session to participants who may have limited technical knowledge.

Identifying the primary outcomes and considering participants will allow the AWC Project Team to identify the main focus or theme of the simulation exercise outlined in Step 2 of Figure . Once the main focus of the exercise is well understood, a tool can be selected that is suited to supporting the focus of the exercise as well as achieving the primary desired outcomes identified in Step 1 of the process.

Table 2 shows some examples of different exercise types and the requirements that supporting tools must have to achieve the desired goals.

Table 2 Examples of exercise types and desirable tool attributes.

Main exercise focus	Exercise description	Potential tool attributes
Broad educational	Non-technical participants would be educated about the general risks of droughts and some of the types of considerations required in managing drought risk.	• Visual interface • Minimal parameters • Do not overload the user with information • Does not need to be basin-specific
Specific educational	Participants may have a basic understanding of drought risk and the focus would be to educate participants on a specific aspect of drought management e.g., the regulatory framework governing drought management, drought plans or roles and responsibilities in a drought.	• Visual interface • Reflects basin operations to the extent necessary to achieve the educational goal
Vulnerability and risk assessment	A technical exercise in which stakeholders and water managers with a depth of knowledge of drought management assess current mitigation processes and identify gaps in plans, policy and legislation that could be addressed to improve drought resilience.	• Realistic representation of basin operations • Realistic present and future climate scenarios • Does not necessarily require a simple user interface
Drought plan testing	A technical exercise in which participants test a specific plan or procedure and identify any improvements that could be made. Participants would likely represent a broad spectrum of water stakeholders with interest in the outcomes	• Capable of realistic scenarios • Easily manipulated to create many scenarios

6.2 Exercise tool selection

It is recommended that when reviewing the tools and identifying which contains the greatest number of desired attributes, the attributes of each are considered individually in the context of how each can support the exercise as well as compared to one another.

6.2.1 Individual assessment of tools

Many tools, including most game-style tools, have been developed for specific purposes; however, many can be adapted to support simulation exercises. Comparison of the features of each tool in the context of the main focus of the exercise and the primary desired outcomes will help narrow the list of tools and identify which groups of tools are most suitable. Table 3 shows some examples of tools that could be grouped with certain exercise types based on how their attributes match the desired attributes identified in Table 2.

Table 3 Example of matching tools to suitable exercises.

Main exercise focus	Exercise description	Example tools with attributes suitable to supporting project goals
Broad educational	Non-technical participants would be educated about the general risks of droughts and some of the types of considerations required in managing drought risk.	• *CAULDRON* • *Catchment Detox* • *Run the River*
Specific educational	Participants may have a basic understanding of drought risk and the focus would be to educate participants on a specific aspect of drought management e.g., the regulatory framework governing drought management, drought plans or roles and responsibilities in a drought.	• *Bow SIM* • *Aqua Republica*
Vulnerability and risk assessment	A technical exercise in which stakeholders and water managers with a depth of knowledge of drought management assess current mitigation processes and identify gaps in plans, policy and legislation that could be addressed to improve drought resilience.	• *OASIS* • *BowSIM* • *IDT*
Drought plan testing	A technical exercise in which participants test a specific plan or procedure and identify any improvements that could be made. Participants would likely represent a broad spectrum of water stakeholders with interest in the outcomes.	• *OASIS* • *IDT* • Paper based *(WATaGAME)*

6.2.2 Comparison of tools

When assessing the suitability of tools, it is important to consider how tools compare to one another, not only in the context of their suitability to achieve the desired outcomes, but also in how well they fit within the boundary conditions of the AWC Simulation Exercise project as a whole. Boundary conditions include considerations such as project timeline, project budget and the spatial area the project will cover.

