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Water Management Solutions

Calgary Metropolitan Region Board

Natural and managed capacity of regional water supply in the Calgary Metropolitan Region

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Executive summary

The Calgary Metropolitan Region Board (CMRB) has a mandate to complete a Growth Plan and Servicing Plan for the Calgary Metropolitan Region (CMR) by December 2020. As part of the Servicing Plan development, the CMRB is undertaking inter-related studies of five Complexities that were identified as part of the CMRB Water Roadmap. The complexities focus on existing water and wastewater servicing, demand management, natural and managed capacity of supply, regulation and policy, and water quality and a background report on stormwater. Natural and managed capacity of water supply is the focus of this complexity study, which documents a summary of learnings from existing literature to provide relevant guidance to the CMRB Growth Plan consultant on the topic of natural and managed capacity of regional water supply.

Precipitation, in the form of runoff from snowmelt and rainfall, is the main source of natural water supply to the CMR, mostly coming from the Rocky Mountain headwaters. Peak runoff from snowmelt typically occurs in May and June, while rainfall can contribute to flow from June to August. Glacier meltwater is a key source of water in the late summer when snow and rainfall do not provide as much source water volume.

Projected changes to precipitation as a result of climate change will impact the natural water supply of the region because precipitation is the major source of water supply. There are two significant ways in which precipitation is projected to change in the CMR and headwaters region:

1. Timing throughout the year: climate projections for future conditions (roughly 2040s) indicate a trend toward more precipitation during the winter and less precipitation during the summer. Warmer air temperatures are projected to result in an earlier spring snowmelt.
2. Variability (quantitative difference between high and low flows): greater variability is projected between months, with higher possibilities of extremely high or low flows in any given year.

In general, climate change is likely to increase the frequency of low flow periods in all sub-basins in the CMR. Historical water supply studies also show long periods of low flows as part of natural variability. This indicates that regardless of climate change projections, water management strategies need to be designed around significant, multi-year droughts.

Management of water supply in Alberta is enacted through legislation, licensing, infrastructure, and planning/operations coordination. In 2007, the Bow and Oldman sub-basins were closed to new applications and water conservation objectives were set for the mainstem and their tributaries. Many reservoirs have been constructed within and upstream of the CMR to manage supply, mitigate floods, produce hydropower, or some combination. Management options that may be available to the CMR as identified in previous work are described in Section 4.5 and include both structural and non-structural options.

Section 5.1 of this report provides a description of high-level key considerations for the CMRB Growth Plan

consultant. These are the dominant themes that relate to future water supply management. They are broad, generalized statements for consideration in the planning process and include:

- Water supply variability
- Coordination among users
- Planning for increasing efficiency
- Risk and vulnerability
- Work with existing initiatives
- Low flows and wastewater
- Systems approach
- Diversity of storage and servicing

All sub-basins in the CMR are expected to experience some degree of water quantity constraints in the next 30 years due to projected changes in the natural and managed parts of the system. Generally, the headwaters have the lowest relative potential to experience constraints over the next 30 years with constraints increasing progressively downstream. Headwaters generally have fewer constraints as they have lower population levels, less development, and a proportionally greater volume of water to draw from. While most CMR municipalities fall within the highest level of constraint, it should be noted that these numbers are relative to other sub-basins in the study area and not absolute indicators of impending shortages.

Addressing the various water supply constraints will require action and cooperation by numerous stakeholders in the region. Specific opportunities for consideration by the CMRB as they proceed with regional planning were extracted from the literature throughout the preparation of this report, and are summarized below and in the final section of this report:

- Establish agreed-upon standards and timeframes for water-related municipal actions
- Develop an overall water supply strategy
- Work with a collaborative working group to identify specific opportunities for coordination of upstream releases and downstream uses, potentially identifying storage projects
- Formalize water sharing agreements
- Connect to academic researchers directly to promote applied research
- Work with AEP through the Land-use Framework to enable headwater protection and integrated land use management

Acronyms

Bow River Operational Model	BROM
Calgary Metropolitan Region	CMR
Calgary Metropolitan Region Board	CMRB
General Circulation Model	GCM
South Saskatchewan River Operational Model	SSROM
South Saskatchewan River Basin	SSRB
Western Irrigation District	WID

Glossary

Water availability: a term encompassing the supply of water, the demand for water, and access to water.

Water yield: the volume of water that runs off an unregulated watershed to become streamflow at a certain point.

Basin: any area of land where precipitation collects and drains off into a common body of water.

Sub-basin: smaller basins included within the basins of larger streams or rivers.

Contents

1.0 Project Background

The Calgary Metropolitan Region Board (CMRB) has a mandate to complete a Growth Plan and Servicing Plan for the Calgary Metropolitan Region (CMR) by December 2020. The CMRB Regulation AR190/2017 sets out the objectives for the CMRB Servicing Plan, which includes facilitating the orderly, economical and environmentally responsible growth in the region. Once approved, the long-term Growth and Servicing Plans will guide regional land-use decision-making in the CMR.

As part of the Servicing Plan development, the CMRB is undertaking inter-related studies of five Complexities that were identified as part of the CMRB Water Roadmap. Natural and managed capacity within the CMR is Complexity C, the examination of which will deliver a common set of resource information as a base assumption for Water Servicing Plan recommendations from the Water Table to the Intermunicipal Servicing Committee (ISC) and CMRB Board. For the purposes of this project, *natural capacity* refers to the natural hydrograph of watersheds and how they may respond to climate variability whereas *managed capacity* is related to the operation of water management structures (e.g. dams) and to water licences issued under the *Water Act.*

Water availability and corresponding water supply for the CMR depends predominantly on a naturally variable surface water system that experiences changes in the magnitude and timing of flow within and between years. Current managed capacity addresses many of the issues relating to variability in the natural capacity of the system. However, changes to the hydrology of the headwater watersheds are anticipated due to changes in consumption, land-use and climate change. These changes will impact the natural capacity of the systems within the CMR and must be understood in order to make informed planning and management decisions as the region continues to grow. This report summarizes learnings from the existing and highly developed body of knowledge surrounding water supply to provide relevant guidance to the CMRB on the topic of natural and managed capacity of regional water sources.

2.0 Objective

This study provides background information about water availability for the CMR based on a review of relevant, existing literature. It provides a summary of the natural capacity and managed capacity of regional water sources with an emphasis on research in climate variability and possible impacts to the CMR.

Specifically, this report:

- Reviews and analyzes the list of reports supplied by CMRB (15) and supplemented by additional reports identified by WaterSMART;
- Summarizes the status of water licences and current water use within the CMR watersheds;
- Summarizes the regulatory and collaborative models used to support planning;
- Compares planning models, highlighting which inputs require work for CMRB planning;
- Summarizes the natural capacity outcomes of climate change, flood hydrology and related studies;
- Summarizes the management options from existing literature for water availability, including risks and

benefits of each;
- Summarizes and tabulates the high-level and specific constraints for CMRB members regarding access to water;
- Graphically illustrates the natural capacity under climate change scenarios for a 30-year time horizon;
- Graphically illustrates water-derived constraints on a watershed level in a map that identifies watersheds and reaches that may experience constraints within a 30-year period; and,
- Identifies data gaps for quantifying water-derived constraints in the CMR.

2.1 Assumptions and scope limitations

This report integrates and builds on existing data, tools, and knowledge to improve the knowledge base and understanding of water supply constraints in the CMR. The analysis and conclusions throughout this report assume that the population and economy in the CMR will continue to grow and that water demand will increase. This report does not examine in detail water conservation and efficiency that can reduce per capita water demand; however, it does provide observations and opportunities relating to demand management due to their relevance to water supply management. A more detailed analysis and recommendations of water demand for the CMR are dealt with in Complexity B Water Use and Conservation in the Calgary Metropolitan Region.

This report focuses on water quantity, with only minor sections identifying water quality factors or options. In addition, this report focuses on surface water supply; groundwater was not identified as part of the project scope and is only briefly discussed within this report. On a regional scale, groundwater plays a significant part in water supply both within alluvial aquifers adjacent to surface water, as well as providing direct discharge during low flow conditions. In addition, several communities and numerous households are dependent upon aquifer supplies. However, assessing the natural and managed capacity of groundwater supply for the region is a large project and could be conducted as a separate initiative.

3.0 Natural Water Supply Review

3.1 Key background

The main factor that determines how much surface water is available to CMR municipalities is the amount of runoff from snowmelt in the Rocky Mountains that typically peaks in May and June. Rainfall also contributes to flows, mostly in June. River flows are highly variable, both from season to season and from year to year. In the Bow River, for example, natural flows usually range between 30 m^3/s and 300 m^3/s but <u>can be above and below</u> this range.

The CMR overlaps with three sub-basins of the South Saskatchewan River Basin (SSRB): the Bow River, Red Deer River, and Oldman River basins (Figure 1). This project examines water availability and management in the basins and reaches of the Bow River mainstem shown in Figure 2. These sub-basins and reaches are relevant to the CMR either by being part of the headwaters, by directly overlapping with the CMR boundary (also shown in Figure 2), or by being a significant downstream reach of the Bow River mainstem. The Little Red Deer sub-basin and the Rosebud sub-basin fall within the Red Deer basin. The Little Bow sub-basin falls within the Oldman River basin.

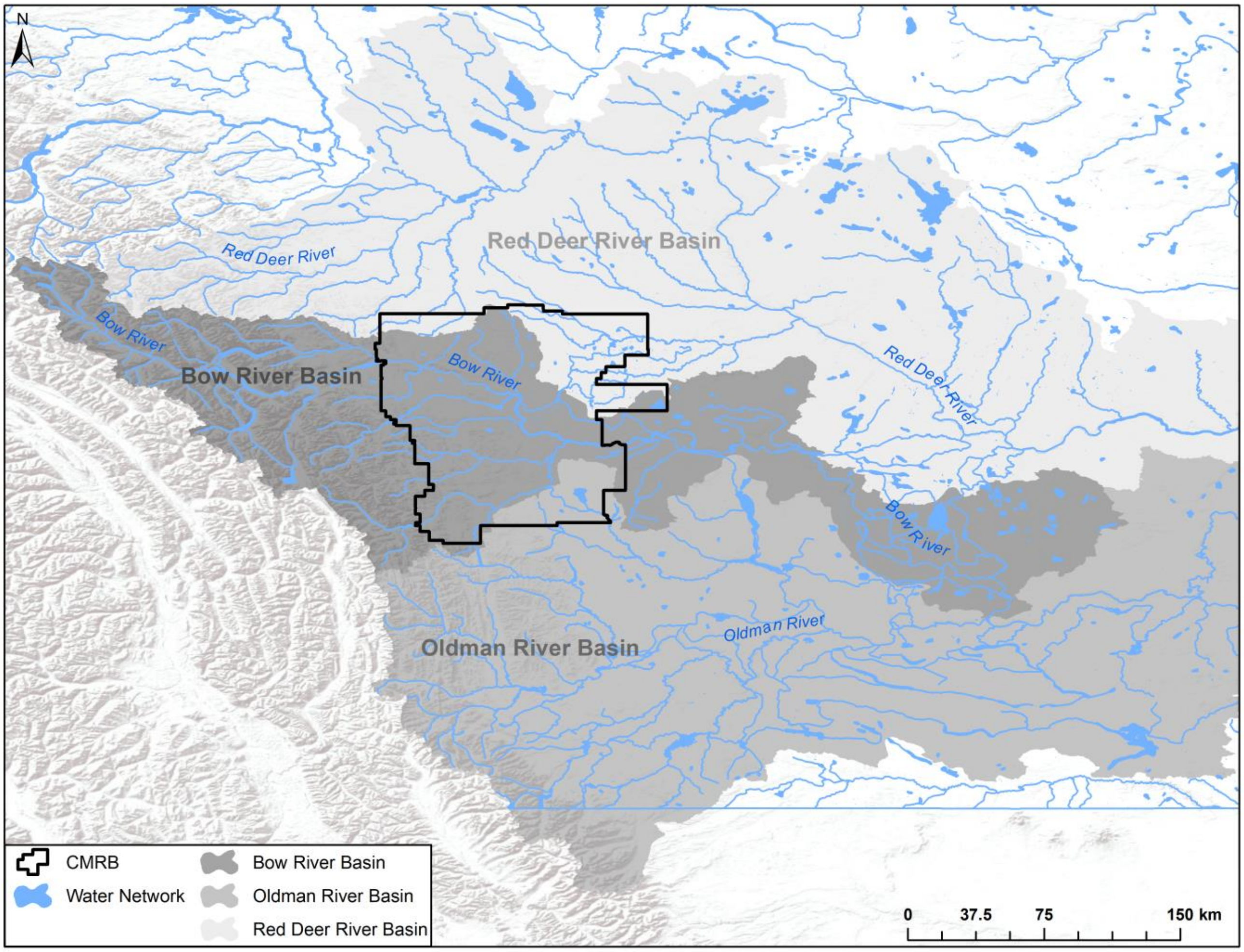

Figure 1. CMR boundary superimposed on the Red Deer, Bow, and Oldman River basins.

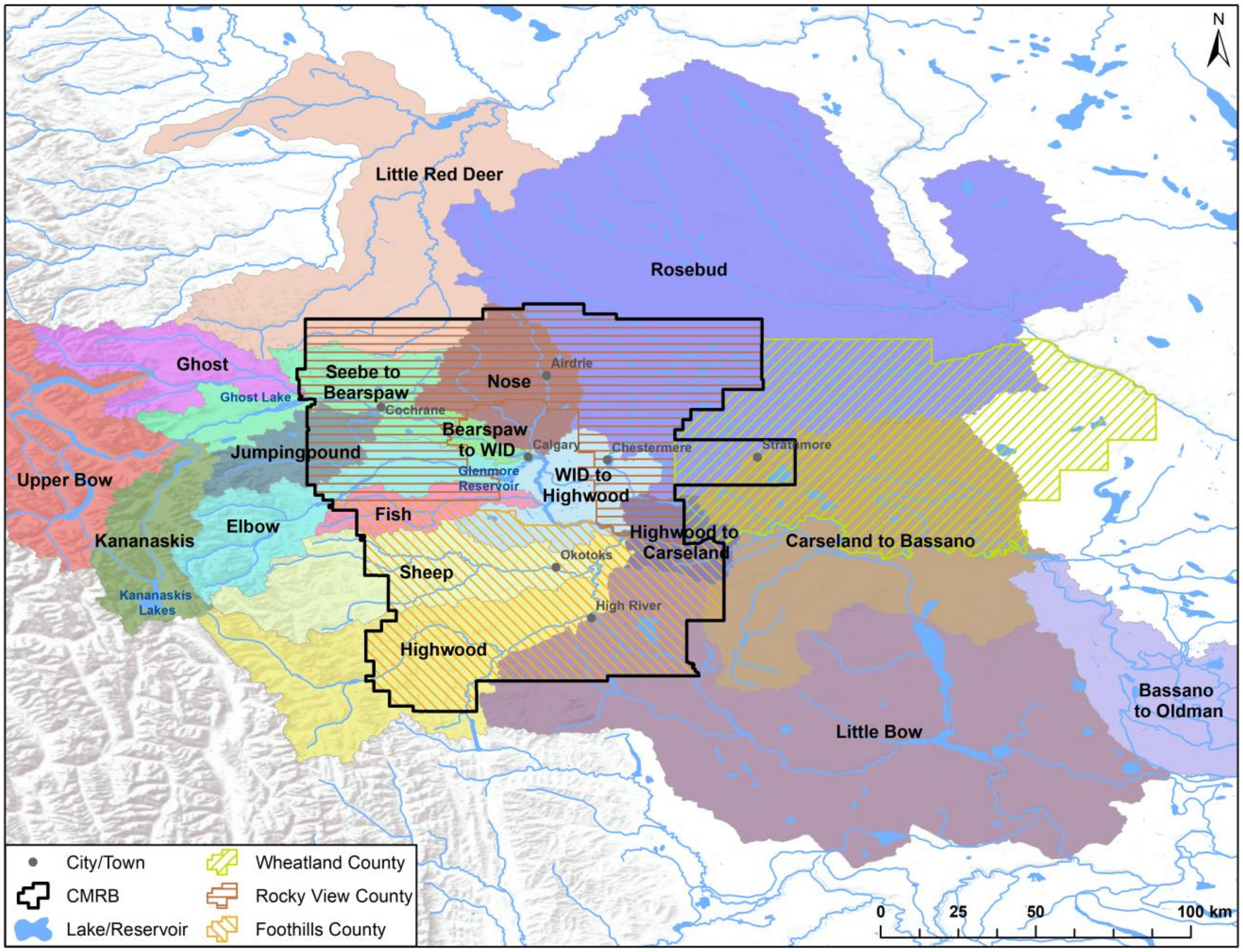

Figure 2. The CMR borders superimposed on the sub-basins and river reaches used in this report.

3.2 Overview of natural supply

The Bow River basin makes up the majority of the CMR, however parts of the Red Deer basin cover the north east and north west corners of the CMR, whereas the south east corner of the CMR is part of the Oldman River basin (Figure 1). Almost all sub-basins within the Bow River basin are of interest for the CMR. Those furthest west, including the Upper Bow, Kananaskis, and Ghost River sub-basins, do not fall within the CMR boundary but constitute the headwaters for the Bow River. Glaciers contribute a small portion of the total annual volume, comprising approximately 3% of the Bow River. However, they play a very important role in supplying water in the late summer, particularly during hot and dry years, by contributing between 8% and 20% of the Bow River's volume at that time (Bash & Marshall, 2014). During winter, the Bow River is heavily influenced by groundwater with approximately 20% of the annual flow coming from shallow groundwater (Bow River Basin Council, 2010). Water contributed to the river from these near-surface sand and gravel alluvial aquifers is called baseflow.

Only one tributary of the Oldman River, the Little Bow River, falls partially within the CMR. The Little Bow River is one of three prairie sub-basins in the eastern part of the Oldman basin. Peak flow is experienced in the early spring due to snowmelt in the headwaters (Oldman Watershed Council, 2010).

Two of the sub-basins of the Red Deer River basin are partially within the CMR boundaries, those being the Little Red Deer River sub-basin and the Rosebud River sub-basin. The Little Red Deer River sub-basin experiences high streamflow early in the year due to spring snowmelt and subsequent peaks throughout the summer from high precipitation events. At its confluence with the Red Deer River, the Rosebud River's discharge rates are relatively constant throughout the year, with maximums occurring in spring (April) and minimums in fall (October). Approximately 38% of the total area does not contribute to drainage, due to flat topography and no runoff to major water bodies (Red Deer River Watershed Alliance, 2009).

3.3 Hydrology

The natural capacity of the source-water bodies in the CMR municipalities is monitored using recorded streamflow measured at hydrometric stations. Water Survey of Canada (WSC) is the national authority responsible for collecting real-time streamflow data from hydrometric stations. Because many of Alberta's rivers are regulated (e.g., by dams and other structures), the Government of Alberta has developed estimates of what the streamflow data would look like without effects of man-made structures. These data are called naturalized flows and are currently available from Alberta Environment and Parks (AEP) for the period 1912 to 2009. Updated estimates for the period 2010 to 2015 are in progress as of the writing of this report.

Measured streamflow data were used for this analysis to develop average water yield estimates based on actual conditions experienced in the sub-basins as a result of both natural supply and management activities. Future work could include a comparison of water yield based on naturalized flow with the values from this study to understand the impact of water management on the estimated natural capacity of the sub-basin. Based on the measured streamflow data, some generalizations and estimates regarding the water yield for each sub-basin are provided below.

3.3.1 Estimating water yield in the CMR source watersheds

In order to estimate water availability, annual runoff and water yield was calculated for 18 sub-basins in and adjacent to the Bow River watershed. Here we define annual runoff as the depth (area invariant) of water that flows out of a sub-basin over a full calendar year, which is expressed in mm/year. Water yield is defined here as the total volume of water that flows out of a sub-basin in a full calendar year, which is expressed in m^3/year. Sub-basins were delineated following the Bow River Basin Council (BRBC) regions which generally follow Water Survey of Canada hydrologic units. See Figure 2 for identification of these sub-basins.

In order to determine runoff quantities from each of the 18 selected sub-basins, representative streamflow records were obtained from the Water Survey of Canada hydrometric stations (see full list in Appendix D: List of Water Survey of Canada hydrometric stations). If available, hydrometric stations were selected that corresponded to sub-basin outlets (i.e. the furthest downstream point in the sub-basin) and runoff was estimated by scaling the mean annual flow by the gross drainage area of the sub-basin. However, in many cases no station was available at the outlet. In these cases, runoff was estimated using regionally representative records, specifically:

- Ghost River was estimated by summing 05BG010 and 05BG006 since no hydrometric station was available near the sub-basin outlet;
- Fish Creek was estimated by deriving a scaling factor with the Fish Creek at Priddis and Fish Creek at Bow Bottom Trail hydrometric stations since the latter station (and sub-basin outlet) only contained three years of data;
- Central Red Deer - Rosebud was estimated by averaging three hydrometric stations (05CE007, 05CE002, 05CE005); and,
- Western Irrigation District (WID) to Highwood was estimated by subtracting 05BL024 from 05BM002.

