South Saskatchewan River Basin Adaptation to Climate Variability Project

Adaptation Strategies for Current and Future Climates in the Bow Basin

Final Report

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This report is available and may be freely downloaded from the Alberta WaterPortal website at www.albertawater.com.

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Acronyms and Abbreviations

AF	Acre-feet
BRID	Bow River Irrigation District
BROM	Bow River Operational Model
BRP	Bow River Project
CDF	Cumulative Distribution Function
cfs	Cubic feet per second
EID	Eastern Irrigation District
FSL	Full Supply Level
GCM	Global Climate Model
ID	Irrigation District
kAF, kaf	Thousand acre-feet
LKL	Lower Kananaskis Lake
PM	Performance measure
PS	Preferred Scenario
Robo-river	This phrase refers to the way the Bow River was managed in the model, with automatic releases made from the water bank as described in a specific scenario; it reflects the fact that there was no human element engaged to more flexibly alter releases from the water bank to adapt to rapidly changing conditions, as would be the case under an agreement between the Government of Alberta and TransAlta.
SSRB	South Saskatchewan River Basin
WID	Western Irrigation District
WRMM	Water Resources Management Model

1 Executive Summary

While Alberta's economy is fuelled by hydrocarbons, it runs on water. The province is facing important water challenges, including an expanding population, accelerating economic growth, and the increasing impact of this growth on the environment. With the added challenge of climate variability and change, sound water management decisions are becoming more complex and more critical to Alberta's prosperity.

One objective of the SSRB Adaptation Project was to identify strategies that would help southern Alberta adjust to climate variability and change, including potential periods of prolonged and severe drought. This report presents the fifteen individual and six combination strategies for the Bow Basin that were suggested, developed and explored collaboratively with a working group representing the major licence holders and interests in the basin. It does not necessarily include every possible adaptation option, and the described approaches are potential ideas that, in many cases, were suggested to address extreme circumstances. These strategies are not being recommended or advocated; rather they are presented as a starting point for discussion and further consideration by those who use, manage and make decisions about water in the Bow Basin.

Participants identified seven strategies that could benefit the watershed and improve overall river management if they were implemented now. These strategies could improve aquatic ecosystem health while continuing to meet the social and economic needs and interests throughout the basin. They would build resilience and help the region adapt to the drier conditions that may occur under future climate scenarios. These "normal" condition strategies focus on changing demands and water management practices rather than building new infrastructure.

Eight strategies emerged that may be less necessary under current conditions, but could be important components in adapting to a more severe future climate. Some of these would require changes in how water is managed, while others involve new infrastructure. These "drought" options, once in place, would also be expected to benefit the region if and when conditions returned to normal. Any new infrastructure and storage would need to be evaluated carefully, considering both positive and negative environmental tradeoffs as well as impacts on the land and landowners.

Recognizing that the Bow River Basin is a complex, dynamic system, it is expected that potential adaptation strategies would be implemented in combination, reflecting the needs of the basin and the appropriate degree of risk management. To examine how adaptation strategies might be layered to produce cumulative and offsetting impacts, the project modelled six strategy combinations. These combinations range from modest-cost, near-term combinations that offer value under normal (current) conditions, to higher-investment, longer-term combinations that might be considered if the risk profile of climate variability warrants more substantial change in the system.

The fifteen individual strategies and six combinations were tested using the Bow River Operational Model (BROM). All modelled strategies and combinations are briefly described in the report, along with the modelling results and impacts, sample performance measures and associated observations. All BROM assumptions and input data will be described and documented in the publicly available electronic BROM files accessible through the University of Lethbridge servers at http://www.uleth.ca/research/node/432/.

Like the Bow River Project before it, the findings from this project provide a valuable and timely opportunity to implement environmental improvements that will contribute to all three *Water for Life* goals. This project has identified options that would benefit the watershed now and into the future, and shows that water in southern Alberta could be managed collaboratively, innovatively and effectively in response to changing climate conditions.

2 Introduction

Alberta's heritage and its social, economic and environmental history are directly tied to its water resources. While Alberta's economy is fuelled by hydrocarbons, it runs on water, and continued prosperity depends on sound water management decisions. In the face of climate variability and change, these decisions are becoming more complex and more critical.

Alberta is confronting important water challenges, including an expanding population, accelerating economic growth, and the increasing impact of this growth on the environment as the climate continues to shift.

The province's geographical landscape encompasses the spine of the Rocky Mountains on its western border, semi-desert plains in the south, parklands in central Alberta and boreal forest across the north. The mountain regions are the water towers for much of western Canada, while eastern and northern flowing rivers are vital to this province as well as downstream neighbours.

Water supply and demand vary considerably throughout Alberta. The health of Alberta's natural resources and its economic vitality depend on an integrated understanding of natural climate variability as well as the management capacity to confront the prospects and potential impacts of climate change.

These challenges present a timely opportunity to capitalize on the knowledge and experience of community and business leaders, government departments, environmental organizations and watershed groups. Water and climate adaptation issues are complex with many facets, and cannot be solved by any single initiative or sector. Alberta has a history of successfully meeting sustainability challenges through multi-sector collaboration and engagement, and the South Saskatchewan River Basin Adaptation to Climate Variability project will further enhance that legacy.[1]

This report presents the individual and combined potential strategies for the Bow Basin that were suggested, developed and explored collaboratively with a working group representing the major licence holders and interests in the basin. Some strategies could benefit the watershed and improve river management if they were implemented now, while others could become especially important during times of severe drought as suggested by the climate variability and change scenarios developed for this project. These strategies are not being recommended or advocated; rather they are presented as a starting point for discussion and further consideration by those who use, manage and make decisions about water in the Bow Basin.