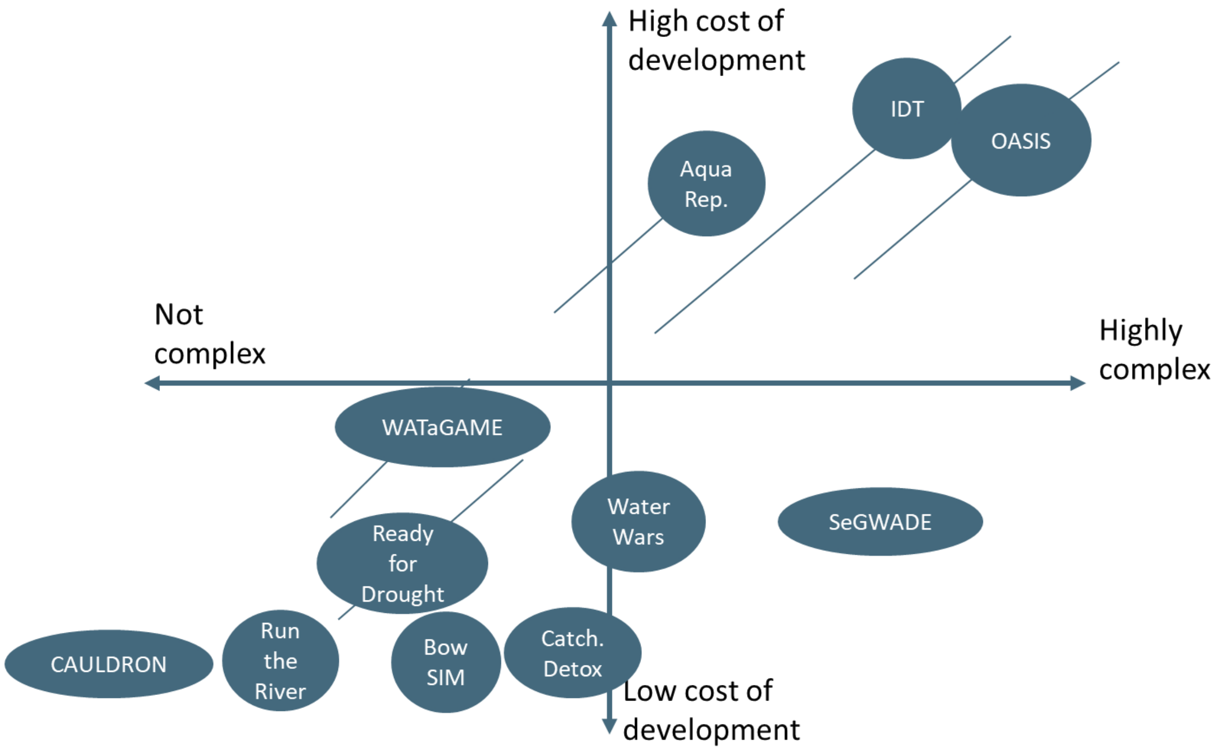

Figure 14 Simulation tools comparison of scenario development cost vs. complexity of the scenario

Figure 14 shows an approximate comparison of the potential cost of certain tools compared to the potential complexity of the scenarios run by the tool. For some tools, a range of costs is associated as they are capable of scenarios varying in complexity and cost of development. This is represented in Figure by the blue lines associated with each bubble. Game-style tools often have fixed scenarios that may be adaptable but cannot be changed. If scenarios are fixed, then the development costs associated with creating an exercise are lower; however, it should be noted that if the AWC were to request the developer adapt the game-style tools to be more specific to Alberta, development costs could increase.

Another comparison that could be made is assessing the tool's intended audience compared to the original goal of development. Tools are always best suited to the audience they were originally developed to address; understanding the intended audience can help match tools to relevant exercise types. Figure 15 shows the intended audience of the tools reviewed in section 4.2 compared to the outcomes that are realistically achievable with the tool. Tools in the bottom left quadrant tend to be more suited for education and understanding as they use simplified scenarios with user-friendly interfaces. Tools in the top right quadrant are suited to decision making and driving policy and tend to be suited to those who already have a technical understanding of drought and watersheds.