In all cases, hydrometric stations that did not contain winter measurements were corrected (using an empirical scaling factor of 0.811) to account for the fact that winter streamflow is typically lowest, and therefore not accounting for this would lead to overestimates in sub-basins with only seasonal measurements. To estimate runoff (mm/year), the mean annual flow (m^3/s) was scaled by gross drainage area at each hydrometric station. Water yield (m^3/year) was then estimated by multiplying the runoff value by the drainage area of the sub-basin, which was often larger than the total of hydrometric stations used to estimate runoff, especially if the station was not located at the sub-basin outlet.

In general, the foothills and mountainous areas of Alberta receive more precipitation, both snow and rain, than the prairie regions. This is highlighted in the following comparison of runoff volumes across the sub-basins in the CMR. Runoff was highest in the Upper Bow River, and generally along the most westerly, mountainous portions of the study area (Table 1). In these areas, high winter snowpack, lower evaporation rates, and glacial melt lead to high water availability. Conversely, runoff was very low along the easterly parkland reaches, most notably the Little Bow River, Rosebud, and Nose Creek where there is little precipitation and high evaporation rates. Water yield was highest along the Bow River at Cochrane, where a large drainage area collects substantial snowmelt runoff. Conversely, water yield was lowest in smaller, arid drainages such as Nose Creek, Fish Creek, and Jumpingpound Creek.

In addition to providing a comparison between the sub-basins, the water yield calculations below could also be compared to water licence data annual allocations (expressed in m^3/year). This comparison could provide an initial indication of the licence size relative to watershed capacity.

Table 1. Runoff and water yield for each sub-basin considered in this study. Values were calculated for individual sub-basins and are not cumulative.

Name	Drainage Area (km^2)	Runoff (mm)	Water Yield (m^3/yr)
Little Bow	7,480	11	79,759,199
Bassano to Oldman River reach of the Bow River	24,975	108	2,707,169,480

Name	Drainage Area (km^2)	Runoff (mm)	Water Yield (m^3/yr)
Carseland to Bassano reach of the Bow River	19,674	121	2,373,426,193
Elbow River	1,253	173	216,125,571
WID to Highwood reach of the Bow River	11,511	225	2,586,239,537
Highwood to Carseland reach of the Bow River	15,519	207	3,217,099,161
Ghost River	937	219	204,794,375
Nose Creek	988	14	13,453,904
Highwood River	4,008	156	623,732,970
Bearspaw to WID reach of the Bow River	7,917	347	2,750,225,112
Rosebud	10,168	19	190,230,142
Little Red Deer	3,725	60	222,529,487
Seebe to Bearspaw reach of the Bow River	7,791	415	3,231,413,035
Fish Creek	447	118	52,820,346
Sheep River	1,569	187	293,575,870
Jumpingpound Creek	603	99	59,605,499
Upper Bow	4,207	535	2,252,524,534
Kananaskis River	946	493	466,053,668

The above water yield values are based on mean annual flow and therefore represent an average annual water yield. An assessment of the potential range of water yields for the CMR sub-basins was not included in this study; however, it is important to note that substantially wetter and drier periods have been recorded that would influence the annual water yield for each basin. An example of the natural variability in precipitation is shown in the total annual precipitation at Calgary Airport from 1885 to 2018 (Figure 3). Variability in climate conditions, and the implications of climate change on the natural variability are discussed in more detail in the next section.

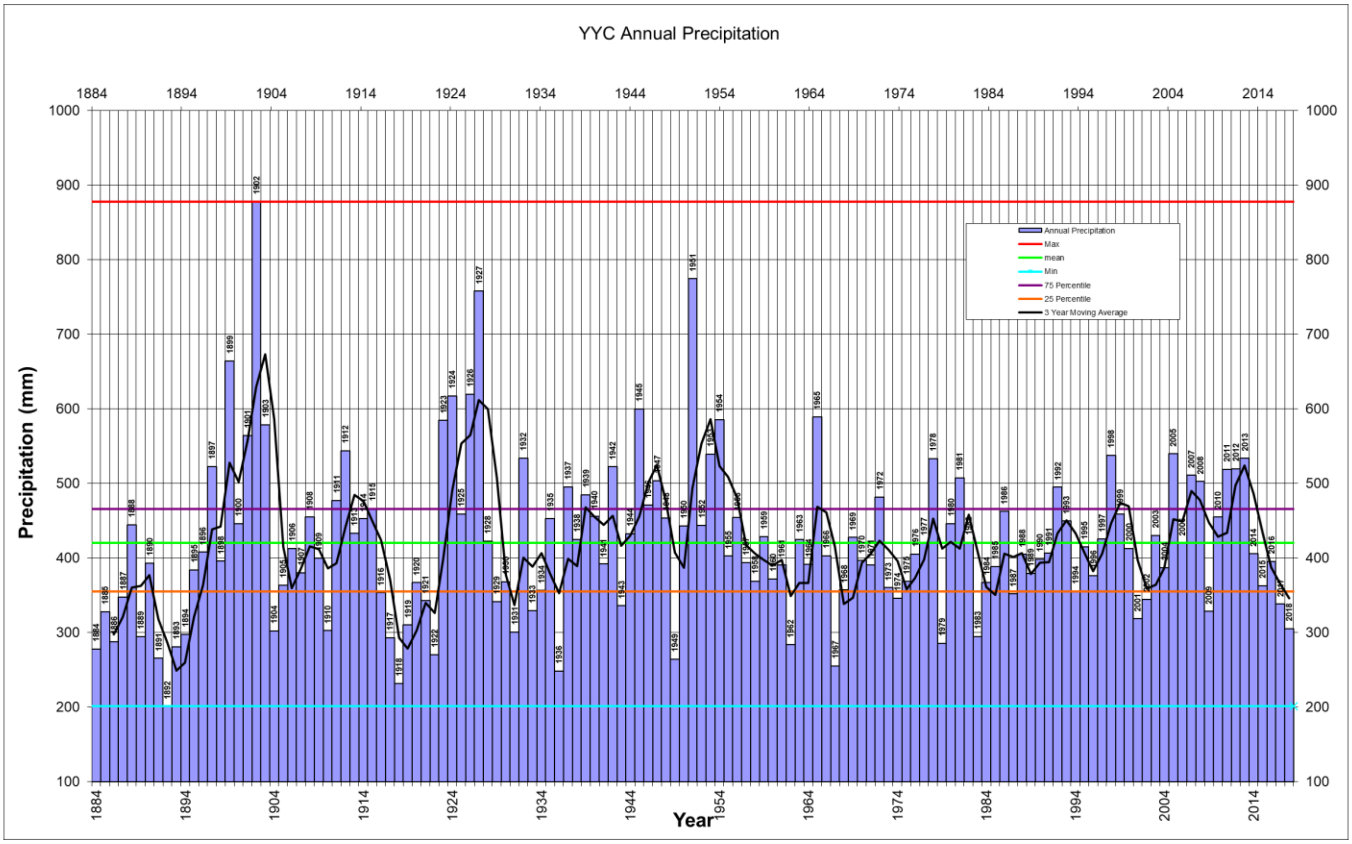

Figure 3 Total annual precipitation at Calgary Airport from 1884 to 2018. Source: City of Calgary

3.4 Climate change projections

The potential natural capacity outcomes of climate change are discussed below in two sections. The first summarizes the relevant conclusions from previous studies, and the second provides the overall summary and picture of the projected trend of climate change for the CMR water supply.

3.4.1 Key projections from the literature review

Warmer air temperatures, changes in precipitation, retreating glaciers, and greater frequencies of extreme events will affect water quality and quantity in the CMR. Climate change is likely to increase the frequency of low flow periods in all basins (including the Red Deer, Bow and Oldman). If future water demand from (primarily) irrigation district expansion increases, this would create the potential for increased deficits to Water Conservation Orders (WCOs) and water users that are junior to irrigation district licences. This could include both irrigation and non-irrigation water users. Changes in demand from non-irrigation water users is likely to be small relative to changes in irrigation water use demands (AMEC Earth & Environmental, 2009).

A consensus has been expressed within a number of studies as follows (WaterSMART Solutions Ltd., Risk Sciences International Inc., Nodelcorp Consulting Inc., WSP Global Inc., & MMM Group Ltd., 2017):

- The rate of air temperature rise due to climate change in Canada has been twice the global average since 1948, increasing at a rate of 1.6°C per century (Figure 4).
- The rate of climate warming for the Calgary area is projected to intensify in the future, with the largest temperature increases occurring in the winter months. In terms of water quantity, climate change models predict increased frequency of short duration, high intensity storms, multi-year droughts and significant stress on water supplies.
- The number of hot days is expected to increase substantially, which may drive higher irrigation demands and increased natural evapotranspiration. Days with a mean temperature above 29°C are projected to increase from an average of 9 days to 27 days by the 2050s.
- Extreme weather events that could potentially overwhelm water servicing infrastructure are important considerations, and could impact service delivery, infrastructure design, and related planning and resource allocation within the CMR.
- Annual average precipitation projections show little to no significant changes. However, the increasing trend in winter precipitation since 1900 is projected to increase slightly.

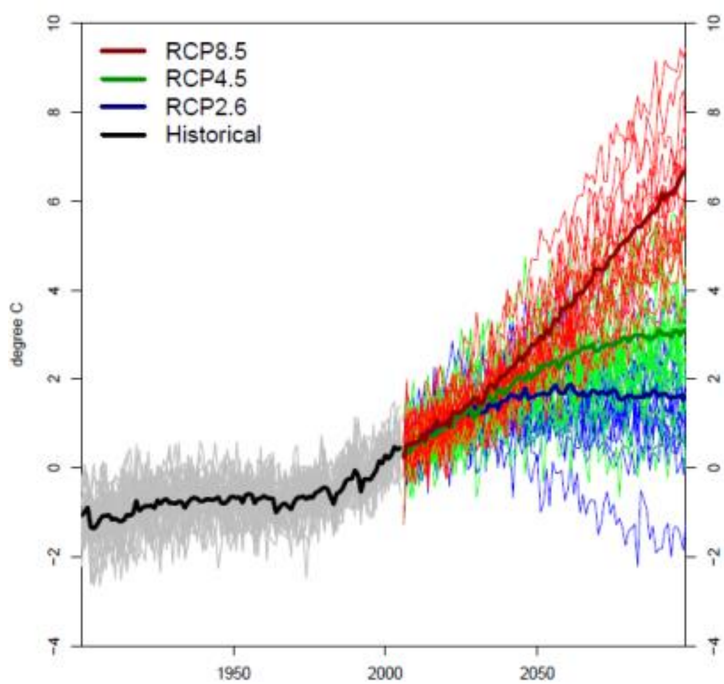

Figure 4 Projected changes in surface temperature from the Canadian Climate Data and Scenarios (http://ccds-dscc-ec.gc.ca/)

Climate modelling suggests earlier snowmelt and spring freshet can be expected in future years (WaterSMART Solutions Ltd., 2016). The challenge created is that lowering reservoirs to manage flood risk depletes the water inventory required to overcome a drought.

In their 2010 Study for Alberta Environment, Golder Associates predicted the following:

- For the Bow basin specifically, increasing flows in winter months and decreasing flows in summer months with significant variability between months were projected (Figure 5).
- The mean annual flow in the Bow River was projected to decrease by up to 18% by the year 2050.
- Within the Oldman River basin, most model scenarios show increasing flows in winter months, decreasing flows in summer months, and significant variability between months (Figure 6).
- The change in mean annual flow for the Oldman River was projected to vary widely including a potential increase of up to 9%, and a potential decrease of up to 15% in 2020 and up to 30% decrease in 2050.
- For the Red Deer basin flows in both winter and summer months were projected to decrease but vary significantly between months (Figure 7).
- The mean annual flow for the Red Deer River was projected to decrease by anywhere from 2% to 44% by the year 2050, depending on the model scenario.

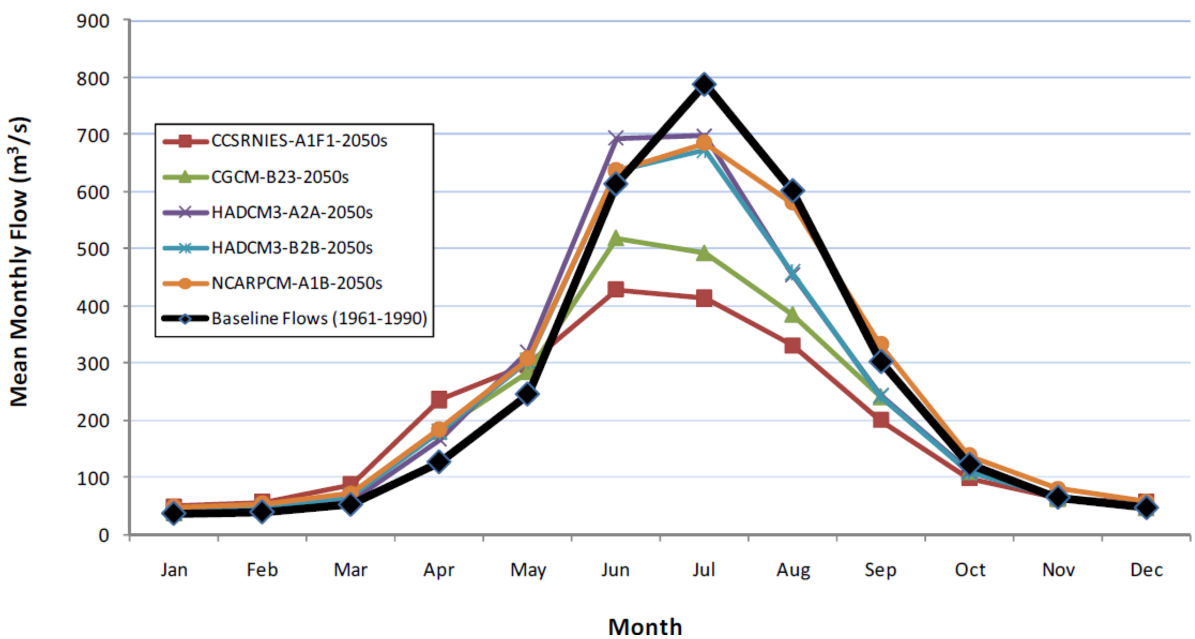

Figure 5 Forecasted effects of climate change for the 2050s on flows at Bow River at Calgary WSC.

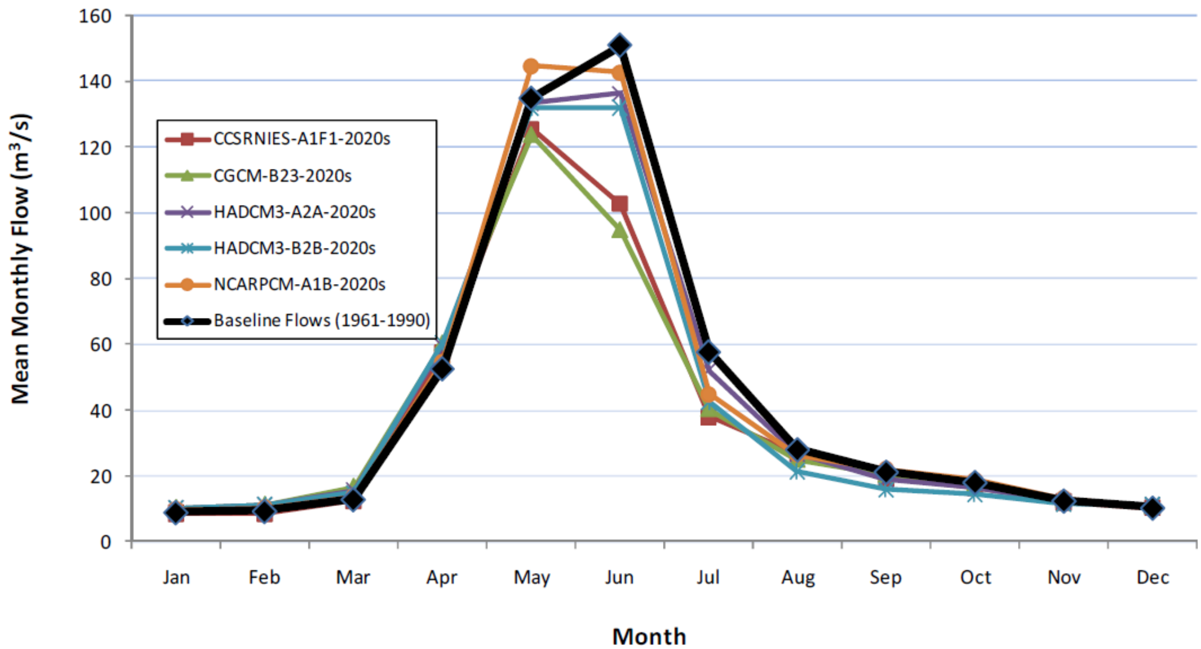

Figure 6 Forecasted effects of climate change for the 2020s on flows at Oldman River near Monarch WSC.

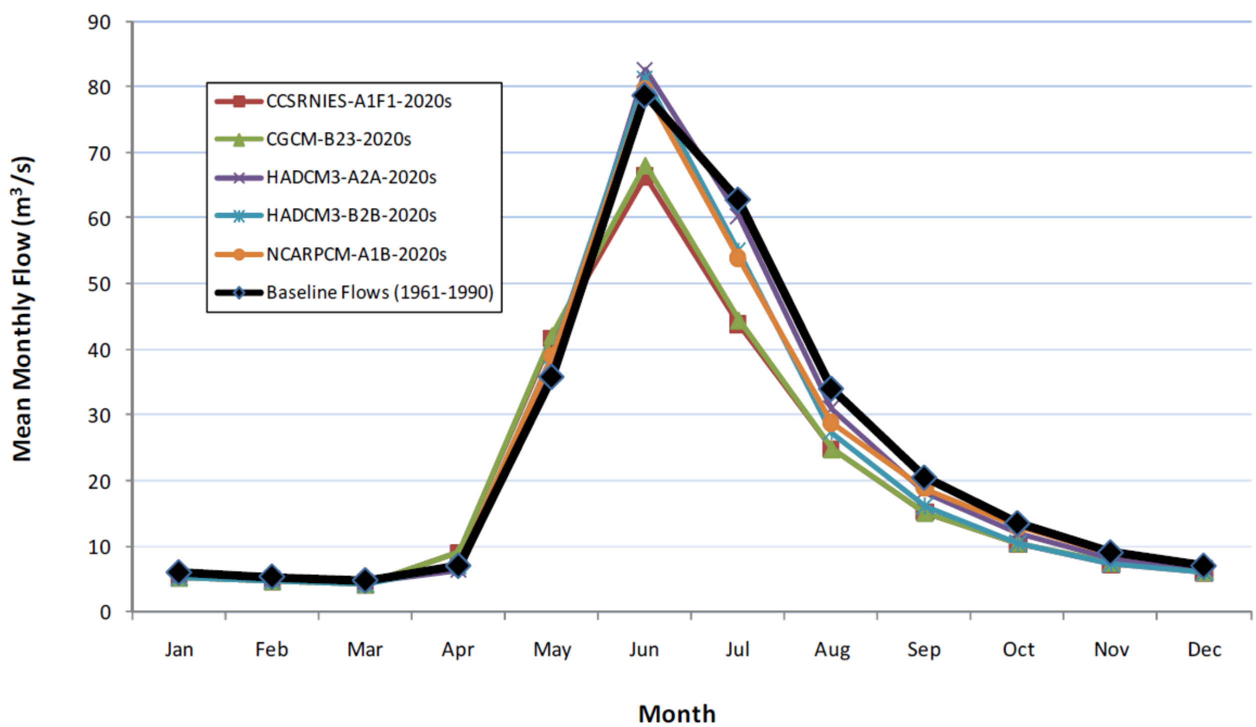

Figure 7 Forecasted effects of climate change for the 2020s on flows at Red Deer River near Sundre WSC.

Combining results from multiples models helps illustrate the range of potential outcomes. None of the models will predict exactly what can be expected, so the average of the combined results from multiple General Circulation Model (GCM) is often used to illustrate the overall climate trend in the future. This was done as part of the *Climate Variability and Change in the Bow River Basin* (2013) study that assessed the results from 10 GCMs and noted that lower mean annual flows are projected in the Bow River, as is the greater probability of extreme low flows (Figure 8) (Alberta Innovates-Energy & Environment Solutions & WaterSMART Solutions Ltd., Climate Variability and Change in the Bow River Basin, Final Report, 2013).