[1] See Appendix A for more information on this project.

3 Process and Methodology

For this project, many of the stakeholders who participated in the 2010 Bow River Project (BRP) Research Consortium[2] again came together to refine the Bow River Operational Model and use it to explore potential strategies for better water management in the Bow Basin, particularly under more severe conditions of climate variability and drought. As was the case for the BRP, participants in this project comprised a group of water users and managers whose members control approximately 95% of all water allocations and estimated water use in the Bow Basin. Participants and their organizations are listed in Appendix B.

This diverse group of individuals brought their knowledge and experience to the project's one-year collaboration. A highlight was a two-day interactive modelling session in which potential strategies were tested under a range of climate scenarios. Participants identified a number of strategies that could benefit the watershed and improve overall river management if they were implemented now. These strategies would become even more crucial during periods of drought, which may occur under future climate change and variability scenarios. Other strategies emerged that may not be needed or appropriate at present, but could be important components in adapting to more dire future climate conditions. All strategies in both categories, along with a set of combined strategies, are described in this report.

Like the BRP before it, the findings from this project provide a valuable and timely opportunity to incorporate environmental improvements that will contribute to all three *Water for Life* goals. The strategies and opportunities identified in this report explicitly support these goals, which are:

- Safe, secure drinking water;
- Healthy aquatic ecosystems; and
- Reliable, quality water supplies for a sustainable economy.

3.1 The Bow River Operational Model

The Bow River Operational Model (BROM) is a mass balance, river system model reflecting the streamflows and operations of the Bow River system. It does not directly take into account groundwater or water quality aspects although both are indirectly and partially encompassed. It was developed as part of the 2010 BRP, which used the University of Lethbridge's South Saskatchewan River Basin (SSRB) model as the starting point. The BROM diverges from the SSRB model and from Alberta Environment and Sustainable Resource Development's Water Resources Management Model (WRMM) in that it attempts to more accurately model existing and potential future operations beyond the constraints of a strict licensing system.

As with most models, refinements and updates are continually made to reflect new information and operations. Several refinements, listed below, were made to the BROM for this project. These refinements are further described in Appendix C.

- Meeting current and future Siksika demands
- Monthly Calgary return flows

[2] The final report from the BRP Research Consortium was published in March 2011 as *Bow River Project Final Report*, and is available online at http://www.albertawater.com/index.php/component/docman/doc_details/29-bow-river-project-full-report-march-2011.

- Demand 807 in the Highwood River System
- New demand and return flow data from Okotoks
- Correction to Lower Kananaskis Lake stabilization, and adjusted weighting on Lower Kananaskis Lake.

All BROM assumptions and input data will be described and documented in the publicly available electronic BROM files accessible through the University of Lethbridge servers at http://www.uleth.ca/research/node/432/.

3.2 Climate Scenarios

Developing climate scenarios that could be used in the BROM was the first step in contemplating potential climate adaptation strategies. Details of the innovative approach to developing these scenarios are described in a June 2013 report entitled *Climate Variability and Change in the Bow River Basin,* and are summarized in Box 1 on page 6.

Fifty annual flow projections (climate scenarios) were generated over 30 years (2025 to 2054). Five of these 50 scenarios were then selected using a simple statistical procedure to rule out potential outliers then identify a maximum average, a median and three annual low-flow scenarios to reflect a realistic range of climate impacts and enable the discussion of potential management options. The 10th percentile of minimum flows was used to eliminate outliers of extreme low flows.

Much of the range in streamflow from the five scenarios covers flow conditions that have been seen throughout the historical record and are well within the recent range of variability in magnitude and duration. Most years in all five scenarios had flows with volumes and timing of water that would not require changes in operations to meet user needs. But because the purpose of this work was to identify strategies for adapting to flow changes that affect water users, scenarios were chosen to highlight impacts related to low flow periods in the Bow River system. It is important to recognize that not all effects are manifested in a linear fashion. For example, if available water for irrigation is reduced too much, some crops simply will not grow, or if river flow drops too low, all fish are likely to die.

Two of the scenarios produced average flows relative to the historical record, and their hydrology resulted in little or no impact on users. The other three scenarios did produce flows that affected users and highlighted the impacts on major licence holders. Among these potential impacts were much lower storage levels (and at times, no storage) for TransAlta reservoirs, reduced flows through Calgary as well as depleted storage in Calgary's Glenmore Reservoir, negative environmental implications for downstream aquatic health, and shortages for the three irrigation districts in the Bow River system, and shortages to non-municipal users throughout the Highwood sub-basin.

These potential impacts present risks to the environment, regional economy, and society, but they also present an opportunity to identify adaptation options and build resiliency in the SSRB for responding to future climate variability and change. Such options were explored in the two-day collaborative modelling session based on the five scenarios, held in February 2013. These options, or adaptation strategies, are the focus of this report.

Box 1: The Development of Climate Scenarios

Global Climate Models (GCMs) are used to project future climates. The GCMs used for the BROM were chosen for their ability to simulate Pacific Ocean temperatures, which drive the Pacific Decadal Oscillation (PDO). The PDO is one of the main factors that control precipitation and streamflow patterns in southern Alberta. Choosing climate models that can simulate the Pacific Ocean temperatures, and thus the PDO, gives a better representation of potential future climates than does focusing on mean changes in precipitation and temperature; the latter approach, known as the Delta Method, is commonly used in climate change work.