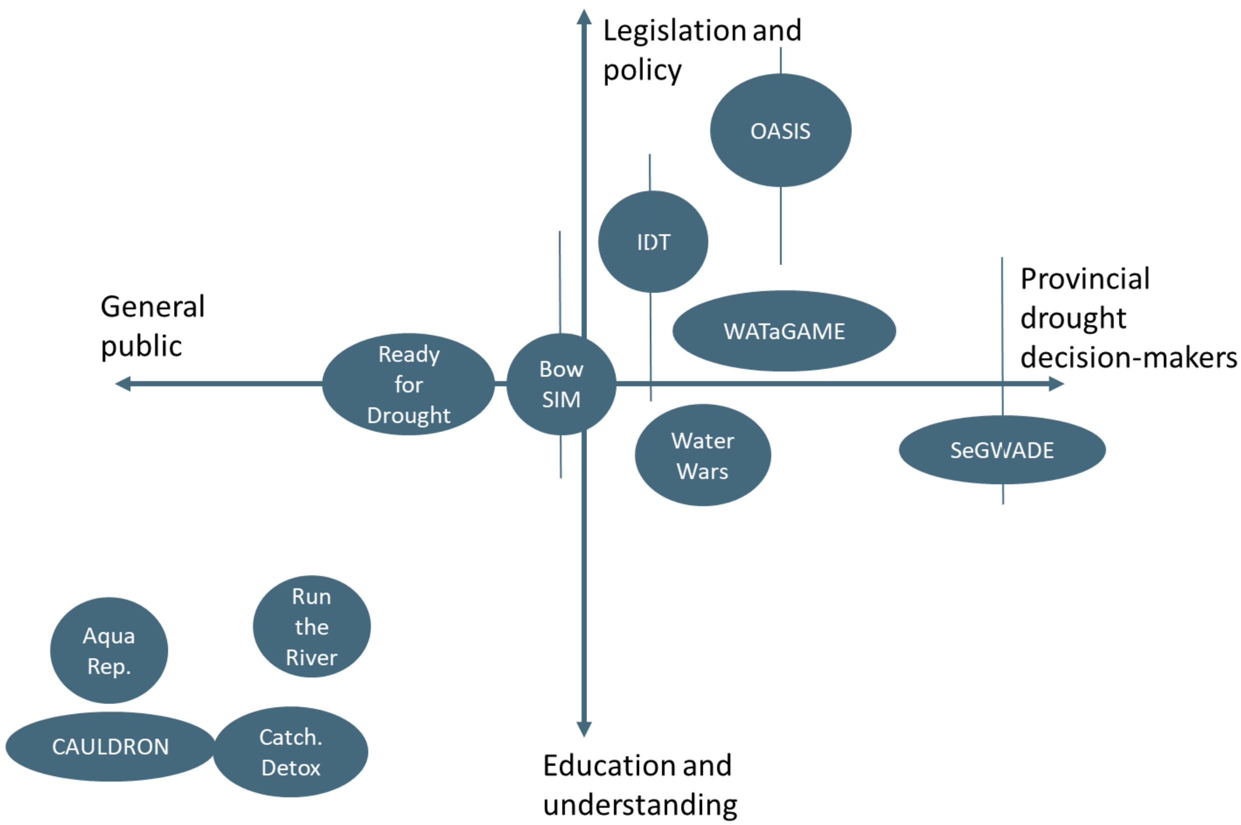

Figure 15 Comparison between the intended audience of tools vs. realistically achievable outcomes from tool scenarios

6.3 Additional considerations

It is recommended the AWC Project Team consider external factors in their exercise and tool selection that could impact the implementation or attendance of the exercise, such as the restrictions currently in place due to the COVID-19 pandemic. The restrictions have resulted in many people working from home which can limit or prevent attendance at in-person events and workshops. Whether the event will be held in-person or virtually is a key consideration as most tools are more suited to in-person workshops. If the event were to be held virtually, the following should be considered:

- Whether the tool requires participants to have software to run it.
- How exercise breakouts groups could be managed.
- If scenarios need to be run beforehand and if the meeting would consist of discussion of scenario outputs.
- The size of the participating group; it may be helpful to limit numbers during a virtual event to avoid technical difficulties or a lack of discussion.

7.0 Conclusions

All four jurisdictions reviewed make use of some form of permitting system to manage water use; however, the intricacies of each regulatory framework differ greatly, meaning there are only limited similarities between jurisdictions. It was noted that Alberta has a structured regulatory framework that allows regulators to control water use diversions during times of water shortage. There are opportunities to further develop provincial and local drought response plans. Actively engaging stakeholders in the development of those plans is likely to lead to positive outcomes in stakeholder understanding and buy-in to the regulatory processes around drought response.

Based on our review of case studies, engaging stakeholders through development of a drought simulation exercise resulted in positive outcomes in all case studies reviewed. Each case study had different objectives but increased participant awareness of roles, responsibilities and understanding of drought impacts was common across the exercises.

There are a number of tools currently available that could be used or be adapted for use in a drought simulation exercise based in Alberta. The suitability of each tool should be determined based on the objectives of the exercise and desired outcomes. It was noted that in general, game-style tools are less complex and require less background data to run but are likely to be more suited to exercises with purely educational objectives.

When considering tools for the AWC Drought Simulation exercise, it is recommended that a stepwise process is implemented in which the desired exercise outcomes are identified, the exercise type and style is selected based upon the desired outcomes and finally, the tool is selected by considering how it can support the desired outcomes and how it fits within the boundary conditions of the project. This approach is more likely to lead to beneficial outcomes of the AWC Drought Simulation exercise that will effectively support improvements to drought resiliency and response in Alberta.

Appendices

Appendix A – Drought Management Literature Review Summary Table

Please refer to the attached document: *AppendicesCombined_2021_03_08*

Appendix B – Simulation Case Study Research Summary Table

Please refer to the attached document: *AppendicesCombined_2021_03_08*

Appendix C – Tools Summary Table

Please refer to the attached document: *AppendicesCombined_2021_03_08*