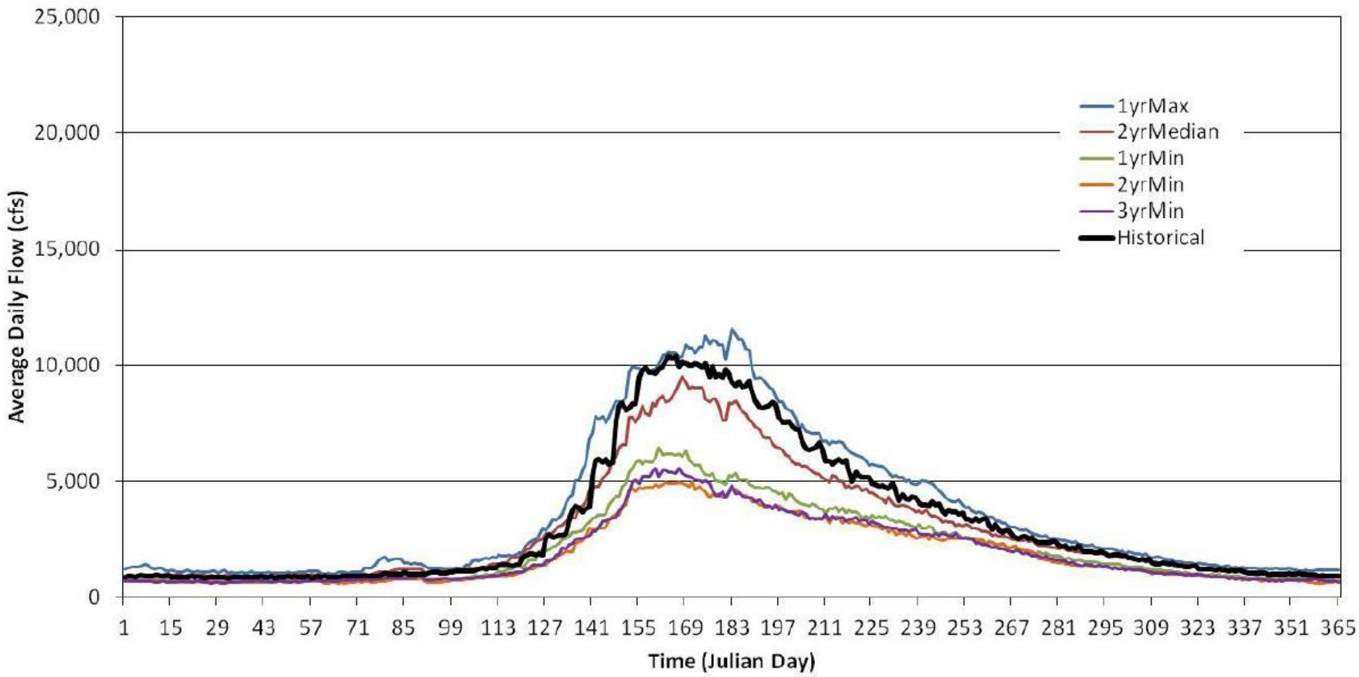

Figure 8 Maximum daily flows for each of the chosen projected climate scenarios, and the historical time series. (Alberta Innovates-Energy & Environment Solutions & WaterSMART Solutions Ltd., Climate Variability and Change in the Bow River Basin, Final Report, 2013)

Studies analyzing tree rings provide information about historical water availability for the region prior to streamflow gauges or precipitation monitoring. Over the past 700 years, the Bow River basin has experienced long periods of low flow as part of natural variability, and southern Alberta has experienced multi-year droughts far worse than have been experienced since monitoring began (Sauchyn, Vanstone, & Dickenson, 2012). This indicates that regardless of climate change projections, the CMR's water management strategies need to be designed around significant multi-year droughts. Figure 9 illustrates a tree ring analysis, reinforcing the importance of adapting and building resilience now, in advance of more extreme events.

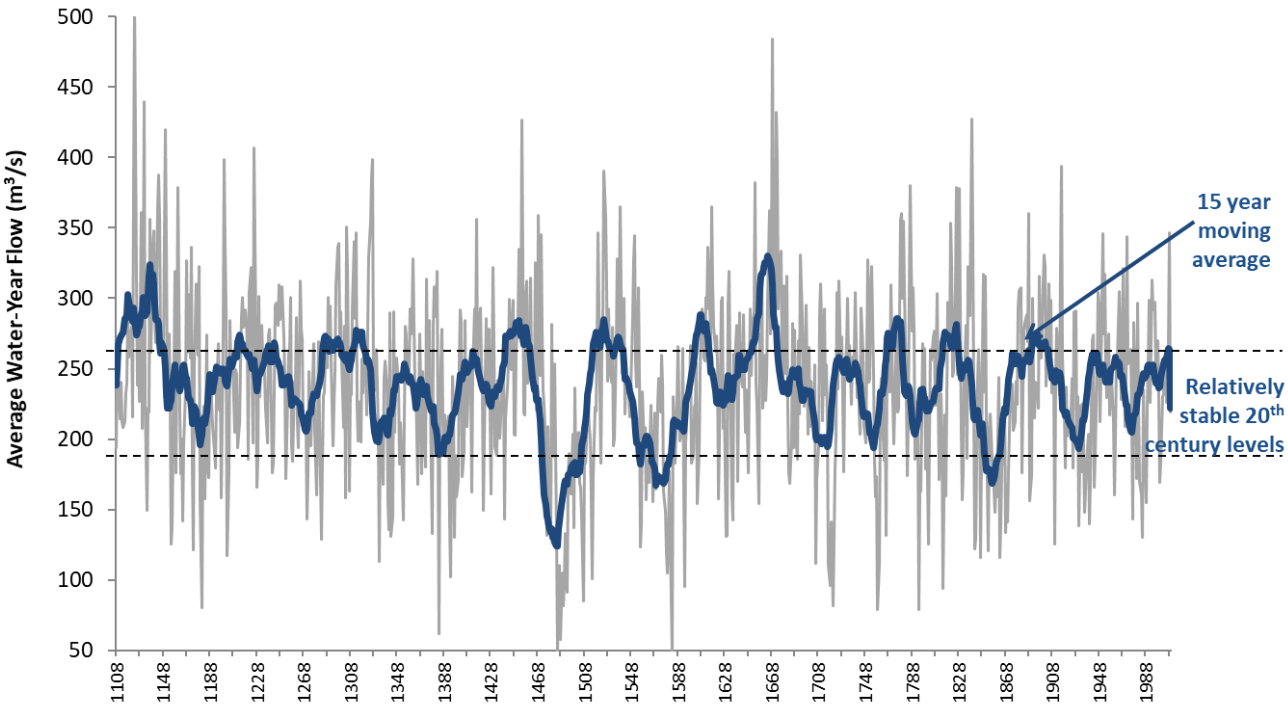

Figure 9 Reconstructed South Saskatchewan River Basin Flows (Bow + Oldman) based on tree ring analysis (Source: Dr. David Sauchyn, Prairie Adaptation Research Collaborative, 2015).

3.4.2 Overall summary of projections from the literature review

The projected precipitation for the CMR and headwaters region differs from the current climate in two ways: the timing throughout the year, and variability (quantitative difference between high and low flows).

In terms of timing, climate projections for future conditions (roughly 2040s) indicate a trend toward more precipitation during the winter and less precipitation during the summer. Additionally, earlier spring snowmelt is projected to correspond to warmer air temperatures.

In terms of variability, greater variability is projected between months, with higher possibilities of extremely high or low flows in any given year.

Figure 10 provides a representation of these trends in a conceptual hydrograph. Precise quantitative estimates depend on local climate change (as well as changes in land cover) and should be investigated using a hydrological model.

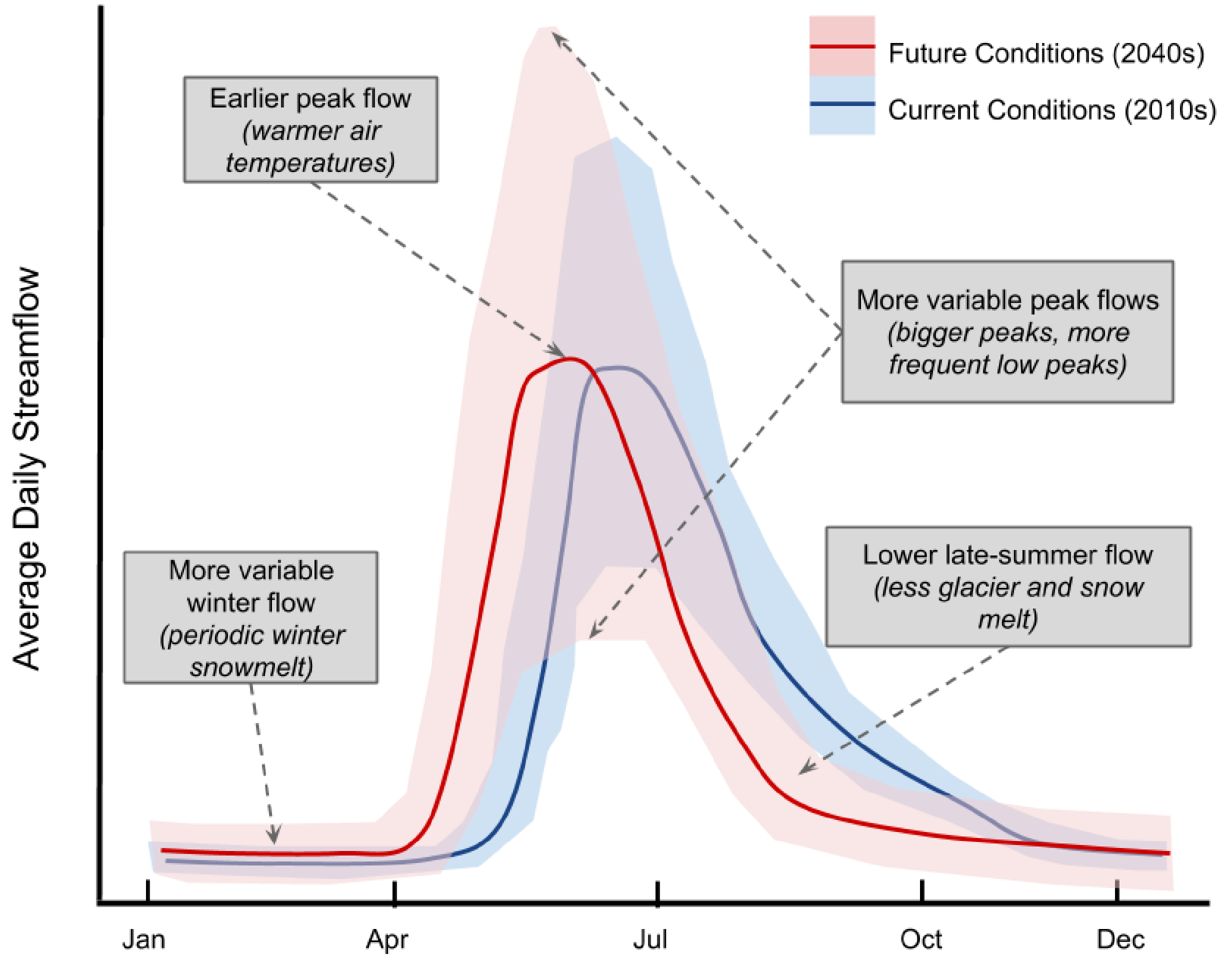

Figure 10. Conceptual diagram illustrating the changes to average daily naturalized streamflow expected to occur between now and the 2040s for a typical mountainous, snowmelt-dominated sub-basin in the Bow River watershed. The solid lines represent an "average" flow, while shaded areas correspond to an expected range of variability. The graph is not based on real data.

3.5 Review of water management models

Several water management models, which have been used previously for areas relevant to the CMR, were reviewed as part of this report. This review (see Appendix B: Review of Water Management Models) provides the description and the key features of the models to assist the CMRB in deciding which model(s) could be used to support planning.

For this project, the RFP included a list of models that could be reviewed including the Water Resource Management Model (WRMM), the Bow River Operational Model (BROM), the South Saskatchewan River Operational Model (SSROM), the Red Deer River Operational Model (RDROM), and the Oldman River Operational model (OMROM). The BROM, SSROM, RDROM, and OMROM were developed with a large stakeholder group in each sub-basin. After development of the models individually as major sub-basins, the sub-basin models (RDROM, BROM, OMROM) were combined into one model (SSROM) that now covers the entire SSRB. After the models were combined into SSROM, RDROM and OMROM were no longer used or updated as independent models as SSROM is the updated model for the whole SSRB. In addition, BROM, which was the first sub-basin model developed, has been maintained as an independent model due to ongoing water management modelling needs in the Bow basin. Therefore, only SSROM and BROM were reviewed for this study. See Appendix B: Review of Water Management Models for the details of this review.

3.6 Key updates and considerations regarding natural water supply

In order to ensure this report captured the most current information regarding natural water supply interviews were conducted with subject matter experts. Below are some relevant points captured from those interviews.

Variability

There is significant natural variability in the water supply systems of the CMR. When demand is modest relative to supply, the variability in supply has relatively limited consequences for communities. We are now at a point where demand is closer to average supply, and future growth will potentially increase water demand. This means that the impacts of natural annual and seasonal variability, even without potential climate change factors, will have higher water supply consequences. (Dave McGee, pers. comm., July 2019)

Current academic research

The Global Water Futures research work, led by Dr. Saman Razavi, includes many projects relating to water availability in the CMR. The *Integrated Modelling for Prediction and Management of Change in Canada's Major River Basins* (IMPC) modelling project, currently underway, may be particularly relevant for the CMR and may provide valuable support for planning when results are published. The project aims to develop integrated modelling capability for predication and management of water resources within Canada's major river basins. Work is ongoing to integrate high-resolution atmospheric modelling, hydrologic modelling and water quality modelling capability to this infrastructure, as well as a hydro-economic model, and environmental and cultural flows to examine triple bottom line tradeoffs between water policy alternatives and climate change impacts. Some results of this work will be available in November 2019. The subsequent phase of this research program will be conducted over the next four years and results from this will include high resolution atmospheric modelling and coupled water quality and hydrological modelling (Hayley Carlson, pers. comm., Aug 2019).

4.0 Managed Water Supply Review

Management of water supply in Alberta is enacted through legislation, licensing, infrastructure, and planning/operations coordination. Demand management is a related mechanism, which allows the same supply volume to support increased activity or population but is not within the scope of this report and is not discussed in detail.

This section of the report starts with a general overview of key background information about water supply management (Section 4.1), then Section 4.2 "Overview of dam and diversion operations" provides detail on the roles and operations of relevant management structures, Section 4.3 "Streamflow requirements" explains the regulation around the water that is required to remain in the rivers, Section 4.4 discusses the system of Water licensing in Alberta, and the final section "Literature Review: Management options identified in previous studies" provides summaries of various management options identified in the literature review.

4.1 Key background

There are several water-related legislative documents, chief among these being the *Water Act,* with its associated tools (e.g. WCOs (See Section 4.3.3)) and Orders (e.g., Bow, Oldman, and South Saskatchewan River Basin Water Allocation Order). Another significant piece of water-related legislation for the CMR specifically 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 and thereby became a required GOA policy document. It made various recommendations including to close the Bow, Oldman and South Saskatchewan River sub-basins to new applications and to designate 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 that formally implemented the recommendation of the SSRB Water Management Plan to close specific sub-basins. Another key legislative piece is the Master Agreement on Apportionment (1969), which outlines how the governments of Alberta, Saskatchewan, Manitoba and Canada share the waters of eastward flowing interprovincial streams.

Many reservoirs have been constructed within and upstream of the CMR. Further discussion of infrastructure is below in section 4.2. Key goals in reservoir operations are flood, drought and/or power supply management. To accomplish these goals simultaneously is challenging. However, increasing forecast, operational and collaborative tools will continue to improve management of available storage to meet these goals. On- and off-stream storage provides opportunities to balance these objectives along with others. For example, on-stream reservoirs are useful for supplementing baseflows for the aquatic environment from releases for hydropower production. Off-stream reservoirs (e.g., irrigation reservoir) allow for large licence allocations to be withdrawn during the time of highest natural supply volume in the river, allowing for more resilience in water supply management. The design of these reservoirs must account for evaporative losses that contribute to a reduction in water supply.

Seasonal variation in consumptive uses also impacts water management. Natural water supply is highest during the snowmelt from mid-May to mid-July and is reduced in late summer. The highest demand for municipal and agricultural uses of water are during the summer growing season and particularly when precipitation is lower and consequently natural availability is reduced. Throughout the year municipal wastewater in the CMR is discharged to local rivers which requires a certain minimum flow in the receiving river to adequately dilute the wastewater. This may become an issue during periods when low flow and high demand coincide, or when ice coverage limits oxygen exchange at the water surface.

Surface water availability in the CMR is also influenced by upstream land use. Therefore, upstream headwaters management and source water protection are important and necessary tools to help manage water supplies and the impacts from urban development, forest disturbance, transportation corridors, and agriculture.

As of the writing of this report there are limited opportunities for implementing water reuse to more effectively use existing water allocations. However, a provincial water reuse policy is anticipated that will increase these opportunities. Once the policy and water reuse systems are in place, water reuse will likely become an important consideration when reviewing managed water supply in the province.

4.2 Overview of dam and diversion operations

This section of the report provides an overview of the operating schemes for the largest management structures, primarily dams, that influence water management in the CMR (see map in **Error! Reference source not found.**).

Generally, dams within and around the CMR fall into three categories: hydropower, irrigation and other water supply, and drinking water.

- Dams that are owned privately and currently operated primarily for hydropower fill during the summer and fall and release during the winter. They are used to supply power quickly to meet peak electricity demands, typically during evenings. As a result, hydropower water releases can have a strong impact on the amount of flow over the course of the day.
- Dams for irrigation and water supply management are typically off-stream and fill mainly during the spring and early summer during peak runoff and release water into canals for downstream diversion.
- Dams for drinking water uses are managed year-round to ensure drinking water availability.
- Dams in the CMR are frequently operated for flood mitigation in addition to the above categories.

In the Bow sub-basin, upstream reservoirs are owned by TransAlta and are primarily operated for hydropower, filling during late spring and summer to be released during the winter. Hydropower production operations can add complexity for downstream users, but it can also result in benefits to downstream users. For example, flow through Calgary in the winter is double the natural flow as a result of how TransAlta has operated their upstream infrastructure for decades for power production. If the operating schemes for hydropower production were to change, winter flows and licences that depend on higher than natural winter flows for withdrawal or effluent dilution could be affected.

The Ghost Reservoir and Ghost Hydro Plant, owned and operated by TransAlta, is of particular significance for communities downstream on the Bow mainstem. Its location on the Bow downstream of numerous mountain tributaries and upstream of more densely populated areas provides an opportunity for effective flood mitigation. In 2014, TransAlta reached an agreement with AEP to operate the facility to help with flood mitigation until 2021. As a result of that agreement, the Ghost Reservoir is now held at low levels until mid-July before being filled, providing more capacity to hold water back during flood season. The Kananaskis Lakes system (Upper Kananaskis, Lower Kananaskis, and Barrier) upstream of the Ghost is subject to a similar operational adjustment intended to support water supply needs.

Bearspaw and Glenmore Reservoirs on the Bow and Elbow mainstems respectively are within the boundaries of the CMR. Bearspaw Dam is owned and operated by TransAlta, while Glenmore Dam is owned and operated by the City of Calgary. The Bearspaw reservoir is an important drinking water reservoir for the majority of the CMR's population, including residents in Calgary, Rocky View County, Airdrie, Chestermere and Strathmore. Both Calgary and Rocky View County have drinking water intakes in Bearspaw Reservoir. The reservoir is also operated to reduce the risk of ice jams and winter flooding downstream in the City of Calgary. Glenmore Reservoir is operated by the City of Calgary to maintain adequate water levels for the water supply intake. Following the 2013 flood, operators have started considering flood management opportunities for this facility. The addition of a new steel gate and hoist system on Glenmore Dam (scheduled for completion in 2020) will help build additional capacity for drinking water supply and flood resiliency plans for the Elbow River.

Water for the Western Irrigation District (WID) and other licensees is diverted from the Bow River into the Western Headworks System at the Harvie Passage in Calgary. The Headworks are owned by the Government of Alberta, but WID holds the licence for the water diversion. Diversion rate and timing are determined by the WID based on water demands and base flow needs within the conditions of their licence.

Two managed diversions in the Bow River basin (the Women's Coulee Diversion and the Little Bow Diversion) move water from the Highwood River into the Little Bow River sub-basin. Historically, High River flood flows recharged springs that fed the Little Bow basin before development in the High River area. Both structures are owned by the Government of Alberta, and operation is governed by a diversion plan that was reviewed as part of the Annotated Bibliography (Alberta Environment, Water Management Plan for the Watersheds of the Upper Highwood and Upper Little Bow, Volume 1, 2008)(Appendix A: Annotated Bibliography).