The methodology used for this project accounts for the inter-annual to decadal variability. Streamflow is modelled as a function of the ocean-atmosphere oscillations that drive the natural variability of the regional climate and hydrology. The very strong regression relationship between the PDO and streamflow in southern Alberta enables the movement from projected changes in climate identified in the GCM, to annual streamflow in southern Alberta.

A statistical downscaling approach can be used to get from projected changes in annual streamflow to daily streamflow, which can then be applied to the BROM. Probabilities from a Cumulative Distribution Function (CDF) are then used to derive daily streamflow from annual averages. A single projected CDF of annual flow probabilities from all the climate scenarios was derived. The probabilities of a flow can be used to get a historical analog year from the gauging record. Downscaling can then be done by time, not by gauge or area. There is a strong correlation between standard deviation in flow and mean flow, so annual flows can be scaled down by the projected mean and projected standard deviation to get projected daily flows. This approach gives projected streamflows that reflect the expectation of more extreme droughts, as opposed to methods that use only shifts in mean climate. Correlating the PDO and streamflows in Alberta gives more robust output from the model than using precipitation.

In summary:

- The flow in each year for each scenario is based on an expected value of annual flow given the sea surface anomaly-annual flow regression relationship.
- Ten GCMs and three fourth-Intergovernmental Panel on Climate Change assessment emission scenarios were chosen based on the best available data.
- Fifty climate scenarios were generated over 30 years (2025 to 2054); each scenario is derived from a combination of one GCM and one emission scenario (one potential future climate).
- All the scenarios provide annual average flows, downscaled to daily streamflow.
- This methodology will show the severe and extended droughts and some earlier shift in the hydrograph.
- This methodology from taking annual flows to daily will not capture the peak high flows; it will capture the high volumes in a given year, but not the flash flood events.

Based on the results of the February collaborative session, it was agreed to use the “3yr Min” scenario (CGCM3T47_3B1) as the basis for modelling the impacts and potential benefits of each strategy. The “3yr Min” scenario was selected by taking the lowest summed 3-year (e.g., 2025+2026+2027, 2026+2027+2028) annual average flow from all years of all scenarios, and selecting the flow at the 10^{th} percentile. The “3yr Min” scenario has the lowest consecutive 3-year cumulative flow (occurring around 2044-2046), but 27 other years in this scenario have less severe flows. Notable effects of the 3yr Min scenario were:

- Extreme low natural inflows occur for an extended period of time.
- Low flows cause the irrigation districts to have near constant senior licence “river calls.”

- TransAlta storage is unable to refill during a river call and thus drains and cannot refill for an extended period.
- With TransAlta storage empty and low natural inflows, Calgary flows fall below 1,250 cubic feet per second (cfs).

The “3yr Min” scenario is the most severe climate scenario of the five examined and was regarded as the worst reasonably likely scenario, thus enabling a rigorous test of the potential adaptation strategies. During the collaborative Bow modelling sessions, it was hypothesized that if current average irrigation district demands were increased by 50% under such extreme conditions the districts would conserve or reduce demand by 30% due mostly to some marginal crops being unsustainable. Thus it was decided that the net demand would be similar to current as no further water would be needed. Demands remained as monthly averages based on the pre-existing data in the BROM. Therefore, in this project, the modelling of demands is likely conservative.

3.3 Performance Measures

Throughout this work, performance measures (PMs) were developed and used to assess and demonstrate the impact and benefits of changes made in the BROM. Six common PMs were developed and examined for all the individual strategies that were modelled; these are:

1. **TransAlta System Low Storage Days**
   This PM notes the number of times that TransAlta live storage reaches critical (<5% storage remaining) and near-empty (<1% storage remaining) levels. The absolute minimum storage in acre-feet is noted below each model run.

2. **Calgary Low Flow Days**
   This PM captures the number of days Calgary experiences extreme low flows, noting flows below 1,250 cfs as well as flows below 900 cfs. The absolute minimum flow that Calgary experiences in a specific strategy (in cfs) is noted below each run.

3. **Bassano Flow**
   This PM captures the number of low flow days below Bassano Dam. It is the same performance measure as shown in previous reports using BROM. It captures the number of days in which flow below Bassano falls into the < 400 cfs, 400-800 cfs, 801-1,200 cfs, and > 1,200 cfs categories. As flow that passes below Bassano has necessarily been in the river all the way down to Bassano, this PM is used as a surrogate for whole river health.

4. **Carseland Flow**
   This PM is identical to the Bassano flow PM, except that it measures flow in the river just after the Carseland diversion. In runs including Eyremore Reservoir, the flow past Bassano is no longer indicative of whole river health, as Eyremore makes releases downstream of Bassano. Carseland flow is thus used as a replacement surrogate for upstream river health in strategies that include Eyremore Reservoir.

5. **Shortage Days**
   This PM captures the number of days of shortages experienced by various groups of licence holders on the Bow River. This is a sum of all days over the entire 30-year scenario record (10,950 total days).

6. **Shortage Volume**
   This PM captures the total volume (in acre-feet) of all shortages experienced by various groups of licence holders on the Bow River. This is a sum of all shorted volumes over the entire 30-year scenario record (10,950 total days).

In addition, the full set of BROM performance measures was processed for each strategy and, in some cases, these are particularly important to illustrate specific points in some adaptation strategies. These charts are included in this report as appropriate and the full set of performance measures is available in the electronic BROM files.

The performance measures are shown over the 30-year climate variability period (referred to as the 30-year period) and focus on the three most severe drought years in the chosen 3yr Min scenario to illustrate the strategy's robustness under the most dire conditions.