Mosquito Creek, a major tributary of the Little Bow River, is fed through the Women's Coulee Diversion that includes a small reservoir and canal. Flow is used for irrigation, stockwater, municipal purposes and waterfowl conservation. The diversion is also used to help meet minimum flow requirements in Mosquito Creek unless the Highwood River is experiencing stress conditions.

The Little Bow Diversion is in the Town of High River. Water from the Highwood River is diverted into a canal that runs through the town and into the Little Bow River. Water is used for irrigation, stockwater and municipal purposes along the Little Bow River between High River and Travers Reservoir.

Downstream of the Women's Coulee and Little Bow Diversions is the Twin Valley Reservoir. Although the reservoir is just outside of the CMR, it is a major component of water management in the Oldman River basin as it stores diverted flow from the Highwood River as well as natural flow of the Little Bow River and Mosquito Creek, regulating flow downstream to match supply with demand (Oldman Watershed Council, 2010).

The Sheep River has no major water management structures in place that are relevant to the managed capacity of the CMR.

Managed capacity in the CMR and surrounding watersheds has been developed in the past to improve or increase capacity to meet the needs of all stakeholders and the environment. On the Bow River, there is an ongoing study that was initiated in 2018 to perform a conceptual assessment on three potential upstream storage options that were identified as part of the 2017 Bow River Water Management Project: Advice to Government on water management in the Bow River basin (Alberta Environment and Parks, 2017). The conceptual assessment will consider flood mitigation potential as well as water availability for drought and the environmental health of the basin. The three options identified in the 2017 study were:

- New Glenbow reservoir
- New Morley reservoir
- Expanded Ghost reservoir

As part of the conceptual assessment, preliminary modelling work is being done with the Bow River Working Group to understand how the potential new storage and its operating scheme could mitigate floods and increase water management opportunities (i.e. drought resilience and environmental health).

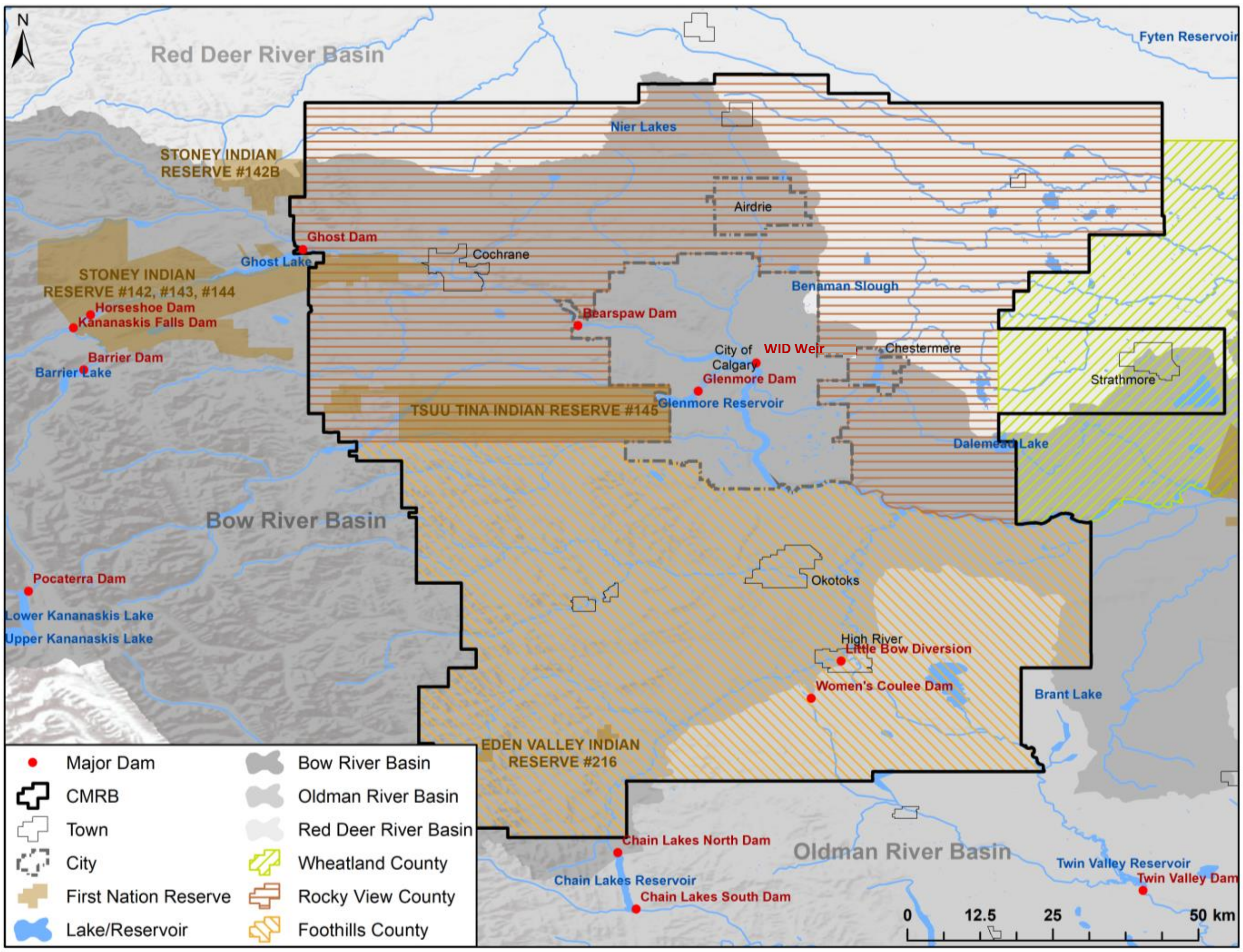

Figure 9 Select water management structures in the CMR and surrounding areas.

4.3 Streamflow requirements

4.3.1 Apportionment for downstream provinces

The Master Agreement on Apportionment is an agreement signed in 1969 by each of the Prairie Provinces (Alberta, Saskatchewan and Manitoba) as well as the Government of Canada outlining how transboundary water is to be shared between the three provincial jurisdictions. The agreement also includes provisions regarding water storage and water quality.

Schedule A of the 1969 Master Agreement on Apportionment states generally that half of the natural annual flow of each east-flowing watercourse be passed on to Saskatchewan. The SSRB is identified in specific subsections under Schedule A, which include a minimum amount Alberta is permitted to divert or consume (Master Agreement on Apportionment, 1969). Alberta is entitled to a minimum of 2,590,000,000 m^3 annually, subject to a minimum flow requirement of 1,500 cubic-feet per second (42.5 m^3/s) in the South Saskatchewan river at the boundary of Saskatchewan and Alberta.

4.3.2 Instream Flow Needs (IFN)

Instream flow needs are a scientific tool for the purpose of assessing flow required for aquatic environment protection. IFNs are based on the natural flow regime over the course of the year and are designed around measurable indicators for aquatic environmental health including water quality, fish habitat, channel maintenance and riparian vegetation.

IFNs are set for many river reaches in the CMR region, including for the Bow River from the WID weir to the Highwood River confluence (Alberta Environment, South Saskatchewan River Basin Water Management Plan: Phase 2 Scenario Modelling Results, 2003).

IFNs were only formally studied and assessed for the Bow River as part of the SSRB Water Management Plan. Generally, it was determined that given the level of water allocations that had already occurred to the time of those studies, they precluded being able to meet the full IFN requirements in most reaches. Hence, the recommendation of WCOs in the SSRB WMP, that balance the existing allocation commitments with the identified need to improve protection of the aquatic environment over time, beyond what instream objective conditions that had started to be placed on licences in the early 1990's.

Water licences are not cut off if an IFN limit is exceeded. The IFN assessment is a science-based value designed to inform a public needs decision for the creation of a WCO. IFN information can be accessed by contacting AEP.

4.3.3 Water Conservation Objectives (WCOs)

WCOs are established under the *Water Act* as a regulatory tool for balancing human and environmental needs for water flows. WCOs can be implemented in several different ways, including by specifying the volume of release from a public reservoir and by specifying when a water allocation licence holder can divert water.

Water allocation licences can include conditions that determine minimum flows that must be present before water can be diverted in order to protect the aquatic environment. WCOs affect flows by governing the amount of water that must be released from a dam, when a licence holder can divert water, and by guiding government officials on decisions about when water can be allocated, and the amount of water needed for flow restoration.

WCOs do not guarantee 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. There are WCOs for the SSRB, recommended as part of the *Approved Water Management Plan for the South Saskatchewan River Basin*.

- For the Bow River mainstem (below Bearspaw Dam to the confluence with the South Saskatchewan River) the WCO is either 45% of the natural flow or the existing instream objective increased by 10%, whichever is greater at any point in time. For the headwater reaches of the Bow River, the existing instream objective is the WCO.
- For the Oldman River mainstem below the Oldman River Dam to the confluence with the Bow River, the WCO is either 45% of the natural flow or the existing instream objective increased by 10%, whichever is greater at any point in time. For the headwater reaches of the Oldman River, the existing instream objective is the WCO.
- For the Red Deer River, the WCO changes throughout the year. For the reach from the Dickson Dam to the confluence with the Blindman River, the WCO is 45% of the natural rate of flow or 16 m^3/s. For the reach from the confluence with the Blindman River to the Saskatchewan border, the WCO is 45% of the natural flow or 16 m^3/s in the winter and 10 m^3/s in the summer. For the headwater reaches of the Red Deer River, the existing instream objective is the WCO (Alberta Environment and Parks, 2019).

4.3.4 Instream Objectives (IOs)

Existing Instream Objectives 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. AEP usually operates provincial infrastructure to meet the current IO.

IOs were historically set on a reach by reach basis. Since the first IOs were developed and applied to licences in the mid-1970s there have been many updated versions used, resulting in an uneven application of restrictions to licences issued since that time. Some reaches within the CMR area which have IOs include the Bow River from the Elbow River confluence to the Highwood River confluence, and the Bow River from the Highwood River confluence to the Carseland weir (Alberta Environment, South Saskatchewan River Basin Water Management Plan: Phase 2 Scenario Modelling Results, 2003).

Not all licenses are subject to IOs or the WCO for the whole SSRB. The IOs for the Highwood, Bow, and the Sheep are established so that often the natural flow is lower than the IO requirements. The amount of time that the river is below IOs has sometimes been used to infer poor river health. Some license holders have concerns that there is poor understanding of how IOs are established and the natural variability of these river flows in relation to those of managed rivers.

4.4 Water licensing in Alberta

With some exceptions, water diversions require a licence from AEP (or the Alberta Energy Regulator for energy-related diversions) under the *Water Act* and associated orders which stipulates the total annual volume, diversion rate, and other conditions which must be met. As noted previously in this report, the SSRB is currently closed to most applications for new water allocations (licences for First Nations projects and storage projects may still be issued by AEP).

The volume, rate, and timing of water diversion stipulated in a licence is referred to as an allocation. A water licence may be issued for both consumptive (water is withdrawn from the system and not returned) and non-consumptive uses (water is withdrawn and eventually returned, after treatment if needed). Depending on the type of water licence, specific volumes for consumptive use, losses (evaporation), and return flows are clearly indicated. Many water users do not always use their full allocation in every year and many return water back to the environment after it has been used, which is referred to as return flow. For municipalities, return flow is mainly treated effluent from wastewater treatment plants. Stormwater can also entre the wastewater collection system, but it is not included in the volume of return-flow on a licence. A certain flow rate in the river is required to ensure assimilation of treated effluent to target water quality levels or below. The return of effluent to the river is governed by approvals for wastewater treatment plants. Background water quality, as well as the nutrient load and levels of other components of treated effluent, are major factors in meeting those targets. During very low flows some municipal wastewater plants are not able to release the treated effluent.

In 2009, the actual licensed use of surface water was estimated at approximately 40% of the total volume allocated for use in the SSRB (AMEC Earth & Environmental, 2009). Within each sub-basin, the percent use of allocated water was estimated at 50% in the Red Deer, 33% in the Bow, and 40% in the Oldman based on actual net use in 2006. Net use is calculated as withdrawals minus return flows.

Alberta's allocation system uses a priority system to specify licences which are entitled to divert water in times of shortage. Priority is the date which is assigned to a water allocation application and is recorded on the licence. This number indicates that in times of supply shortage, the most senior licence has the right to withdraw their full allocation, provided any conditions on the licences are met, including stream flow. There is no priority based on the purpose of use.

Under this system, the more junior the licence (i.e. the more recently it was applied for), the greater the risk of not receiving all or part of the allocated water in low water years. However, during emergency situations, the Government of Alberta has the power to suspend a water licence and reassign the water for other uses with compensation. A licence can also be cancelled for non-use or for failing to satisfy a condition of a licence.

During the 2001 water shortage in the Oldman River basin, Alberta Environment brought together multiple licence holders to implement voluntary temporary agreements ensuring that junior licence holders were able to continue operations as a result of concessions by senior licence holders. In case of water shortage due to drought conditions in southern Alberta, the irrigation districts will not only participate in water sharing but will also prioritize the water that is needed for human and livestock sustenance. In 2011, and later re-affirmed in 2018[1], Alberta's thirteen irrigation districts (acting through the Alberta Irrigation Districts Association) passed a declaration entitled "Sharing Water for Human Needs and Livestock Sustenance During Water Shortages".

4.4.1 Licences of potential impact to CMRB members

4.4.1.1 Licences of potential impact, separated by municipality

A screening level analysis was conducted on each municipal licence for CMRB members to identify potential water supply availability issues specific to each municipality. This analysis looked at the total annual allocation volume, however seasonality of withdrawal by other users can also increase or mitigate potential constraints. A future in-depth analysis of licences of potential impact could assess seasonality of withdrawals.

For each municipal licence, the licences in the Bow River basin that were senior to that licence were identified. From that set of senior licences, the total number of licences and the total annual volume were calculated (Table 2). Only licences from the Bow River basin were included because all CMR municipal surface water licences fall in that basin. Broadly speaking, during times of shortage, all licences in the basin would be considered in the calculations for restricting water withdrawals, and in times of emergency the government has the power to change the rules and the priority system may or may not apply.

Water use data from the Water Use Reporting System (WURS) was received from AEP but was not included in this analysis because:

- Allocated volumes are more relevant than actual use volumes for the analysis as they represent the maximum volume that could potentially be used by each licence holder, which is useful in identifying licences with the greatest potential to affect availability for CMR members.
- The water use data are incomplete, missing for many municipalities, and in some cases, appear to be incorrect.
- The issue of 'sleeper licences' is avoided (when licence holders do not currently use their licence but might in the future). The analysis was based on licence data provided by AEP and supplemented by data supplied by CMRB members, where possible.

The following factors should be kept in mind when assessing licences of potential impact:

- **Licence priority:** This is the most important consideration. In times of water shortage, licences that are senior will be allowed to divert water first. For example, the City of Calgary's licence from the 1980s is their main licence for future growth but is relatively junior and could be a constraint based on licence priority in the watershed.

[1] https://www.smrid.com/alberta-and-its-recurrent-drought-conditions/

- **Diversion rate:** The maximum diversion rate stated on each licence can impact downstream licensees where the diversion rate is high relative to the streamflow at a particular point in time. Winter low-flow conditions on the unregulated CMR rivers (rivers with no control structures) are also potential limiting factors.
- **Volume:** Licences with large annual diversion volumes have a greater potential to impact access to water for municipalities.
- **Diversion timing:** Municipalities need access to water year-round. One major challenge is that there are several senior irrigation licences with large diversion volumes that divert primarily in the summer. Water storage can help with this. Senior licences only have an impact on other licensees when they are being utilized.
- **Existing agreements:** TransAlta has an agreement with the Government of Alberta until 2021 to release water for downstream needs and to provide flood mitigation. Aside from that agreement, TransAlta operates their Bow River hydro assets for hydropower generation needs, and downstream considerations where warranted. If the timing of releases from upstream reservoirs were to change from historical norms, this could impact municipal access to water during certain times of the year.

The following filters were applied to the data received from AEP:

- **All cancelled and expired licences were removed**
- **Only term licences for surface water were included** (i.e. groundwater licences and temporary diversion licences were removed)
    - Groundwater licences were excluded because nearly all CMR municipal licences are surface water (groundwater licences should have virtually no impact on water availability for CMR municipalities).
    - Temporary diversion licences were excluded as they have no priority over term licences. In times of water shortage, temporary diversion licences would have no impact on water availability for CMR municipalities.
- **Non-CMR licences with a total annual allocated volume less than 5,000 m^3 were excluded**
    - This volume was deemed sufficiently small as only two of over forty total CMR municipal licences have a volume less than 5,000 m^3 and only four have a volume less than 100,000 m^3.

To show the relative potential constraints related to water supply for each CMR municipal licence, the total number of licences senior to it and the total annual volume of senior licences were calculated (Table 2). While there are no definitive guidelines as to what a large or small number of senior licences or of senior licences' total annual volume is, in general, having fewer licences senior to the licence and a smaller annual volume of senior licences is desirable. However, there are several other factors that may be important for a municipality to assess constraints on one of their licences, including the other licences held by that municipality (including their priority, volume, quantity, and diversion rate), other licences in the basin, water storage, and streamflow.

While the total annual volume of senior licences appears large for many licences, it should be considered relative to the annual supply at each location, as shown in Table 1. A direct comparison is not provided here as there were errors with the annual allocated volumes in the dataset received from AEP found during the analysis that would require a full audit of the data to correct. While not specific to CMR municipal licences, the SSRB 10-Year Review conducted a full analysis of annual allocated volumes relative to supply in the SSRB and its sub-basins and can be referred to for additional information (Basin Advisory Committees, 2018).

Table 2. Licence overview for CMR municipal licences. Data source: AEP.

Municipality	Licence Number	Priority	Annual allocated volume (m^3/year)	No. of licences senior to licence	Total annual volume of senior licences (m^3/ year)
Town of Strathmore	00264455-00-00	19781031002	1,110,141	450	2,244,774,460
	00264457-00-00	20010611001	555,075	849	2,773,212,519
	00264461-00-00	20041125001	555,067	893	2,829,998,251
City of Calgary (*incl. Airdrie and Chestermere)	00046164-00-00	18950802001	5,550,665	5	1,041,066
	00044679-00-00	19291024001	66,666,000	29	1,519,865,526
	00044679-00-00	19711125001	41,975,892	286	1,699,427,507
	00046164-00-00	19711129002	135,066,280	286	1,693,901,512
	00034656-00-00	19811102003	210,925,420	523	2,041,990,074
Town of Cochrane	00039803-00-00	19600921001	431,719	144	1,747,644,215
	00039803-00-00	19850910002	4,502,207	593	2,508,040,236
Rocky View County	00240846-00-00	19030904001	2,220,268	8	6,953,141
	00045938-00-03[2]	19030904001	3,083,700	8	6,953,141
	00331300-00-00	19740820002	86,343	337	2,195,992,879
	00160306-00-00[3]	20011126010	3,300,000	854	2,773,910,389
	00234476-00-00[4]	20031120001	803,000	881	2,778,846,984
Bragg Creek	00255373-00-00	19741024001	277,533	341	2,196,260,633
Wheatland County	00045938-00-02[5]	19030904001	1,233,480	8	6,953,141
Town of High River	00045676-00-00	19271231001	1,161,238	30	1,511,167,248
	00045676-00-00	19390630005	172,688	67	1,590,494,849
	00045676-00-00	19390630006	118,416	68	1,591,656,087

[2] RVC has a lease agreement with the licence holder, the Western Irrigation District.
[3] RVC has an agreement with the licence holder, Mountain View Regional Water Commission.
[4] RVC has an agreement with the licence holder, Aqua 7 Regional Water Commission.
[5] Wheatland County has a lease agreement with the licence holder, the Western Irrigation District.

Municipality	Licence Number	Priority	Annual allocated volume (m^3/year)	No. of licences senior to licence	Total annual volume of senior licences (m^3/ year)
	00045676-00-00	19720707001	237,816	292	1,936,753,174
	00045676-00-00	19720707002	202,288	293	1,936,871,590
	00045676-00-00	19770302002	3,944	403	2,230,012,031
	00045676-00-00	19780315003	102,624	429	2,236,962,644
	00045675-00-00	19840213002	1,386,614	553	2,499,129,492
	00045675-00-00	19840213003	247,930	554	2,499,232,116
	00045675-00-00	19840213004	247,930	555	2,500,618,730
	00045674-00-00	19950127010	3,194,273	897	2,832,635,236
	00045674-00-00	19950127011	672,000	898	2,832,883,166
	00045674-00-00	19950127012	672,984	899	2,836,077,439
Town of Okotoks	00268349-00-00	19440915001	28,864	89	1,643,953,701
	00327785-00-00	19440915001	45,516	89	1,643,953,701
	00035110-00-00	19521231002/ 19850122004	250,455	104	1,645,685,971
	00348644-00-00	19640320002	99,912	205	1,750,507,778
	00342912-00-00	19770324004	85,037	410	2,237,069,065
	00283404-00-00	19770324005	36,634	410	2,237,069,065
	00035105-00-05	19791210001/ 19791210002/ 19721210003/ 19850122005/ 19850122006	790,909	469	2,270,451,329
	00391311-00-00	19800303002/ 19800322002	88,810	479	2,270,989,119
	00268353-00-00	19801204001	216,476	498	2,280,007,710
	00353780-00-00	19820317015	9,770	525	2,501,333,183
	00336563-00-00	19830531014	15,231	544	2,504,056,764
	00379987-00-00	19830607020	14,476	548	2,504,341,534
	00390822-00-00	19840808010	22,536	569	2,506,038,692
	00035112-00-00	19850122003/ 19850122007	660,910	565	2,505,447,595
	00379986-00-00	19850321008	4,341	572	2,506,303,705
	00385019-00-00	19920205010	244,229	702	2,533,606,298
	00202472-00-00	19920610010	62,908	714	2,669,715,499
	00072884-00-00	19920610011	11,101	714	2,669,715,499
	0035104-00-00	19961129001	91,313	782	2,686,136,666
	00074820-00-00	19990322001	444,056	802	2,726,063,584
	00191251-00-00	20020829001	454,372	850	2,773,511,608
	00368797-00-00	20051002001	36,908	886	2,830,665,658

*Airdrie and Chestermere receive water from the City of Calgary, though it is not known which Calgary licence their supply comes from.

Each individual water licence may be subject to a variety of terms and conditions, which may include flow conditions. Municipalities are counselled to review a water licence document if there is interest in understanding the associated terms and conditions.

4.4.1.2 Licences of potential impact, compiled for all CMRB members

A separate screening-level analysis was conducted to identify a set of licences that have the potential to impact most CMRB municipal licences. Ultimately, the list could be used as a starting point for the CMRB to identify potential partnerships or other collaborative opportunities for water supply management. These licences might become opportunities by following certain processes (e.g., licence transfers). These processes can vary in the level of effort, expense, or complexity that would be involved. A more in-depth analysis could be conducted to assess the licences from this screening for their potential impacts in greater detail, including seasonality.

This analysis was conducted using the same filtered dataset as the previous analysis. A subset of licences in the Bow basin was created based on priority, annual diversion volume, and diversion rate. Under provincial legislation, any licence that has priority over a municipal licence, regardless of priority number or total volume, has a potential to impact the municipal licence. However, creating a subset list using the criteria stated below allows for a manageable number of licences identifying key opportunities. Specifically, the following criteria were used to identify licences in the basin that could impact the majority of CMRB municipal licences during times of shortage:

- Priority > 1960 – 42 of CMRB municipal licences currently being used are junior to 1960, 7 are senior, therefore 1960 is a cut-off criterion that has potential to impact the majority of CMRB municipal licences;
- Annual diversion volume > 500,000 m^3 – this volume is greater than 37 of 42 CMRB municipal licences; and
- Diversion rate > 0.2 m^3/s – only 3 CMRB municipal licences have a higher instantaneous diversion rate.

Logical statements were applied during the filtering process such that the priority criterion must always be met for inclusion, while either the annual diversion volume or diversion rate criteria could be met.

The analysis returned a total of 21 licences, three of which were CMRB municipality licences and were removed, with the other 18 warranting additional review, including:

- 10 irrigation/ stockwatering licences[6]
- 2 municipal licences
- 1 flood control licence

[6] It is worth noting that the Albert Irrigation Districts Association signed and published the *Human Use of Water and Livestock Sustenance Declaration* in 2018. This declaration states that the member districts will participate in water sharing with other licence holders in good faith so that sufficient water can be distributed for basic human use and for sustenance of livestock. See the declaration posted on their webpage http://www.aipa.ca/theme/common/page.cfm?i=12942.

- 2 industrial licences
- 3 habitat/ water management licences

The full list of licensees is provided in the Appendix C: Water licences of potential impact (section 8.3).

4.5 Literature Review: Management options identified in previous studies

Based on the literature review, below is a summary of options that may be available to the CMRB, as a collective group, to manage water availability. These options are grouped by categories within the subsections below.

Many of the options listed were developed as a result of collaborative watershed work involving multi-stakeholder working groups. As a result, options may not be specific to a single watershed stakeholder but rather are watershed-scale management decisions that would require further collaborative efforts to refine and implement. As major licence holders in the region, the members of the CMRB play an important role and are well positioned from a licensing standpoint to support the implementation of management options with other partners in the respective watersheds.

In addition to providing a brief description of the management options from the literature review and other stakeholders that might be involved, a high-level assessment of the risks and benefits of each option to the CMRB is included. A detailed assessment of feasibility and associated technical study, timelines, costs, and other key aspects of each option would need to be developed in future work and is outside the scope of this project.

4.5.1 Support the construction of new water storage

Specific water management options relating to new water storage include:

- Three new water storage options are being studied as part of a conceptual assessment for flood and water management on the Bow River upstream of Calgary and multiple CMR municipalities. These options include either a new Glenbow reservoir, a new Morley reservoir or an expanded Ghost reservoir. This study is expected to be complete in February 2020 (WaterSMART Solutions Ltd., 2016).
- In July of 2019 Alberta Irrigation Districts Association (AIDA) submitted their preferred storage options for additional storage capacity in the SSRB. As an example, Eyremore Reservoir low in the Bow River basin has been discussed for years and was examined as part of a collaborative modelling study, the *Climate Vulnerability and Sustainable Water Management in the SSRB Project*. A reservoir like Eyremore, while located well downstream, was shown to provide more upstream water storage flexibility both on the Bow and Oldman basins in terms of being able to meet upstream needs while meeting downstream apportionment flows.

Benefits

- Increases available water supply during times of water shortage or drought.
- Opportunities for meeting environmental flow targets if operations are coordinated with existing reservoirs.

- Potential for hydropower production.
- Ability to better manage changes in timing and magnitude of runoff.
- Provides flood mitigation opportunities if designed with co-benefits in mind.
- The Eyremore reservoir would alleviate pressure and provide flexibility for managing existing facilities, especially in the Oldman basin which has been identified as a concern under future demand scenarios (Alberta Environment and Parks, 2017; WaterSMART Solutions Ltd., 2016).

Risks

- High cost relative to other options.
- Footprint of new or expanded reservoir removes existing riverine habitat.
- Long and uncertain timeframes for completion including consultation, environmental approvals and construction.

4.5.2 Support changes to the operation of existing water storage

Specific water management options relating to changes in existing water storage include:

- Development of a communications system to time the release of water from storage for water deliveries to match when irrigators can use the water (Alberta Environment, Water Management Plan for the Watersheds of the Upper Highwood and Upper Little Bow, Volume 1, 2008).
- Operating irrigation district reservoirs to protect junior licences from having to cease diversions during low flow periods (Alberta Innovates - Energy & Environment Solutions & WaterSMART Solutions Ltd., 2013).
- Establishing a virtual water bank within the existing TransAlta storage reservoirs, capable of providing 60,000 acre-feet of storage to be used to offset low flow periods in the Bow and to stabilize Lower Kananaskis Lake and Kananaskis River (Alberta Innovates - Energy & Environment Solutions & WaterSMART Solutions Ltd., 2013).
- Adjusting fill times for the three largest TransAlta reservoirs (Minnewanka, Spray, Upper Kananaskis) (Alberta Innovates - Energy & Environment Solutions & WaterSMART Solutions Ltd., 2013).
- Entering into long-term, flexible agreements between government and TransAlta for drought and flood mitigation (WaterSMART Solutions Ltd., 2016). The current five year between TransAlta and AEP is a pilot that will provide learnings can be applied to a future long-term deal. Formal negotiations on a follow up agreement have not started but it is understood that this is currently being discussed by government department leadership.
- Raising winter carry-over levels in reservoirs in the Bow and Oldman basins (WaterSMART Solutions Ltd., 2016).

Benefits

- Relatively low cost compared to potential new infrastructure.
- Can be implemented in the near term and offer immediate value.

Risks

- Changes in operational priorities may shift political will to advance some of these opportunities.
- Winter carry-over options may have uncertainty given changes in timing and variability.
- Potential impacts to meeting peak power demands.

4.5.3 Support modification of existing water storage

Specific opportunities for this option include:

- Restoring the Spray Reservoir to full design capacity (Alberta Innovates - Energy & Environment Solutions & WaterSMART Solutions Ltd., 2013). This would allow for increased upstream water storage and flood mitigation for downstream water use.

Benefits

- More time and cost efficient than building new upstream storage.

Risks

- While geotechnical technologies have advanced that would allow Spray reservoir to return to full capacity, it is unknown if this action would have the desired outcomes.
- Additional studies would be required to determine if the additional storage would provide significant downstream benefit to CMR municipalities

4.5.4 Actively participate in regional water management discussions

Specific management options relating to regional water management discussions include:

- Support the GoA in reaching a long-term agreement with TransAlta and other key stakeholders and licensees in the Bow basin to collaboratively manage the Bow watershed (Alberta Innovates-Energy & Environment Solutions & WaterSMART Solutions Ltd., 2014; WaterSMART Solutions Ltd., 2016).
- Support the GoA in finalizing the draft stormwater / wastewater reuse policy (Alberta Innovates-Energy & Environment Solutions & WaterSMART Solutions Ltd., 2013).
- Become an active participant in discussions and recommendations related to the SSRB 10-year review to ensure that CMR municipalities are part of the discussion on health of the river in accordance with the plan (Basin Advisory Committees, 2018).
- Continue to participate in the Bow River Basin Water Management Options project. If it continues beyond the conceptual phase, continue to participate to voice the municipal perspective on possible infrastructure options.

Benefits

- Engaging in water management discussions provides opportunity to influence priorities for the basin,

whether health and safety, economic, supply focused, or other.
- A unified CMR voice represents over 1.5 million Albertans and a significant portion of Alberta's population.

Risks

- There is a risk of not participating in discussions; no risks were identified in participating in the broader water management discussions.

4.5.5 Develop improved monitoring and forecasting tools to inform water management decisions

Specific management options relating to monitoring and forecasting tools include:

- Development of a water management decision support system similar to the New York City Department of Environmental Protection's Operations Support Tool in partnership with the irrigation districts, TransAlta, and Alberta Environment and Parks (Alberta Innovates - Energy & Environment Solutions & WaterSMART Solutions Ltd., 2013).
- Improve resourcing and forecasting tools in the basin, including all private and publicly owned reservoirs (WaterSMART Solutions Ltd., 2016).

Benefits

- Development of data-driven tools could form the basis of partnerships and lead to more collaborative work and discussions about water management in the region. Appropriate governance structure would need to be established for the partnerships.
- Accurate forecasts are essential for adaptive basin management to balance risks and coordinate mitigation actions across all sectors and water users.

Risks

- There is a risk of not doing anything in this regard and not having the tools to help with adaptation and resilience.
- Monitoring and forecasting tools must be used for planning and decisions in order to have an impact. There is a risk of developing a tool and then it not being used for water management decisions.

4.5.6 Further implementation of demand management

The CMRB is undertaking a separate study (Complexity B) to identify opportunities for water conservation and efficiency. However, demand management is a critical component of water availability and is therefore briefly discussed here to provide a complete overview of management options for consideration by the CMRB. Results of the demand management study are anticipated to be more specific to the CMRB and to build upon the following options that were noted in the literature review.

Specific management options relating to demand management include:

- Reducing water demand in Calgary in the summer months (Alberta Innovates-Energy & Environment Solutions & WaterSMART Solutions Ltd., 2014). This conclusion can be expanded to all parts of the CMR.
- Supporting the implementation of conservation measures in Irrigation Districts (Alberta Innovates-Energy & Environment Solutions & WaterSMART Solutions Ltd., 2014).

Benefits

- Water conservation begins with public education. Anecdotally, citizens of CMR may be unaware of the current water system on which they rely. Many regions of the world have curbed poor behavior with a combination of water conservation measures; however, a common theme is public education.
- Conservation measures are generally well-established, especially for urban areas (e.g. public education, adopting high-quality plumbing fixtures, repairing leaks, limiting outdoor use of water).
- Demand reduction measures could be implemented at any time and are significantly low-cost compared to major infrastructure projects. Sufficient time and research are needed to understand customers such that demand reduction programs can be implemented successfully.

Risks

- Public support of demand reduction may be low due to perception by some customers that this would result in higher utility rates and/or taxes. Low public awareness of how water is used and the impacts of water demand at a regional scale may be a challenge for implementing demand management strategies.
- Not educating the public in an effective way. Communicating only facts and science may not create the awareness of the importance of individual action in reducing demand. Clear, focused communications with help create meaningful change in the demand management realm.
- A lack of focus internally among municipalities themselves. Often water conservation is not the highest priority for management or may be under the control of a third party, such as a water cooperative. There must be strong internal support for demand management in principle and the work properly resourced to make demand management successful.

4.5.7 Water Quality

The following options were identified in the literature review and additional potential water quality constraints are flagged in Appendix E. These are intended to support potential future water quality studies.

Specific opportunities for water quality management that relate to water supply and availability include:

- Ensuring lagoon operators coordinate to release effluent at optimal times, specifically during high flow for maximum dilution (Government of Alberta, 2014).
- Supporting the establishment of regional watershed targets for phosphorus (Government of Alberta, 2014).
- Supporting a review of the lagoon Code of Practice and regulations to allow for maximum phosphorus

removal (Government of Alberta, 2014).

Benefits

- Reduction in treatment costs for downstream users.
- Improved water quality outcomes for the health of aquatic and riparian ecosystems.

Risks

- No risks were identified in the specific opportunities for water quality outlined above.

4.5.8 Opportunities related to water licences

- Several municipalities rely on the natural flows of the Highwood and Sheep river systems, which lack substantial water management structures. With growing populations and changes in flows due to climate change, there is increasing risk of shortages on these river systems. A potential management option is to move municipal licences from the Highwood/Sheep system to the highly regulated Bow River (Alberta Innovates - Energy & Environment Solutions & WaterSMART Solutions Ltd., 2013) and provide water supply from the Bow River.
- Take part in conversations related to the Upper Highwood/ Upper Little Bow including (Alberta Environment, Water Management Plan for the Watersheds of the Upper Highwood and Upper Little Bow, Volume 1, 2008):
    - Removal of a July cutoff condition for irrigation licences that have the condition.
    - Establishment of a WCO.
    - Consideration of an amendment to the licences of the Women's Coulee and Little Bow Diversion works to incorporate the Highwood Diversion Plan as a condition.

5.0 Considerations for the growth planning consultant

This report supports decision-making relating to water supply by providing a base understanding of the current state of natural and managed water supply in the region. Planning for water supply over a 30-year timeframe must link with other types of planning and policy development. The timing and funding horizons for major water treatment and distribution infrastructure influenced by demand and development patterns is a multi-decadal scale. Therefore a 30-year plan for may not be prudent for all planning aspects.

The following section suggests some of the key considerations for water supply management planning and provides a high-level breakdown of the potential constraints on water supply for each CMRB member municipality to consider in individual and collective planning.

5.1 Key considerations for water supply management for municipalities

Below is a list of the key considerations for CMR municipalities to assist with sustainable planning for growth and servicing of the region over the next 30 years. These were identified by subject-matter experts and throughout the literature review and analysis of the project.

The key considerations listed here are the dominant themes that relate to water supply management. They are broad, generalized statements for consideration in the planning process. Overall, they point to pursuing a long-term and integrated approach to planning due to the many uncertainties about water supply and the interdependency of water supply and municipal planning.

- **Water supply variability**: Higher degrees of variability in water supply may be expected in the future. The river systems supplying water to the CMR have experienced significant natural variability in the past and in addition, climate change may introduce some level of variability. Planning for greater variability than has been experienced in recent decades is a pragmatic approach; in particular, multi-year droughts are likely.
- **Coordination among users**: Various kinds of storage and synchronizing upstream releases with downstream purposes offer opportunities. These could be in the form of upstream-downstream water management agreements and changing reservoir operations, or basin-wide shortage sharing and reallocation frameworks.
- **Planning for increasing efficiency**: Enabling growth while maintaining the same level of water consumption is possible through efficiency. Rates for water use must reflect the full cost of service and promote conservation.
- **Risk and vulnerability**: Water infrastructure must be designed to withstand extreme weather events. Extreme weather events in the headwaters may impact water availability or quality.
- **Low flows and wastewater**: Low river flows may impact municipal services by having inadequate volume for wastewater dilution.
- **Work with existing initiatives**: Many local and regional water management initiatives are underway already. New water management initiatives should tie-in with existing and under-development efforts to benefit the region as a whole.
- **Watershed changes are linked to water supply:** The important role that the whole watershed and tributaries play in contributing water quantity and water quality to the mainstem is often overlooked. Opportunities may exist in coordinating management efforts from a systems approach regarding land use changes and the stewardship of smaller tributaries. Similarly, increasing water withdrawals from or wastewater inputs to sub-basins may have unforeseen impacts to the mainstem.
- **Diversity of storage and servicing**: A range of types of water storage provides better resilience and allows for more fine-tuned supply management, both of which are highly valuable in a variable and high-demand system like the CMR.

5.2 Potential constraints for municipalities

Each municipality has potential constraints regarding access to water depending on their water source supply and quality, and available storage. The potential constraints on municipal water supply arise from reduced natural supply, poorer water quality, and increased demand or timing of peak demand. The population of all CMR communities is projected to increase at a rate of approximately 2 to 4% per year. Water demand will increase if per-capita water use remains the same, which may lead to constrained water supply for all communities. Table 3 outlines the potential constraints for each of the CMR municipalities.

Table 3: potential constraints specific to each CMRB member

CMRB member	Specific constraints regarding access to water
City of Airdrie	• Constraints are expected to be the same as the City of Calgary as they supply drinking water to Airdrie because their drinking water is supplied by Calgary. Potential nutrient loading during low flows is also a constraint as Airdrie would be subject to the same wastewater return flow constraints as Calgary because they send their wastewater to Calgary. • The population of Airdrie is projected to increase at a rate of approximately 3% per year. Water demand will increase if per-capita water use remains the same, this may lead to constrained water supply.
City of Calgary	• Constraints include low flow periods corresponding with high demand times. • As the city does not have the most senior allocations on the Bow, if more senior licence holder were to exercise their first-in-time right the city's licence could be constrained in high demand season in the summer. • Nutrient loading during low flows is also a potential constraint. • The population of Calgary is projected to increase at a rate of approximately 3% per year. Water demand will increase if per-capita water use remains the same, this may lead to constrained water supply. • Degrading quality of source waters from upstream land uses, practices and changes. • Operational constraints stemming from regulatory approvals e.g. maximum diversion capacity; effluent loadings • Supply risks stemming from climate change shifts to water supply quantity and timing, and the capacity of existing reservoirs to maintain water availability.
City of Chestermere	• Constraints are expected to be the same as the City of Calgary as they supply drinking water to Chestermere because their drinking water is supplied by Calgary. • The population of Chestermere is projected to increase at a rate of approximately 4% per year. Water demand will increase if per-capita water use remains the same, this may lead to constrained water supply.
Town of Cochrane	• The population of Cochrane is projected to increase at a rate of approximately 3% per year. Water demand will increase if per-capita water use remains the same, this may lead to constrained water supply. • Potential nutrient loading during low flows is also a constraint as Cochrane would be subject to the same wastewater return flow constraints as Calgary because they send their wastewater to Calgary.
Foothills County	• Foothills county sources water from groundwater which may be constrained by increasing demand paired with uncertain future yields. • The population of Foothills County is projected to increase at a rate of approximately 2% per year. Water demand will increase if per-capita water use remains the same, this may lead to constrained water supply.
Town of High River	• High River sources its water supply from a number of shallow groundwater wells

CMRB member	Specific constraints regarding access to water
	that draw groundwater under the direct influence (GUDI) of surface water from the Highwood River. The Highwood River, which has a less reliable natural water supply than the Bow River mainstem and no major upstream storage. Constraints include low flow periods corresponding with high demand times on the Sheep/Highwood system. The Highwood River has experienced water quality issues in the past, including harmful dissolved oxygen (DO) levels during low flow conditions. • High River relies on several licences in combination to achieve total water supply; several of these licences are junior in priority. • The population of High River is projected to increase at a rate of approximately 3% per year. Water demand will increase if per-capita water use remains the same, this may lead to constrained water supply.
Town of Okotoks	• Okotoks sources water from the Sheep River, which has a less reliable natural water supply than the Bow River mainstem and no major upstream storage. • Okotoks relies on several licences in combination to achieve total water supply; several of these licences are junior in priority. • The population of Okotoks is projected to increase at a rate of approximately 3% per year. Water demand will increase if per-capita water use remains the same, this may lead to constrained water supply.
Rocky View County	• There are 70 independent water cooperatives within RVC each with their own water licence and water treatment plants. Coordination is challenging. • The population of Rocky View County is projected to increase at a rate of approximately 2% per year. Water demand will increase if per-capita water use remains the same; this may lead to constrained water supply.
Town of Strathmore	• Constraints are expected to be the same as the City of Calgary as they supply drinking water to Strathmore because their drinking water is supplied by Calgary. • The population of Strathmore is projected to increase at a rate of approximately 3% per year. Water demand will increase if per-capita water use remains the same, this may lead to constrained water supply.
Wheatland County	• The portion of Wheatland County within the CMR boundary is serviced by individual groundwater wells, which may be constrained by increasing demand paired with uncertain future yields. A portion of Wheatland County that is dependent upon allocation of a portion of the WID flow to Rocky View County may experience a water supply constraint if the Bow if constrained. • The population of Wheatland County is projected to increase at a rate of approximately 2% per year. Water demand will increase if per-capita water use remains the same, this may lead to constrained water supply.