In summary, the following important notes should be kept in mind while reading this report:

- The "3yr Min" climate scenario is the basis for all model runs described in this report. After dropping the lowest 10% to prevent statistical outliers, this scenario was the most severe of the five developed and was regarded as the worst reasonably likely scenario.
- Some graphics in this report have dates along the horizontal axis. These dates indicate future years in the 21st century, as shown in the model runs; for example, 01/16/43 is January 16, 2043. The span of years is indicated in the title for each of these figures.
- Performance measures are shown over the 30-year climate variability period (referred to in the report as the 30-year period) and focus on the three most severe drought years in the chosen 3yr Min scenario, around 2044-2046.

4 Potential Climate Adaptation Strategies for the Bow Basin

During this project, participants suggested and explored a wide range of strategies, acknowledging that more work is needed to assess the socio-economic and environmental benefits and costs of the strategies. Seven strategies could be considered or implemented now to improve aquatic ecosystem health and create opportunities for economic development in the watershed. They would also be valuable in building resilience and helping the basin adapt to more severe climate conditions should these conditions arise. For the most part, these “normal condition” strategies focus on changing demands and management rather than building new infrastructure.

Eight strategies were proposed to help water users and managers in the basin respond to potential stresses associated with more severe future climate change and variability. Some strategies would require demand adjustments, while others would involve changes to infrastructure. Any new infrastructure and storage would need to consider both positive and negative environmental impacts as well as impacts on the land and landowners, and recognize that there are tradeoffs. These “drought” options, once in place, would also be expected to benefit the region if and when conditions returned to normal.

Recognizing that the Bow River Basin is a complex, dynamic system, it is expected that potential adaptation strategies would be implemented in combinations that reflect the needs of the basin and the appropriate degree of risk management. To examine how adaptation strategies might be layered to produce cumulative and offsetting impacts, the project modelled six strategy combinations. These range from modest-cost, near-term combinations that offer value under normal (current) conditions, to higher-investment, longer-term combinations that might be considered if the risk profile of climate variability warrants more substantial change in the system.

All strategies were compiled and tested using the BROM. In this report, the strategies that were modelled are presented in three categories, as shown in Table 1. Strategies that could benefit the watershed under normal (current) climate conditions appear first, in section 4.1, followed by strategies that would become increasingly important for adapting to severe drought conditions (section 4.2). Several individual strategies were suggested but not modelled, and these are noted in section 4.3. Combinations of strategies are presented in section 4.4. All modelled strategies and combinations are briefly described, along with the modelling results and impacts, sample performance measures (PMs) and associated observations. In the presentation of performance measures, related strategies are compared for each PM to show the impact on that specific PM of each strategy.

In 2011, the BRP recommended, with unanimous agreement, a Preferred Scenario for re-managing the Bow River. The Preferred Scenario with one refinement (the addition of a trigger) is presented in this report as “Strategy N1” and is also included in the combination strategies. Each strategy has a title that conveys its main intent, as well as a short form of the title that is used in the charts and graphs.

Table 1: List of strategy titles

Full strategy title	Short title for PM charts
Strategies to benefit the watershed under normal conditions	
N1. Implement preferred scenario with trigger	Preferred scenario
N2. Adjust fill times for three largest TransAlta reservoirs (Minnewanka, Spray and Upper Kananaskis)	New TA rules
N3. Reduce seasonal consumptive demand in Calgary	Calgary consump dmd
N4. Implement seasonal consumptive reuse in Calgary	Calgary dmd + reuse
N5. Move municipal licences from Highwood/Sheep system to Bow River	H/S muni dmds to Bow
N6. Increase winter carryover in Travers Reservoir	Travers ↑ carryover
N7. Implement additional demand reduction in Irrigation Districts	ID dmd reduction
Strategies for adapting to severe drought conditions	
D1. Restore Spray Reservoir to full design capacity	Restored Spray
D2. Draw Ghost Reservoir down preferentially to 6.6 feet (2 metres) below normal pattern	Ghost 2m lower
D3. Reduce minimum river flow through Calgary	Calgary minimum flow
D4. Increase off-stream storage in the WID (Bruce Lake)	Bruce Lake
D5. Manage return flows from WID through Crowfoot Reservoir	Crowfoot Reservoir
D6. Increase Little Bow/Travers storage capacity	Travers + 20k AF
D7. Increase on-stream storage downstream of Bassano (Eyremore Reservoir)	Eyremore
D8. Operate ID reservoirs to protect Junior licences	Protect juniors
Combined Strategies	
C1. Preferred scenario (water bank + stabilized LKL) + reduce minimum flow through Calgary (from Oct to Dec, with low storage trigger)	PS + Calgary min flow
C2. Preferred scenario (water bank + stabilized LKL) + adjust fill times for three largest TransAlta reservoirs + increase winter carryover in Travers Reservoir	PS + reservoir changes
C3. Preferred scenario (water bank + stabilized LKL) + move municipal licences from Highwood/Sheep system to Bow River + implement additional demand reduction measures in Calgary and in irrigation districts	PS + demand reduction
C4. Preferred scenario (water bank + stabilized LKL) + adjust fill times for three largest TransAlta reservoirs + increase winter carryover in Travers Reservoir + increase off-stream storage in the WID (Bruce Lake)	PS + on- and off-stream storage
C5. Combination 4 + increase on-stream storage downstream of Bassano (Eyremore Reservoir)	C4 + Eyremore
C6. Stepwise combination for maximum drought adaptation	High potential strategy

Several important terms are defined in Box 2 for the purpose of this report.

Box 2: Key Definitions

Conservation: Any beneficial reduction in water use, loss, or waste that results in a reduction in demand for water by a licence holder.