5.2.1 Maps of water-derived constraints

All watersheds in the CMR are expected to experience some degree of water quality and/or quantity constraints in the next 30 years due to projected changes in the natural and managed parts of the system. Potential water-derived constraints were classified on a sub-basin basis (e.g. watersheds within the Bow River basin) and are presented in two maps below (Figures 12 and 13), and an additional map in Appendix E. Generally, the headwaters have the lowest relative potential to experience constraints over the next 30 years while constraints increase progressively downstream. Headwaters generally have fewer constraints as they have lower population levels, less development, and a proportionally greater volume of water to draw from. While most CMR municipalities fall within the highest level of constraint, it should again be noted that these numbers are relative to other sub-basins in the study area and not absolute indicators of impending water constraints. This report is intended to indicate high-level constraints. Additional studies could be conducted for greater detail.

Figure 12 illustrates watersheds that are more vulnerable to climate change based on projected changes to climate in the CMR. Warming temperatures and changes in timing and nature of precipitation (e.g., more rain-on-snow events) put the reliability of natural supply as a higher constraint for these watersheds in the CMR. Watersheds that were considered snowmelt dominated based on reviews of available data and professional judgement were assumed to be the most vulnerable to climate change. Figure 13 illustrates potential constraints related to managed capacity. Sub-basins with no water storage (e.g. a dam) in the sub-basin or upstream will be more vulnerable to water supply constraints in the future. Storage infrastructure allows for changes in timing and magnitude of precipitation to be stored and released to more evenly distribute natural water supply.

A constraint score of 1 was applied to the sub-basin if the constraint was present, with a score of 0 otherwise. This analysis was based on available data, and after discussion with the Water Table it was decided to make three independent maps rather than one map that was aggregated. These maps are simplified expressions of where water constraints are more likely based on this analysis. In order to gain a full understanding of current and future constraints, further study would be required.

In summary, constraint scores were assigned as follows:

- Most vulnerable to climate change (Figure 12)
    - 1 if sub-basin is snowmelt dependent, and therefore more likely to be most vulnerable to projected changes in climate; and
    - 0 if sub-basin is not snowmelt dependent.
- Water storage (Figure 13)
    - 1 if major water storage (e.g. a dam) is present in the sub-basin or upstream; and
    - 0 otherwise.

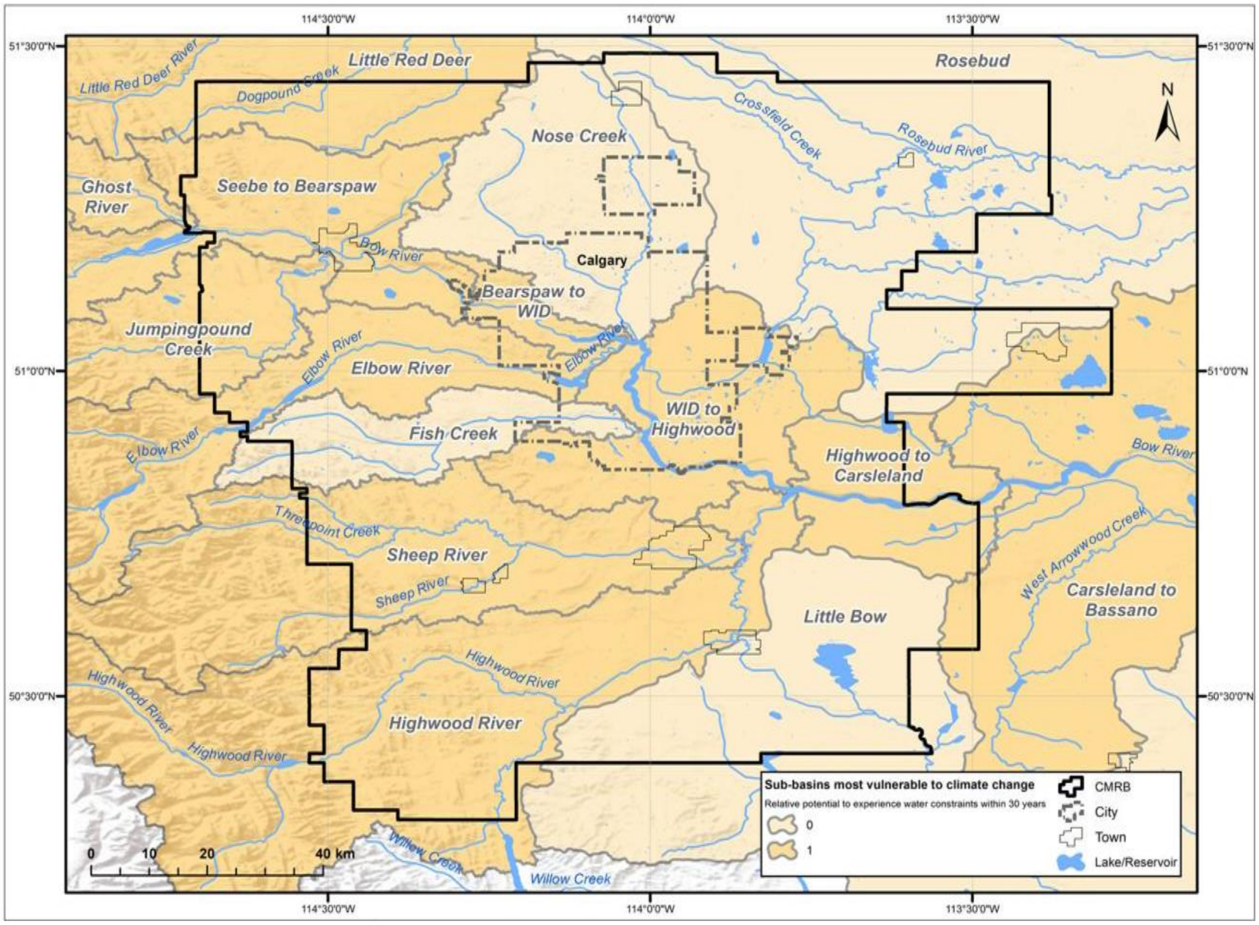

Figure 12 Watersheds deemed to be more vulnerable to climate change (1 or darker orange) based on projected changes to climate in the CMR. Snowmelt dominated watersheds are deemed most vulnerable to climate change based on reviews of available data and professional judgement.

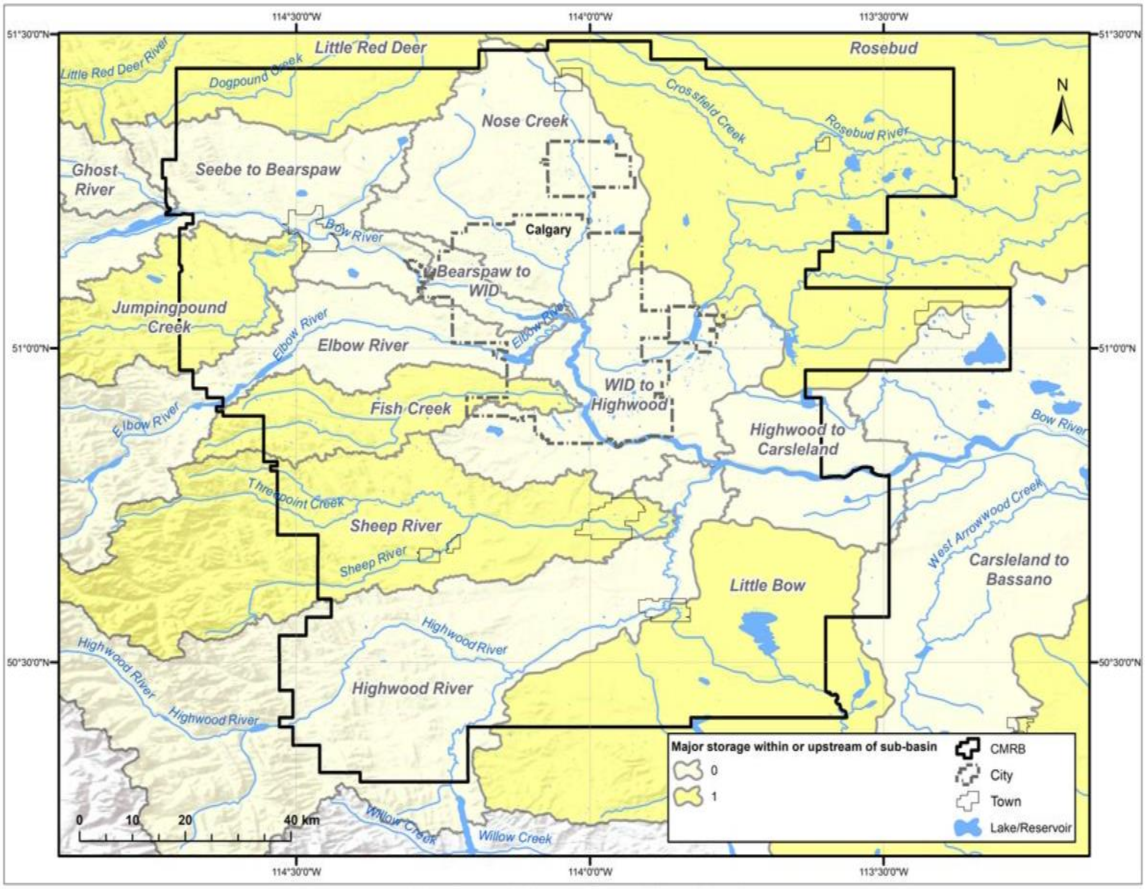

Figure 13 Watersheds with no water storage (e.g. a dam) in the sub-basin or upstream were deemed to be more vulnerable to water supply constraints in the future (1 or darker yellow).

6.0 Observations, gaps and opportunities

6.1 Observations

It was noted throughout the literature review and in preparing this report that there is value in implementing and maintaining water supply management in the short-term, rather than waiting for large projects (such as storage) to be approved and completed. Short-term initiatives, such as demand management, buy time for bigger management projects. Below is a list of some shorter-term strategies observed while reviewing material for this report.

- Informed water operations staff, clear and coordinated operations plans, and well-maintained infrastructure can go a long way in getting the most from the existing water supply. It is critical that these activities are properly funded over the long term. Costs for operation and maintenance will increase with a growing population and funding should keep pace with rising costs to avoid challenges and enhance efficiencies.
- Where a junior priority number makes a municipal water allocation vulnerable, a reverse licence transfer[7] would provide greater security.
- Increase awareness of potential water supply challenges expected to occur in the future. Specifically, long-term droughts have been repeatedly identified in climate studies for the region as having potential to impact water supply. Development of materials to increase public awareness of local drought response strategies can help facilitate water supply management for municipalities if a long-term drought occurs and water restrictions must be imposed. It would also allow the public to plan landscape and domestic patterns carefully.
- Since the SSRB Water Management Plan came into effect the GoA has been requiring Water Shortage Response plans to be submitted by licence applicants as a mechanism for ensuring understanding of risk. CMRB members may choose to share existing Water Shortage Response plans as part of growth planning.
- Where possible, consider municipal operational efficiencies for water diversions and conveyance and identify solutions that maximize efficiencies in both areas. Some solutions to individual water supply challenges may avoid municipal political challenges and allow greater autonomy or control over water supplies but may be more expensive or result in unintended inefficiencies and costs over the long term.
- Long term water management also includes proactive initiatives to mitigate events which will negatively impact the water supply in the long term. This includes source water protection, land-use planning, and water quality initiatives.
- Land-use management and development decisions for upstream areas of the relevant watersheds are key to water supply management. Coordination with government bodies who have jurisdiction over upstream land-use and riparian and stormwater planning within each municipal jurisdiction is important to water

[7] This is where a municipality transfers its junior licence to a senior licensee in exchange for an equal amount of senior priority water and pays a negotiated fee for risk compensation to the senior licensee.

supply.

6.2 Gaps and future studies

This section is divided into two subsections. The first identifies the potential future studies or additional work that would help complete the understanding of natural and managed capacity of water supply for the CMR. Many of these studies were noted previously throughout this report. The second subsection here identifies the datasets that were missing or incomplete for the analysis work of this current study.

6.2.1 Gaps in understanding

The subject of water management is complex and many aspects about what can be expected in the future for natural and managed capacity of water resources are not known. There are some gaps in understanding that could not be addressed through this study. Below are some possible additional studies that could be considered to provide more detailed information to support planning:

- Regional climate study for water supply change projected on a scale relevant for sub-basins and reaches of the CMR. This might include a detailed analysis of current and future water availability under climate change, current water allocation, water use from water bodies relevant to CMR, and future water needs based on growth projection to identify constraints (related to water availability) for each of the municipalities of CMR that assist with the suggested recommendations.
- Assessment of natural and managed capacity of groundwater supply for the region to understand whether opportunities exist similar to the groundwater supply for Langdon.
- Reservoir study to understand the current roles and opportunities of existing reservoirs from a regional perspective.
- Small-scale storage opportunities study to identify opportunities for small-scale storage and coordination among them.
- Multi-year drought regional water supply management study to understand the impact of prolonged dry periods on water availability and potential responses.
- In-depth study of water-derived constraints and representation with maps.
- Detailed assessment of other licences with potential to impact CMRB licences, building off of section 4.4.1 of this report. Particularly regarding seasonality of demand.
- Extract needed information from annual reporting done by municipalities under Environmental Protection and Enhancement Act for their drinking water and wastewater systems to supplement the incomplete data in the WURS system. CMRB and associated municipalities might find that information useful for some of their future next steps.

6.2.2 Data gaps

This section consolidates data gaps identified throughout the project that should be addressed for effective planning by CMRB.

Table 4: Gaps in datasets as identified through review of material for this study.

Dataset	Gaps
Water licence data – AEP	• Data are current as of July 3, 2019. Although not substantive, any new licence data after this date is not included. • Data were pulled by AEP from an existing database and were not audited prior to transmission to WaterSMART.
WURS - water use data	• Generally, water use data is inaccurate, incomplete, or missing for many licences. • Acquiring water use data for licences of potential impact may be valuable, but also may be inaccurate. • Water use data does not cover entire lifespan of older licences (earliest data for any licence is 1977; many licences are much older than that). This may not be an issue as recent use data is most valuable. • Additional study could be done to compile this information for the CMRB municipalities.

6.3 Opportunities

Addressing the various water supply constraints will require action and cooperation by numerous stakeholders in the region. Specific opportunities for action were extracted from the literature throughout the preparation of this report are summarized below for consideration by the CMRB as they proceed with regional planning:

Establish agreed-upon standards and timeframes for water-related municipal actions

- Leveraging the advantages of a collective decision-making planning entity can create resiliency in the region, benefiting all. The CMRB could establish goals which members agree to implement independently on a certain timeframe based on the rural or urban context of each municipality. Actions could include increased water conservation, storage and intermunicipal connections.

Develop an overall water supply strategy

- There may be an opportunity for members of CMRB to agree on a coordinated series of steps toward an overall water supply strategy and work with the Government of Alberta. This could include steps that individual municipalities would implement and steps that would be done by the CMRB. This approach is likely to be resource efficient, lead to more robust solutions, and would support all members.
- This could include working with multiple users by timing upstream hydropower generation water releases to the peak water demands and/or filling new downstream storage, specifically small reservoirs, for other purposes. Coordinating various forms of storage offers opportunities to make the same water supply go further.

Work with a collaborative working group to identify specific opportunities for coordination of upstream releases and downstream uses, potentially identifying storage projects

- The CMRB administration and its predecessor (Calgary Regional Partnership) are or have been part of the Bow River Working Group (BRWG) since its inception in 2010 as participants change based on the nature of the water management opportunities being looked at. This collaborative group of stakeholders from across the Bow River basin includes representatives from the provincial government, municipalities, industry, First Nations, irrigation districts, the BRBC, watershed stewardship groups, environmental non-governmental organizations, and others. The BRWG is a powerful mechanism to collaboratively explore and advance water supply and climate adaptation opportunities to create resiliency as a watershed for all residents in the wake of uncertain water supplies and management needs. The BRWG is currently meeting as part of the conceptual assessment for water management options on the Bow River. The CMRB could communicate closely with AEP in understanding how they can leverage the expertise in this group to add value to water management planning in the basin. A decision support process using the BRWG to help with water relation planning needs could be led by AEP to support uptake of outcomes from the process.
- Collaboration is most effective under predictable and comprehensive regulatory and policy frameworks that align land-use planning with management of the water resource. Key investment decisions are required that may be perceived to create inequities in water availability that have significant economic and political consequences within the region's diverse communities. Administrators at all levels of government are tasked with solving decadal-scale problems within four-year electoral cycles using two to three-year plans constrained by annual budgets. Regional management will be required to help identify, select, and manage the investment in infrastructure solutions that overcome the challenges created by this hierarchy of oversight. A collaborative process and approach could be an appropriate regional model that considers ecological, municipal and irrigation needs.

Formalize agreements for water sharing in times of scarcity

- There may be an opportunity to initiate discussions with licensees who have priority allocations to establish water sharing agreements in times of water scarcity in the region. It would be of value to understand as a region how the water could or would be shared, and what this would mean for each licensee in terms of being prepared (e.g. infrastructure, local by-laws, communication pieces) to deal with water scarcity when it comes. This can be done so that at regional and local levels, existing plans on drought response are understood and implemented effectively. This again, could be done within the setting of a regional collaborative group (such as the BRWG) to allow for a more regional understanding and agreement of water management principles and plans to deal with periods of low water availability. This strategy was very successful dealing with drought in the Oldman Basin in 2001.

Connect to academic researchers directly to promote applied research

- Reach out to academic research institutions to promote applied research opportunities specific to CMRB needs. For example, Global Water Futures (GWF) at the University of Saskatchewan could be contacted regarding the results of the project *Integrated Modelling for Prediction and Management of Change in Canada's Major River Basins* (IMPC). Staff at the GWF have invited the CMRB to speak to them about running specific scenarios of interest using the model they are currently building.

- Global Water Futures has staff dedicated to communicating the academic findings to non-technical audiences. For example, GWF is planning to present their initial results in 2020. The results from this modelling project will be the most current information available on climate projections and potential impacts for this region.

Work with AEP through the Land-use Framework to enable headwater protection and integrated land use management

- Collaborate around upstream land use change. Work with AEP to implement and refine environmental management frameworks (i.e. Surface Water Quality Management Framework) based on regional issues (e.g. source water quality). This may include coordinating with landowners, government bodies with jurisdiction, stakeholders and user groups to help support implementation of land-use plans that maintain and enhance hydrological ecosystem services. This could leverage previous projects that used the land-use model ALCES for assessing opportunities in the Bow River basin with the Bow River Basin Council.

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8.0 Appendices

8.1 Appendix A: Annotated Bibliography

Included as a separate PDF file.

8.2 Appendix B: Review of Water Management Models

This appendix provides a detailed review of several water management models that have been used previously for areas relevant to the CMR. This review provides the description and the key features of the models to assist the CMRB in deciding which model(s) could be used to support planning.

8.2.1 The Water Resources Management Model

The Water Resource Management Model (WRMM) was developed by Alberta Environment and Parks (AEP). A WRMM was developed for each of the sub-basins in the South Saskatchewan River Basin, and the scenario modelling was done with these models to support the South Saskatchewan River Basin Water Management Plan development in the early 2000s. The WRMM is the overarching regulatory tool currently used and updated to support regulatory decision-making. It is used to model the availability of water given water licences, seniority and constraints including the Apportionment Agreement between Alberta and Saskatchewan.