Consumption: Use of water that is permanently withdrawn from its source.

Consumptive reuse: Treated water reused in a consumptive way rather than being returned to the river. This form of reuse does not change a withdrawal or diversion, but does lower the return flow. The concept is to accomplish more with the same amount of water by keeping the diverted amount constant but reusing that water for more than one purpose, in effect reducing the net amount of water needed.

Demand(s): Volume of water requested by a licence holder for a particular use in the model.

This project has not necessarily looked at every possible adaptation option; those described in this report are potential ideas that, in many cases, were suggested to address extreme circumstances. These strategies are not being recommended or advocated; rather they are presented as a starting point for discussion and further consideration by those who use, manage and make decisions about water in the Bow Basin.

The potential individual strategies are presented as they would appear geographically in the basin, starting in the headwaters. The Bow Basin is shown in the map in Figure 1.[3]

[3] The map in Figure 1 is provided courtesy of the Bow River Basin Council (www.brbc.ab.ca).

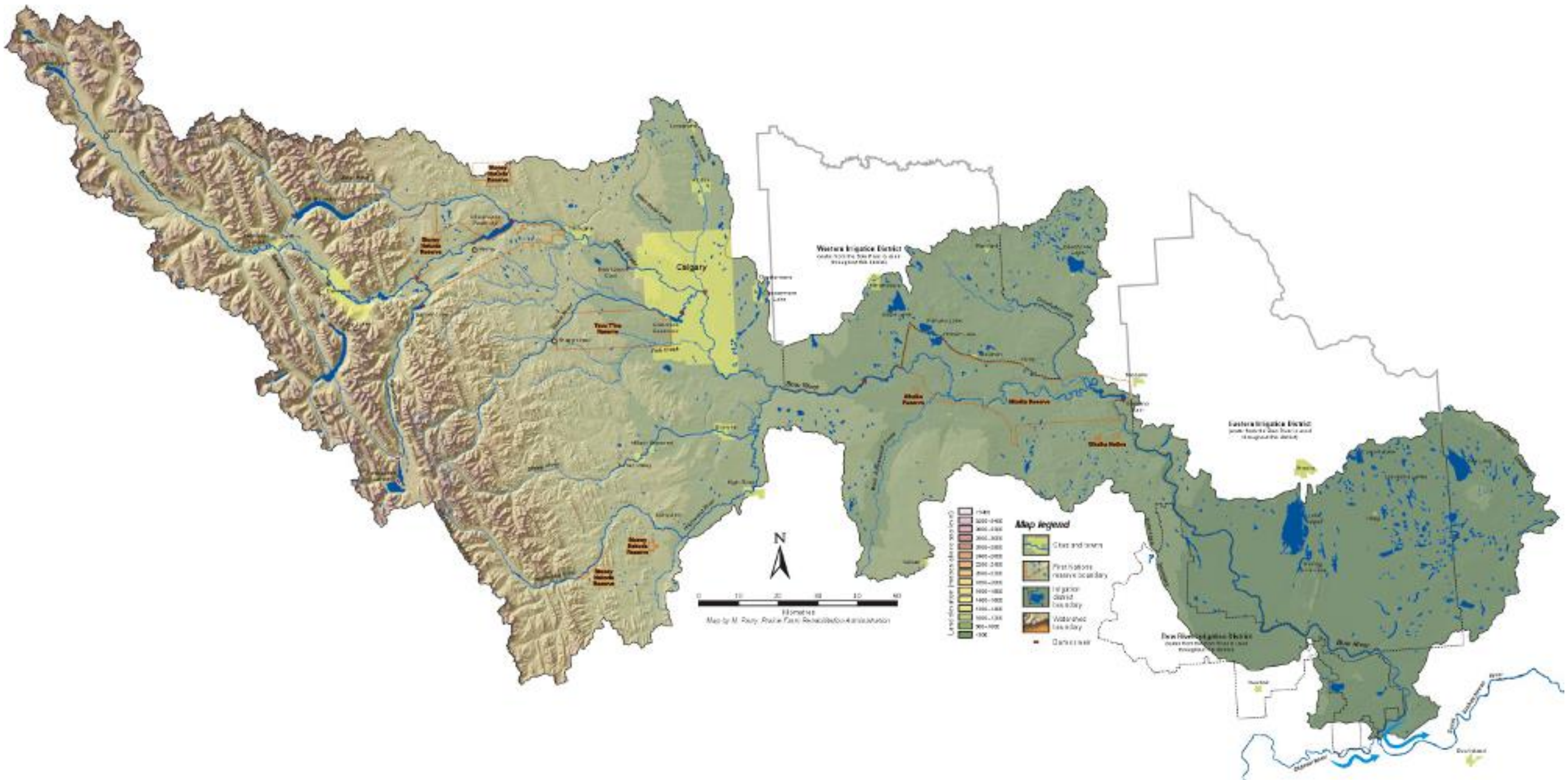

Figure 1: The Bow Basin

4.1 Strategies to Benefit the Watershed under Normal Conditions

N1. Implement Preferred Scenario with trigger

The Preferred Scenario put forward in the BRP involved several substantial changes in the way the Bow River is managed; specifically, it features the following major changes from current operations:

- A "water bank" of 60,000 acre-feet (AF) to be used for supplementing flows throughout the Bow River during high demand and low flow periods from Bearspaw to below Bassano. The water bank is an accounting measure, and does not refer to storage located in any particular reservoir, but to water stored by TransAlta throughout their reservoirs as best meets their needs. For purposes of the model, water would be taken in proportion to the reservoir supply levels at that time from every TransAlta reservoir above Ghost Dam. TransAlta may choose to draw the water bank flows from wherever they wish, with the exception of Lower Kananaskis Lake, which is proposed to be stabilized at some flexible level. Releases from the water bank are triggered to supplement low flows past Bassano Dam, and thus also enhance environmental flows from Bearspaw to Bassano as well as below Bassano. The water bank refills using approximately 10% of the calculated natural inflows that can be captured in TransAlta reservoirs during periods when senior licence calls are not being made downstream.
- Lower Kananaskis Lake is stabilized at 1663.5 metres – 3.5 metres below the current 1667-metre full supply level – with a fluctuation of ± 0.5 metre; this is a significant change from current annual fluctuation of up to 13.5 metres. This reservoir is not allowed to use its spillway unless elevation rises above 1667 metres.
- Discharge flows into the Kananaskis River from the Pocaterra power plant are held steadier, with the objective of ensuring that within-day instantaneous flows vary by no more than a factor of three, maximum day-to-day instantaneous flows vary by no more than a factor of two, while minimum day-to-day instantaneous flows vary by no more than a factor of 0.5.
- The capacity of Langdon reservoir in the Western Irrigation District is doubled from 6,750 AF to 13,500 AF.

The two primary aspects of the Preferred Scenario are 1) the water bank, and 2) the approximate stabilization of Lower Kananaskis Lake and river system for ecological improvements throughout that series of parks and protected areas. The water bank amounts to approximately 10% of TransAlta storage and capturable inflows in any given year. Under ideal conditions, this would be about 60,000 AF, but this volume would likely not be reached every year. The water bank is not physically tied to any particular reservoir, but is rather an agreement that allows upstream water to be called upon, by request, to meet a particular need. The approach is intended to minimize negative environmental effects to the reservoirs and minimize costs to TransAlta by enabling the company to draw water from any of the reservoirs they wish, with the exception of the stabilized Lower Kananaskis Lake. The water bank water releases were intended to supplement in-stream flows below Bassano Dam, which were used as an indicator of adequate flow throughout the river system; that is, if flows were adequate in this reach of the river, it was likely that aquatic health in the rest of the river was also improved compared to the base case.

Stabilizing Lower Kananaskis Lake would result in a number of benefits, among them the opportunity to re-create spawning habitat for Westslope Cutthroat Trout in the old Kananaskis River channel between the lakes, where they historically spawned before outflow was diverted through the Interlakes power plant. Stabilizing Lower Kananaskis Lake would permit some spawning habitat to be restored below the falls, even though there is currently very little flow in the channel. Not only would this reduce the need to stock cutthroat trout in Lower Kananaskis Lake, it would also create an excellent interpretive opportunity for the public (especially campers using the nearby Interlakes campground) to view spawning cutthroat trout in the spring.

The model was then set to automatically release water from the water bank under any conditions that created minimum flows below 800 cfs downstream of Bassano Dam. This original scenario was referred to as "robo-river" since there was no human element engaged to more flexibly alter releases from the water bank to adapt to rapidly changing conditions.

The BRP envisioned that the water bank would be managed collaboratively, flexibly and in an adaptive manner with the intent of maximizing river health and environmental conditions for as long as possible. The obvious value of this flexibility was demonstrated in a one-year simulation conducted by the BRP in October 2011, showing how the Preferred Scenario could further reduce shortages and retain environmental flows better than applying the "robo-river" model priorities alone. That flexibility in releases was always the core goal, with the BROM simply demonstrating substantial improvements even when using automatic releases in accordance with pre-established priorities. The current study includes more extreme and prolonged drought conditions and the Preferred Scenario does not achieve all the desired objectives as measured by the PMs, using the "robo-river" approach.

For purposes of this study, some of the Preferred Scenario priorities were altered to better adapt to the extreme drought conditions of supply and demand modelled under the 3yr Min scenario. Primarily, it was found that the original "robo-river" version of the Preferred Scenario performed counter-productive operations during severe droughts in an attempt to improve environmental conditions by boosting downstream flows. Even though TransAlta storage was at critical levels, the Preferred Scenario ("robo-river") continued to force TransAlta to release extra water for supplementation, thus causing TransAlta's storage to run out sooner during the three-year drought. In a real drought, upstream storage would not be released to increase flows below Bassano at the expense of possibly not having water to supplement flows downstream of Calgary. Under "robo-river," the Preferred Scenario forces TransAlta storage to zero by supplementing flows below Bassano. As this would never happen, participants decided to improve the "robo-river" operations of the Preferred Scenario by adding a trigger. These improvements still do not enable the system to work as well as it would under human operations, but they eliminated the extreme minimum low flow under the Preferred Scenario as seen in Figure 2.

The Preferred Scenario as described in the original BRP report forced a consistent release from the water bank with the intention of increasing flows downstream of Bassano to at least 800 cfs. This supplementation occurred whenever flows in that stretch fell below 800 cfs irrespective of any other circumstances. In the revised Preferred Scenario (identified as the "Preferred Scenario with Trigger" strategy), the supplementation releases are informed by the condition of TransAlta storage. The new rules for making releases from the water bank are:

- If flows below Bassano drop below 800 cfs, begin supplementation.
- Once flows below Bassano exceed 1000 cfs, cease supplementation.
- If TransAlta storage is within 100,000 AF of seasonal full levels, supplement to target 800 cfs below Bassano.
- If TransAlta storage is more than 100,000 AF below seasonal full levels, supplement to target 650 cfs below Bassano.
- If **total** live storage in TransAlta reservoirs falls below 100,000 AF, cease all supplementation activity for the year unless TransAlta refills to seasonal full levels.