Training support from AEP is limited, yet this model is widely used in Alberta; therefore, support may be available if desired by contacting AEP directly. A user manual does exist yet is accessible only upon model acquisition. The WRMM is currently a free program; however, an updated version of the WRMM, coined WRM-DSS, is currently in development (in the Beta testing stage) and will require a licence for the solver software (Alberta Innovates-Energy & Environment Solutions; WaterSMART Solutions Ltd., 2012; Unitech Solutions, 2013)

The WRMM is a river-node model aiming to facilitate long-term basin planning and short-term operational planning for water use within a river basin (Alberta Innovates-Energy & Environment Solutions; WaterSMART Solutions Ltd., 2012). A windows-based Graphical User Interface (GUI) is being developed for the WRM-DSS. The model uses C++ programming language, but prior knowledge of this code is not necessary as data are entered using specific syntax rules in text files (Alberta Innovates-Energy & Environment Solutions; WaterSMART Solutions Ltd., 2012). The WRMM is a powerful model as its simulation time is fast (minutes) and it stores output files in a database to link to other models sequentially.

The WRMM was developed for weekly time steps; however, simulating other time steps is possible up to a maximum of 52 steps per cycle (e.g., run the model at a daily time step for 52 days). This river node model can simulate at any river basin scale and is flexible with basin configuration. The WRMM model is limited to approximately 500-800 components, while the WRM-DSS version is considered to be unlimited. Model outputs are linked to MS Access or Excel for graphical display.

Until the development of the GUI in the WRM-DSS version is complete, the WRMM is not user-friendly for meaningful and direct stakeholder engagement. This model has been shown to be effective having been used in the South Saskatchewan River basin (SSRB) project. Phase 2 modelling results of the project show scenarios in which available water is allocated to various demands, including environmental requirements, and water storages are managed to minimize shortages during low flow periods (Alberta Environment, South Saskatchewan River Basin Water Management Plan: Phase 2 Scenario Modelling Results, 2003). WRMM has also been used on numerous studies in Indonesia, China, India, and Africa to assess the potential for increased reservoir yield by implementing a more efficient reservoir policy (Ilich, Simonovic, & Amron, 2000).

WRMM

The WRMM was originally developed on IBM mainframe in 1980 following the technical specifications provided by Acres Consulting services. The original text version was written in Fortran. Latest text version was written in C++. Output could be written to ACCESS database (or in text file), and displayed with graphical viewer developed in VB. It might have equalizing deficit feature. It could only use time lag, without channel routing capability, and no MTO feature. Using OKA algorithm for optimization, total number of components is limited to under 1000. Running time is fast. WRMM executable is available for users to build their own model. User manual is fairly comprehensive with detailed examples, and hence, minimal or no training is needed for users to setup their own model.

The model is based on the use of a network flow solver known as the Out-of-Kilter algorithm, and it employs a much faster version of this algorithm known as SuperK. It is based on the use of penalty weight factors that represent the priority of allocation. The main model features are:

- User manual available;
- Formatted text files are used as input while output can be stored in either text file format or MS Access DB
- Flexible river basin configuration;
- Up to 300 nodes and up to 500 channels; and
- Only single time step solutions are available, which implies that the model requires user input reservoir operating rule curves which have to be the same from year to year.

WRM-DSS

The original text version was written in C++ but lack of database and graphical connection capability as well as error debugging mechanism. It was using LINDO solver for optimization (free of charge but later requires run-time license) with MTO partially developed. It has channel routing, could handle much more components and might have equalizing deficit feature. We were/are also not aware of any evaporation calculation issue in WRMDSS using actual precipitation and evaporation (shallow or deep lake) data. Actually, using surface area of reservoir to calculate net evaporation was added to the program. Only used and tested with small and medium size complex models, but not tested with larger complex models like SSRB. WRM.DSS C++ exe is available for users to build their own model. The manual is virtually same as the WRMM user manual, with the exception of a revised table for text file setup.

- User manual available from AEP;
- Model originally written in C++ by Optimal Solutions Ltd. using object-oriented approach;
- Formatted text files can still be used as inputs (same format as for the WRMM) while output is stored in either text file format or SQL DB. The model should also be able to read input data from SQL DB but this should be verified;
- Flexible river basin configuration;
- Unlimited number of nodes and channels;
- Single time step solutions are available, and multiple time step solutions which are essential for proper planning of reservoir operation have been under development for some time. Their usability should be

confirmed with AEP;

- Originally used the Lindo solver library. The model now uses public domain LP mixed integer solver obtained from IBM Watson Research Lab;
- It is not clear if AEP is willing to provide the model to third parties (this should be checked);
- There may be issues with the way net evaporation losses are calculated in the model which should be verified by the user; and
- The model can run hydrologic channel routing using variable coefficients in a single time step solution model. However, significant skill on the part of the modeler is required due to the previously identified issues.

WRM-DSS/GUI

This model is recently under development and testing including migrations of all existing WRMM models to GUI platform. The latest text version of WRMDSS was developed using commercial standards, written in C# with free CBC commercial solver as well as using dynamic memory allocation DMA. Theoretically it has unlimited components and channel routing capability (not fully tested), with MTO feature build in but not tested. All key features of WRMM and WRMDSS C++ were reconstructed in C#, with non-critical features being planned for future phase. Building from the latest WRMDSS C# version, WRM-DSS/GUI has database and graphical connectivity as well as better error debugging mechanism. It is equipped with schematic builder, result viewer and could read/write to SQL database. We continue to use WRMM, WRMDSS C++ and WRMDSS C# text versions to support our internal needs during this development and testing phase. WRMDSS C# text version and WRMDSS/GUI are not available at present.

8.2.2 WEB.BM

This is water resources management model but was not created by AEP and is not supported by or available from AEP.

- Web based basin management model written in C#;
- The model is available free of charge;
- Uses commercial LP solver library;
- Developed for Irrigation Districts as a seasonal operational model (although it can also be used as a planning model), it is funded by the Irrigation Districts, Optimal Solutions Ltd. and Alberta Innovates;
- SQL server database stores input, and the output can be saved on the local computer or in the database;
- Models any type of water use (in-stream, off-stream and hydro power generation);
- Flexible time step length (any multiple of one day);
- Uses linear channel routing for daily time steps with coefficients updated using the SSARR modeling approach that is the most frequently used method in the Canadian prairies;
- Technical support is available from Optimal Solutions Ltd.;
- User-friendly graphical interface that allows building a modeling schematic as a layer in Google Maps where all objects in the schematic are connected to SQL database (;

- There are many major improvements compared to WRM-DSS, including:
    - Multiple Time Step Optimization (MTO) solution mode;
    - Equal deficit sharing constraint for components in the same priority policy group;
    - Diversion licence and apportionment targets included as constraints with the MTO;
    - Net evaporation properly accounted for as a constraint within MTO;
    - Significantly reduced the number of binary variables within MTO solution mode;
    - All water demand components streamlined into off-stream, on-stream and hydro power; and
    - Proper modeling of return flows as a fraction of consumptive use.

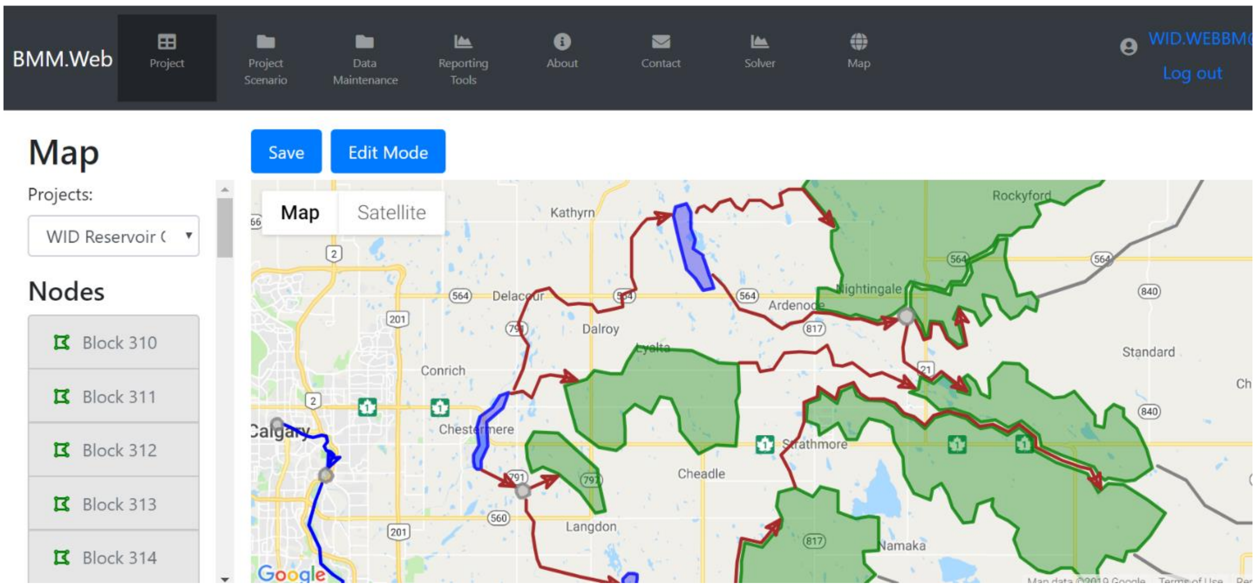

Figure 14 WEB.BM Model Interface

8.2.3 The Bow River Operational Model

The Bow River Operational Model (BROM) is a water resource systems management model built in collaboration with Bow River licence holders and stakeholders. Initiated by the Bow River Project Research Consortium in 2010 (Figure 15). It is based on HydroLogics' widely-used OASIS modelling platform. The BROM is intended to be a trusted, open, and transparent tool to support collaborative exploration of integrated water management decision-making opportunities at an entire watershed scale. Model simulations are consistent with Alberta's water regulatory framework. It is a systems model reflecting how the river is currently operated incorporating licensed priorities and water management plans. The BROM also includes an optimization component that allows users to modify their goals and maximize adaptive alternative uses for the basin. Together, this allows users to understand today's integrated demands and operations and track the impacts and benefits throughout the entire system that could accrue from changes in operational or storage strategies including:

- Long term simulation incorporating historical normal flows, floods and droughts within a single simulation with current or dynamic forecast demand;
- Testing new capital and operational alternatives at a screening level;

- Stakeholder-driven development of alternatives and combinations;
- Using performance measures to represent multi-interest resilience over the long and short term;
- Exploring a variety of growth or pressure situations for the basin; and
- Basin wide effects, with local effects determined by the specific data available.

The BROM is available to support a variety of collaborative water management discussions in the Bow basin as needed and support a productive discussion amongst technical water experts. The BROM complements rather than duplicates other tools required in a broad water management discussion (e.g. irrigation demand models, electric generation system, land use, climate change/climate variability, seasonality of urban return flow rates, and storm water management systems). The facilities, demands, and operations in the BROM model are easily modified to evaluate proposed management options for the basin. Key features of the BROM include:

- Base case simulations that reasonably represent current actual operations, as tested and confirmed by operators and stakeholders in the basin. This ensures realistic comparison of alternatives with known current conditions;
- Utilizing operating rules as described and reviewed by system managers and stakeholders to dictate reservoir stages/releases, irrigation diversions, minimum flows, and others;
- Operating rules are input through a simple user interface and "plain English" code that makes it easy for stakeholders to design, develop, and code such rules;
- Run times that vary but are under fifteen minutes for the daily model and under one minute for the hourly model;
- A suite of over 40 Performance Measures co-developed by the stakeholders to ensure BROM can specifically answer the full range of questions important to them under whatever scenario is modelled;
- No "black boxes" or internal workings that cannot be reviewed by users and stakeholders. Its speed of execution, flexibility, and capacity to interface with other types of models creates the confidence needed for users and stakeholders to work together on common goals, test good and bad ideas, reject the unworkable, and move on with those that appear to improve the intended outcomes;
- The ability to accept a variety of data types beyond hydrology data (e.g. hourly wholesale power prices, climate scenarios, and irrigation district water usage). As an OASIS model, BROM can directly interface with existing models in either parallel or sequence to accommodate specific inquiries outside of surface water management (groundwater models, water quality models, land use models, weather forecasting models, etc.);
- Utilizing appropriate time steps for evaluations. Daily time steps are used for planning management options which allows BROM to ensure that evaluations realistically represent the difficulties of dealing with daily flow changes. Hourly time steps are used for simulating flood operations alternatives to allow evaluation of peak flows for floods similar to 2005 and 2013, or for other flood sequences created by forecasts or other means;
- It has been used to run drought exercises and prepare stakeholders for making "real-time" drought decisions by presenting them with the type of problems they would face and allowing them to adjust operations mid-simulation;

- It can duplicate the licence implementation logic of other models (such as WRMM) and become the basis for regulatory decisions (if desired). This allows regulators to consider the practical as well as the legal implications of their decisions and how to best utilize regulatory discretion;
- Its Position Analysis Mode provides near-real-time assessments of risks of droughts, floods, and other water related events like riparian habitat recruitment. Similar risk assessments are being used for operations support for systems large and small, including New York City's new Operations Support Tool (OST). BROM was used to evaluate the impact of operational alternatives for Ghost Reservoir on the risk of flood and drought for Calgary for the spring pilot with TransAlta in 2014;
- BROM is supported by HydroLogics and WaterSMART, who have well-respected, experienced, and accessible modelling teams;
- It is designed to be used by non-modellers. Models based on the OASIS platform have a long history of being run independently by agency staff, private corporations, environmental groups, and other stakeholders; and
- It is public. The BROM base case is available online for evaluation and comparison with user defined alternatives. Those alternatives can be run online as well. There is a defined process for gaining access to the model, and user data is secured by password.

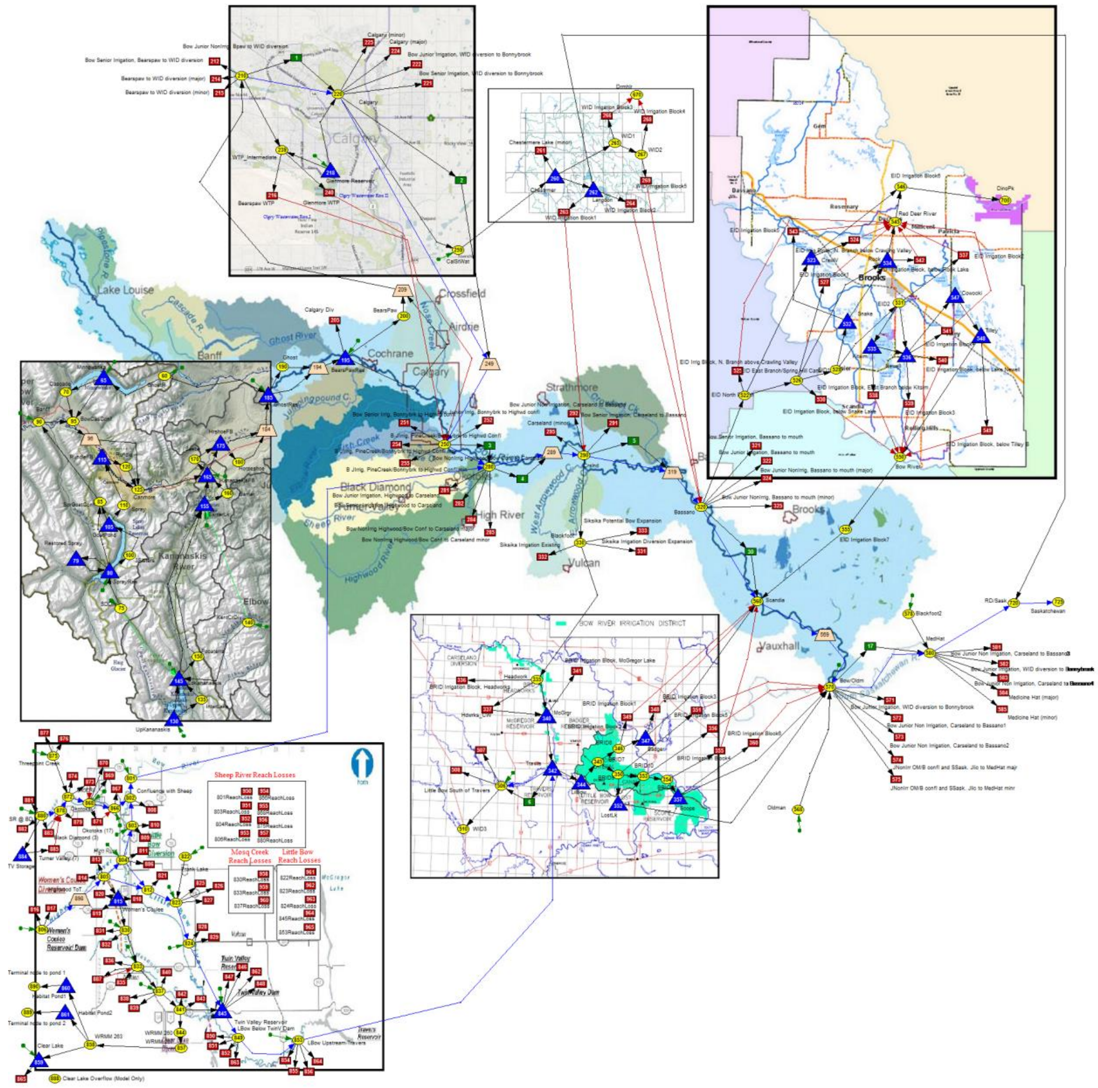

Figure 15 A schematic for the Bow River Operational Model (BROM)

Construction of the BROM

BROM utilizes a variety of physical inputs and operating rules. Physical inputs include available data on the physical system (reservoir, dam, canal, and diversion structure information), inflows from the naturalized flows for 86 years of record, demand data (actual current use, allocations, irrigation demand data, return flows, and municipal water use, diversion rates/limits. It also incorporates operating rules such as instream flow objectives/WCOs, and system operations (licence constraints, water sharing agreements, priority systems, and reservoir/dam operating rules). Specifically, BROM includes the following raw data:

- Weekly naturalized flows disaggregated to daily with hydrologically appropriate statistical noise;
- Licence data provided by WRMM Scenario 18 (2008). Approximately 90% of licences by volume modelled individually and the remainder modelled as per WRMM nodes;
- Irrigation demands from Alberta Agriculture and Rural Development Irrigation District Model (IDM) reflecting current weekly use. Several districts had their use scaled down, based on actual use from stakeholder feedback, to reflect a more realistic current scenario;
- Municipal demands based on actual information, reflecting today's demands and seasonally adjusted return flows;
- Operations based on what stakeholders "would actually do" independent of legal priority as described by stakeholders themselves (e.g., Irrigation Districts have not and would not use their licence priority to short municipal users as Irrigation Districts in drought circumstances informally share water independent of licence priority);
- Operations for TransAlta reservoirs that were reviewed internally by TransAlta are considered to be reasonably representative of actual operations;
- Alberta Electric System Operator data related to electricity supply/demand, dispatch and pricing;
- Potential system inflows based on 50 different GCM and carbon emission scenarios; and
- Flood event data from Water Survey of Canada at the hourly level to support flood mitigation modelling efforts.

BROM has undergone extensive refinement and vetting by major licence holders and stakeholders, beginning in 2008:

- In 2008, the University of Lethbridge, in collaboration with HydroLogics Inc. and the University of Texas at Austin, conducted a pilot project to improve integrated and collaborative water management decision-making in the SSRB.
- In 2010, the Bow River Project Research Consortium engaged HydroLogics to develop the BROM to model current and potential future operations of the entire Bow River system (including tributaries) beyond the constraints of the mechanistic representation of Alberta's water management licensing system. Operating rules were developed to reflect current demands and operations by the infrastructure managers. As the model was being developed, Consortium members reviewed the results and operating rules and provided input on sources of inflow and return flows, demands that should always be met, projected available system storage, and developed performance measures and other means of representing the operations of

the entire Bow River basin.

- In 2011, the Consortium helped design a simulation test, essentially gaming whether or not, and by how much, they could manage water demands, storage, and release in a collaborative manner under stressful water supply conditions. Key stakeholder groups (municipal, irrigation, regulators, and environmental groups) worked collaboratively to decide how the water supply was to be used or stored, and where and when it was to be released. Without their knowledge, a test year was selected from the historic record along with weekly and daily (if needed) temperatures, precipitation, and weather forecasts. What they learned in a full-day exercise was that collaborative allocation of water for each week of the stressful, water-short period was far more effective in balancing water needs and interests than the base case of independent decision making. Both environmental flows and sufficient allocation of water to each user were significantly improved.
- In 2012, many of the contributors to the Bow River Project Research Consortium reconnected with additional participants to further refine the BROM and examine options for adapting to climate variability and change in the SSRB. One of the major enhancements was the addition of the Highwood and Sheep river systems as dynamic systems in their own right, rather than just as a flow input to the Bow River.
- In 2013, the catastrophic floods in the Highwood, Sheep, Elbow, and Bow systems required an urgent and accurate assessment of what happened and what future flood mitigation might be possible. The Bow River Working Group and many other flood experts gathered to identify options that would have provided the resilience needed to mitigate the 2013 flood as well as alternative flood conditions.