Modelling of these new operations showed that they eliminated many of the "robo-river" releases that would not occur in a real-life situation. Thus TransAlta storage does not drain to extreme lows as quickly or as often as it does under the original Preferred Scenario (Figure 3).

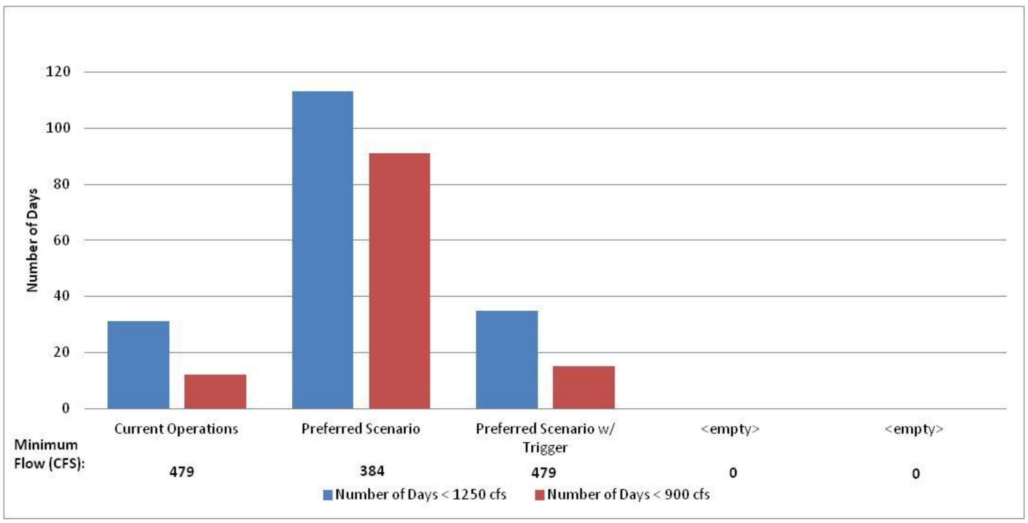

Figure 2: Calgary low flow days

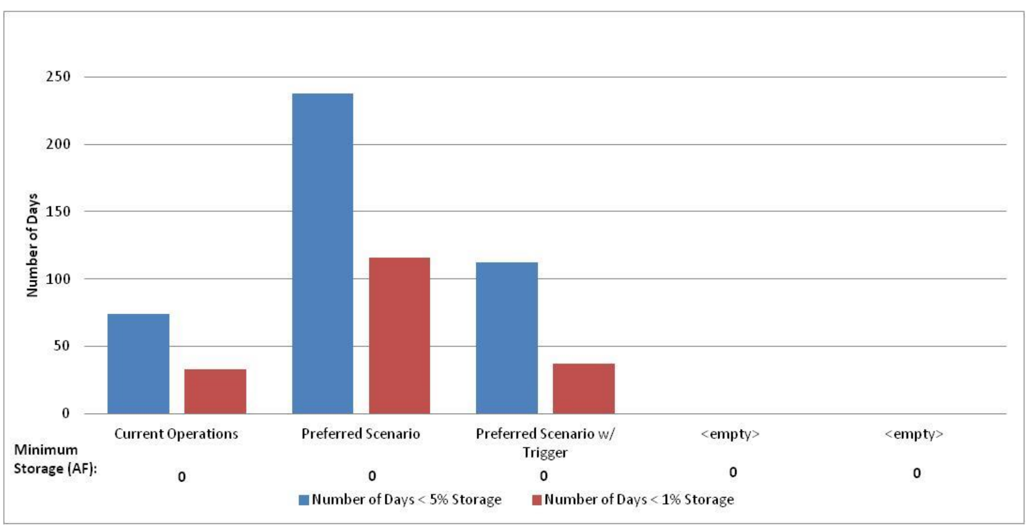

Figure 3: TransAlta system low storage days

The cost of these improvements is a slight degradation in performance relative to flows below Bassano. The Preferred Scenario with Trigger alternative is not quite as effective as the original at reducing the number of Bassano low flow days below 800 cfs. However, its positive effect is still quite substantial as seen in Figure 4. In the more detailed analysis, it can be seen that this occurs in part due to a number of the flow-days being shifted to the new 650 cfs target. Figure 5 shows that percent of days in the 800-1000 cfs category decreases by approximately 2% between the original and trigger versions of the Preferred Scenario. These are largely replaced with days in the 650-800 cfs range, representing more realistic operations.