8.2.4 The South Saskatchewan River Operational Model

In principle, the South Saskatchewan River Operational Model (SSROM) has the same functionality as the BROM and is built on the OASIS platform. Therefore, the description of BROM also applies to the SSROM. The SSROM was developed as part of the South Saskatchewan River Basin Adaptation to Climate Variability Project. The primary difference between the BROM and SSROM is that the SSROM includes the Bow, Oldman, Red Deer, and South Saskatchewan river basins to the Alberta-Saskatchewan border (Figure 16 Schematic of the South Saskatchewan River Operational Model (SSROM). The SSROM model operates at a daily time step for the period from 1928 to 2009, with operational rules developed through multiple collaborative modelling workshops and inputs from stakeholders in each of the sub-basins. Similar to the BROM, the SSROM has a wide range of Performance Measures (PMs) that can be used to evaluate alternative scenarios.

The SSROM has been used to evaluate land use and climate change scenarios by coupling with other modelling tools including the ALCES land use model, and climate change scenarios derived through Regional Circulation Model (RCM) and General Circulation Model (GCM) outputs. Recently, the SSROM was applied by the Bow River Working Group to evaluate the effects of additional reservoir capacity on drought mitigation for the Bow basin, which provided a valuable decision support tool.

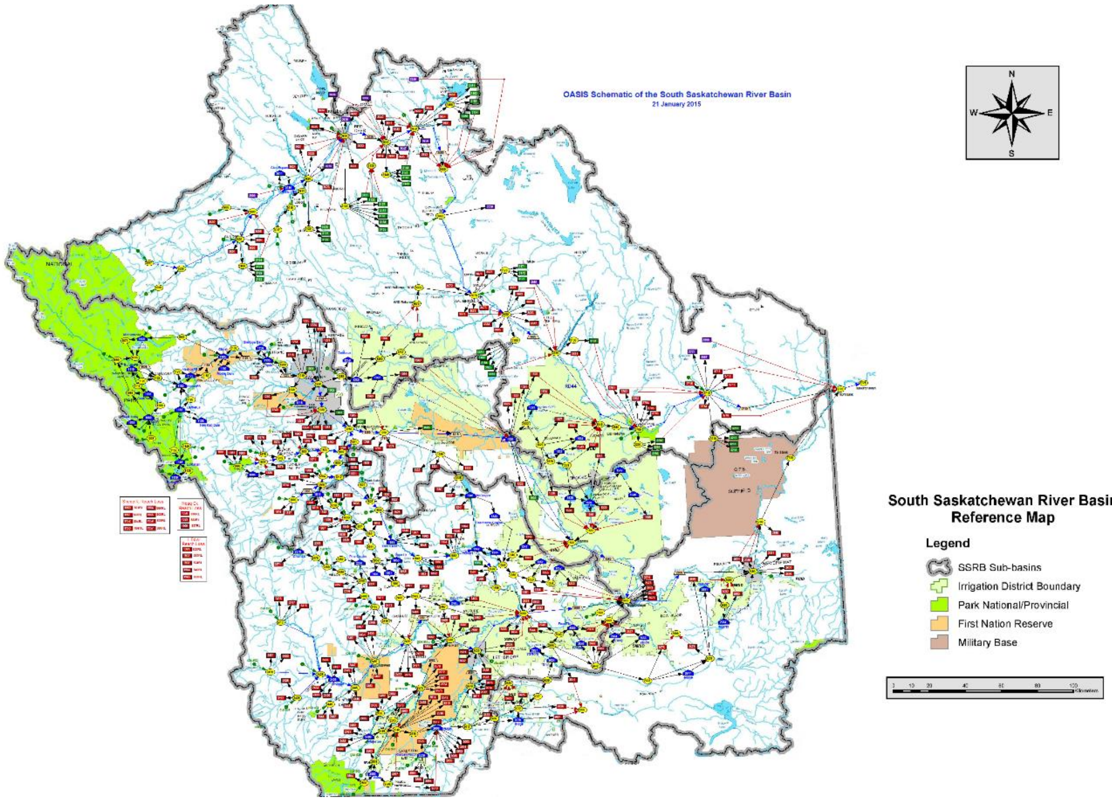

Figure 16 Schematic of the South Saskatchewan River Operational Model (SSROM).

8.2.5 Other models from literature

The following table summarizes other models that were identified during the literature review. This information provides a general overview; the cited documents are discussed in more detail in Appendix A: Annotated Bibliography.

Table 5: Other models that were identified during the literature review that were not part of the model review.

Model name	Purpose	Citation
Nested tree-ring model	Flow reconstruction of the Bow River from 1107-2007	Sauchyn, Vanstone, & Dickenson, 2012
CMR population projection model	Estimates population size of CMR municipalities in 5-year increments from 1986-2076	Rennie Intelligence, 2018
Bow River maximum allowable Load model	Determines the maximum Total Phosphorus load that can be present in the Bow River mainstem from the Bearspaw to Bassano Dams such that it still maintains Dissolved Oxygen water quality objectives considering critical conditions and seasonal variation	Government of Alberta, Bow River Maximum Allowable Load: Source Identification and Assessment of Total Phosphorus, 2018

Model name	Purpose	Citation
Water Quality Based Effluent Limits Procedure	Estimates the potential for contaminants to exceed surface water quality guidelines (used specifically for ammonia)	Alberta Environment and Parks, 2018
HSPF (Hydrological Simulation Program – FORTRAN)	A provincially accepted model that simulates watershed hydrology and water quality. Can be used with global climate model scenarios to make watershed scale projects for temperature and precipitation projections under climate change.	Golder Associates, 2010

8.3 Appendix C: Water licences of potential impact

Table 6. List of licences of potential impact to CMRB members based on priority, maximum diversion rate, and annual allocated volume.

Approval holder	Licence number	Priority	*Maximum diversion rate (m^3/s)	Annual allocated volume ($m^3/year$)	Purpose	Source
19354 YUKON INC.	00042571-00-00	19401017001	1.7	1,171,814	Water Management	Bow River
76 LAND & CATTLE INC.	00045742-00-00	19071003001	0.084	618,677	Irrigation	Pekisko Creek
BOW RIVER IRRIGATION DISTRICT	00045810-00-00	19081027002	0	185,022,300	Irrigation	Bow River
BOW RIVER IRRIGATION DISTRICT	00045810-00-00	19130325001	0	185,022,300	Irrigation	Bow River
BOW RIVER IRRIGATION DISTRICT	00045810-00-00	19530625001	0	98,678,560	Irrigation	Bow River
DUCKS UNLIMITED CANADA, EDMONTON	00036344-00-00	19481214002	0.283	613,040	Habitat Enhancement	Bow River
EASTERN IRRIGATION DISTRICT	00045541-00-00	19030904002	85	938,679,798	Irrigation	Bow River
EASTERN IRRIGATION DISTRICT	00044792-00-00	19261102001	3.172	185,020	Municipal	Bow River
INDIAN & NORTHERN AFFAIRS	00043192-00-00	19380613003	4.134	4,561,420	Irrigation	Bow River
LAFARGE CANADA INC.	00045822-00-00	19060510001	0.119	3,700,450	Commercial	Bow River
LEHIGH HANSON MATERIALS LIMITED	00040408-00-00	19540708001	0.037	555,070	Commercial	Bow River
PIRMEZ CREEK IRRIGATION SOCIETY	00042981-00-00	19390204001	0.212	1,480,180	Agricultural	Elbow River

Approval holder	Licence number	Priority	*Maximum diversion rate (m^3/s)	Annual allocated volume (m^3/year)	Purpose	Source
TOWN OF BASSANO	00045555-00-00	19121223001	0.283	716,650	Municipal	Bow River
TRANSALTA CORPORATION	00042551-00-00	19410203001	0	43,171,870	Dewatering	Ghost River
WATER OPERATIONS BRANCH, LETHBRIDGE	00044553-00-00	19331005001	0.71	4,933,930	Water Management	Highwood River
WESTERN FEEDLOTS LTD.	00046187-00-00	18931030001	0.5	177,630	Irrigation	Highwood River
WESTERN IRRIGATION DISTRICT	00045938-00-00	19030904001	21	195,383,523	Irrigation	Bow River
WESTERN SECURITIES LIMITED	00308969-00-00	18931015001	0.05	621,674	Irrigation	Elbow River

*Some licences have more than one diversion rate depending on water levels and/ or the time of year; the number shown is the maximum diversion rate specified in the licence.

8.4 Appendix D: List of Water Survey of Canada hydrometric stations

Table 7. Water Survey of Canada hydrometric stations used in this study. Data from 1980 onward were used as this range is the most recent, scientifically established 30-year 'climate normal'.

Station Number	Station Name	Latitude	Longitude	Min Year	Max Year	Drainage Area (km^2)
05AC023	LITTLE BOW RIVER NEAR THE MOUTH	49.9	-112.51	1980	2018	5,900
05BB001	BOW RIVER AT BANFF	51.17	-115.57	1980	2016	2,210
05BC001	SPRAY RIVER AT BANFF	51.16	-115.55	1980	2015	751
05BD005	CASCADE RIVER ABOVE LAKE MINNEWANKA	51.29	-115.53	1980	1996	454
05BF025	KANANASKIS RIVER BELOW BARRIER DAM	51.04	-115.03	1980	2016	899
05BG006	WAIPAROUS CREEK NEAR THE MOUTH	51.28	-114.84	1980	2017	333
05BG010	GHOST RIVER ABOVE WAIPAROUS CREEK	51.27	-114.93	1983	2018	485
05BH004	BOW RIVER AT CALGARY	51.05	-114.05	1980	2017	7,870
05BH005	BOW RIVER NEAR COCHRANE	51.17	-114.47	2006	2014	7,410
05BH009	JUMPINGPOUND CREEK NEAR THE MOUTH	51.15	-114.53	1980	2006	571
05BH901	NOSE CREEK NEAR THE MOUTH	51.05	-114.02	1980	1989	986
05BJ001	ELBOW RIVER BELOW GLENMORE DAM	51.01	-114.09	1980	2016	1,240
05BK001	FISH CREEK NEAR PRIDDIS	50.89	-114.33	1980	2016	261

Station Number	Station Name	Latitude	Longitude	Min Year	Max Year	Drainage Area (km^2)
05BK003	FISH CREEK AT BOW BOTTOM TRAIL	50.91	-114.02	1989	1993	442
05BL012	SHEEP RIVER AT OKOTOKS	50.72	-113.97	2006	2015	1,490
05BL024	HIGHWOOD RIVER NEAR THE MOUTH	50.78	-113.82	1980	2015	3,950
05BM002	BOW RIVER BELOW CARSELAND DAM	50.82	-113.44	1980	2016	15,700
05BM004	BOW RIVER BELOW BASSANO DAM	50.75	-112.54	1980	2017	20,300
05BN012	BOW RIVER NEAR THE MOUTH	50.05	-111.59	1980	2017	25,300
05CB001	LITTLE RED DEER RIVER NEAR THE MOUTH	52.03	-114.14	1980	2017	2,580
05CE002	KNEEHILLS CREEK NEAR DRUMHELLER	51.47	-112.98	1980	2016	2,430
05CE005	ROSEBUD RIVER AT REDLAND	51.29	-113.01	1980	2018	3,570
05CE007	THREEHILLS CREEK NEAR CARBON	51.56	-113.07	1980	2018	1,080

8.5 Appendix E: Potential water quality constraints

Potential water quality issues and constraints were noted during the literature review process. These water quality issues for consideration are intended to inform a subsequent water quality study potentially being initiated by the CMRB in the future and have not been assessed in detail as part of the current work. Section 4.5.7 of this report describes several management options that were identified in the literature review relating to water quality that also relate to water supply and availability.

8.5.1 Water quality concerns in the Bow River sub-basin:

- A reduced minimum flow at Calgary was identified as a potential mitigation strategy for water storage concerns for upstream water storage during prolonged droughts. Reducing minimum flows could extend storage and provide longer periods of flow augmentation, but could have serious consequences for water quality downstream and significantly stress aquatic ecology of the river system (WaterSMART Solutions Ltd., 2016);
- Reduced flows projected at Calgary could impact water quality (due to less flow to assimilate discharge from wastewater treatment plants) (Alberta Innovates-Energy & Environment Solutions & WaterSMART Solutions Ltd., Climate Variability and Change in the Bow River Basin, Final Report, 2013); and
- Water quality constraints in the Bow River, particularly relating to nutrient loading and oxygen deprivation in the reaches between Bearspaw to Bassano, may increase if the quality or volume of water flowing into the Bow from tributaries like the Highwood River is decreased (Shirley Pickering, pers. comm., August 2019).

8.5.2 Water quality concerns in the Upper Highwood and Upper Little Bow sub-basins:

- Water temperature and dissolved oxygen are of concern for the Highwood River fishery in the Highwood River between the Women's Coulee diversion and its confluence with the Sheep River (especially in late summer during low flow season);
- Frank Lake water quality impacts on the Little Bow River and Twin Valley Reservoir due to nutrient accumulation within the Frank Lake wetland complex;
- Downstream impacts on oxygen, ammonia, and metals in the Little Bow;
- Fish mercury residues in Twin River Valley Reservoir and downstream of the Little Bow; and
- Sediment loads in Mosquito Creek associated with channel destabilization within the Women's Coulee diversion channel (Alberta Environment, Water Management Plan for the Watersheds of the Upper Highwood and Upper Little Bow, Volume 1, 2008).

8.5.3 Water quality concerns for all watersheds within and adjacent to the CMR:

- Lower water flows may cause increased retention times in reservoirs, higher nutrient retention and larger/longer algal blooms.

Lower water levels in prairie lakes can increase lake salinity (AMEC Earth & Environmental, 2009);

- Water quality impacts of municipal return flow may offset the benefits of increased return flows; and
- Smaller reservoirs often have poorer water quality with elevated nutrient levels and often high organic matter content. This is a challenge for municipal drinking water systems to treat and use (WaterSMART Solutions Ltd., 2016).

Water quality constraints map

Potential water-derived constraints were classified on a sub-basin basis (e.g. watersheds within the Bow River basin) and are presented in the map below (Figure 17) for water quality issues. Water quality issues refer to whether a water quality parameter such as total dissolved solids, salinity or total phosphorous, was identified as having exceeded guidelines or desired thresholds, and was noted as a concern in State of the Watershed reports or a water quality monitoring study. In summary, constraint scores were assigned as follows: a 1 if water quality issues present in sub-basins for which water quality has been flagged as a concern as identified through reviewed literature; and 0 otherwise.

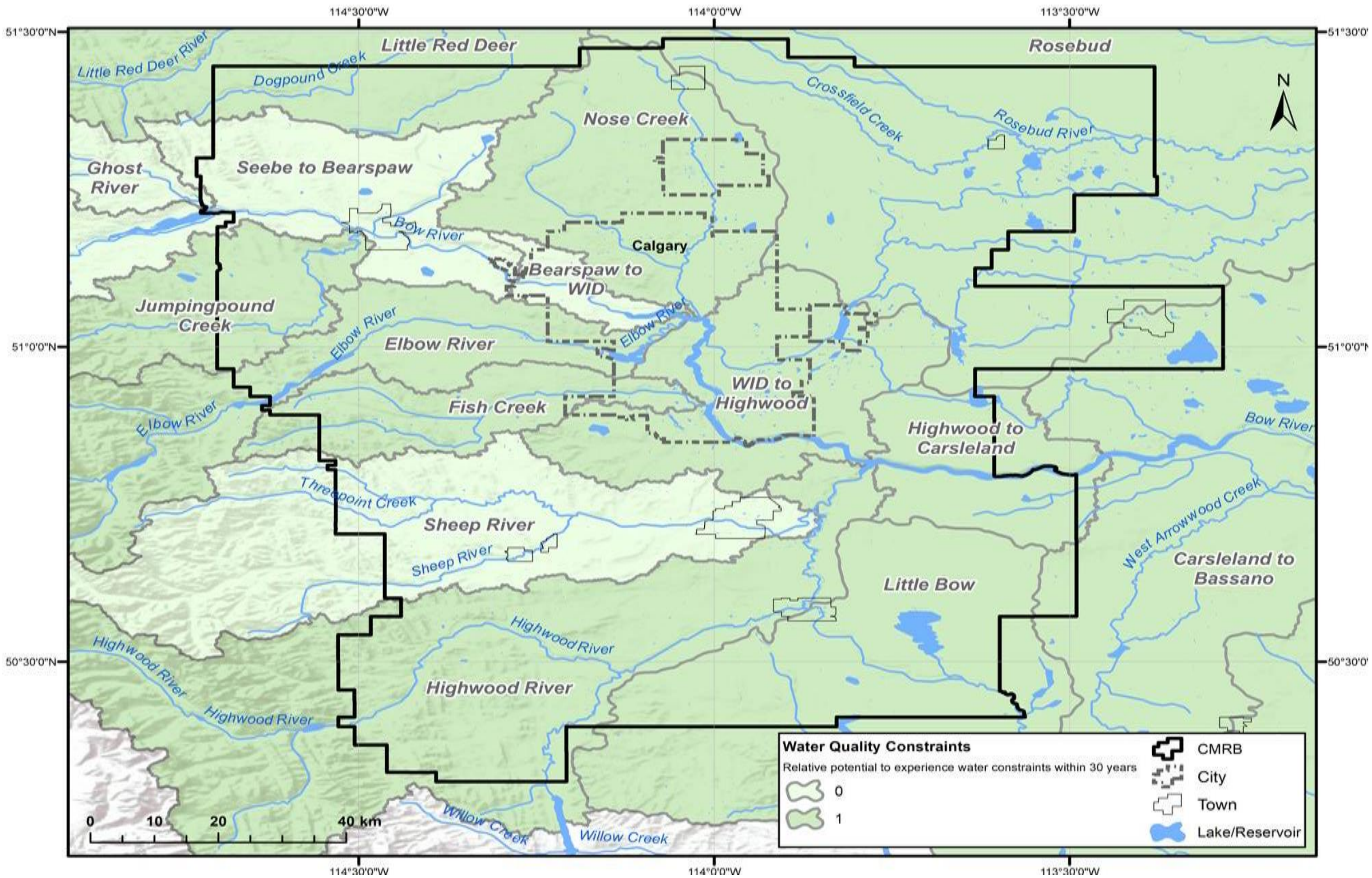

Figure 17 Watersheds where water quality has been identified as an issue (1 or darker green) based on literature reviewed for this project.

8.6 Appendix F: Specific information on the Highwood and the Sheep River system

Some information and perspectives were gathered through communications with a subject matter expert pertaining to the Highwood and the Sheep River system. Some of the information is summarized here and provides some updates to the literature that was reviewed for this study.

The Highwood River and the Sheep River, a major tributary of the lower Highwood River, have highly variable flows. Water-related management and planning should consider the entire region (i.e. the Highwood River, Sheep River, and Little Bow River systems). Water management in the region is a fine balance between diversions and the health of the aquatic environment and water quality. This balancing approach relies on a continuous cycle of monitoring outcomes and applying adaptive management to make necessary adjustments as the water supply is fully allocated. Currently, demand is met most years. However, licence deficits do occur, and the need for water conservation measures are required during prolonged low precipitation events, particularly in carry-over years when storage is required to bridge between high-precipitation years.

Water supply and demand studies on the Highwood-Sheep system indicate municipal growth will be limited by lack of local water supply, particularly on the Sheep River. There have also been drought management studies examining a number of on-stream and off-stream reservoir options in Highwood, but it was found that as a result of historical variability of flow, in years when water was most needed, there was not enough natural flow for much-needed carry-over storage.

The bottom line for the Highwood/Sheep/Little Bow River system is that there is no more water available for allocation expansion, and efforts need to focus on securing the stability of the existing water supply and its quality. There have also been flood management and mitigation studies conducted to look at various infrastructure options, including dams/reservoirs, berms, and diversions along with buyouts. This work is still ongoing. (Shirley Pickering, pers. comm., Aug 2019)

Aside from water supply, the Highwood River plays a key role as a tributary to the Bow River downstream of Calgary and the WID Diversion:

- The Highwood River restores some of the lower Bow River natural flow volume. Management of Highwood-Sheep water quantity and quality is part of an AEP led Bow Phosphorus Management Plan to maintain or improve Bow River water quality downstream of the Highwood confluence with the Bow.
- The Highwood River and its tributaries provide key spawning and rearing habitat for a significant portion of the valuable sport fishery of the Bow River. The water levels and water quality on the Highwood-Sheep River system require special fishery management conditions (IOs, Water Temperature and dissolved oxygen levels) in supporting this downstream economic activity.

- The Highwood River helps restore part of natural base-flow water supply to the lower Bow River during the summer low flow period. This augmentation of Bow River flow is important for riparian maintenance in the summer season (Shirley Pickering, pers. comm., Aug 2019).