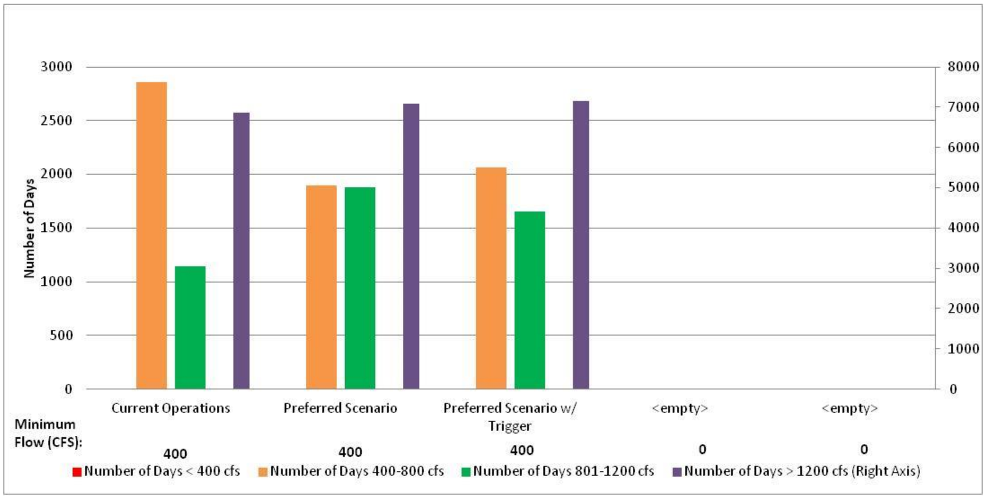

Figure 4: Bassano low flow days

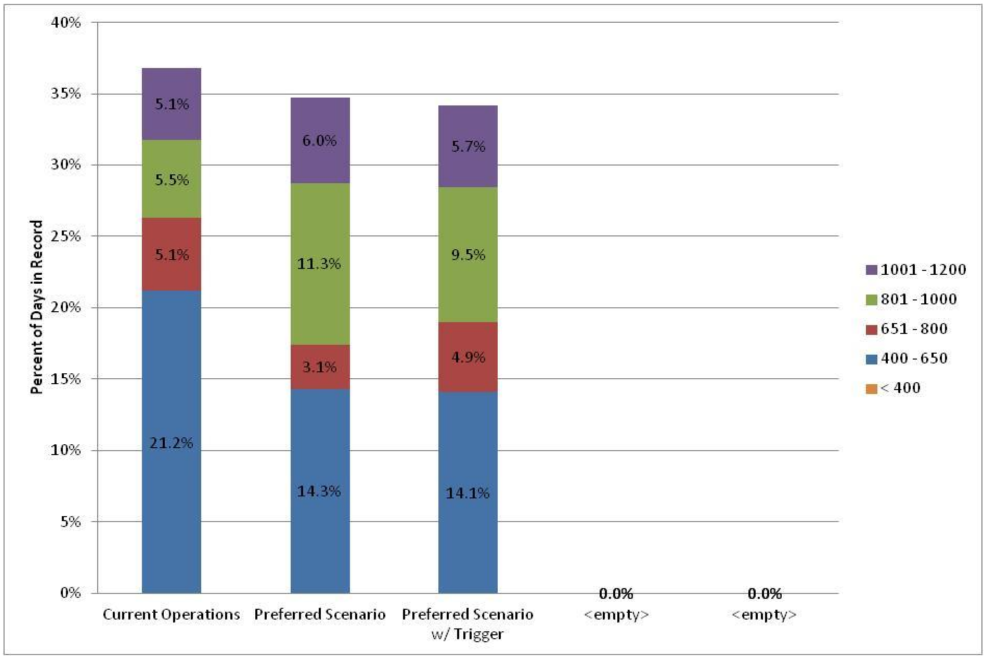

Figure 5: Percent of days with low flows past Bassano

Model results and impacts

N.B.: Based on this analysis, the "Preferred Scenario with Trigger" was chosen for further examination as a potential climate adaptation strategy. Thus, from this point forward, discussion pertains only to the performance of the "Preferred Scenario with Trigger" strategy. Unless otherwise noted, any labels indicating "Preferred Scenario" imply the inclusion of the trigger.

Under normal conditions, the water bank is heavily used and is regularly emptied, as seen in Figure 6.

Figure 6: Water bank storage under normal conditions (2028-2032)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

Under multi-year drought conditions, as reflected in the climate variability scenario chosen for this project, the situation is quite different, as seen in Figure 7. Here, TransAlta experiences near constant calls for water releases, which prevents the capture of inflows, and the water bank is unable to effectively refill for a three-year period.

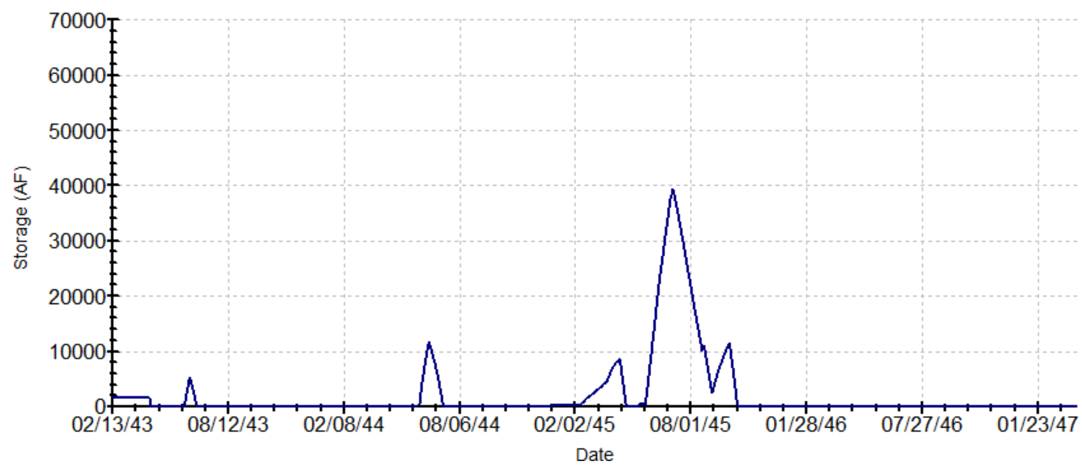

Figure 7: Water bank storage under multi-year drought conditions (2043-2046)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

As long as the water bank has water in it, it has a positive effect on the number of low flow days at Bassano, as seen in Figure 8; water bank releases reduce the number of days of 400-800 cfs from about 2,850 under current operations to about 1,880 (roughly a one-third reduction), over the 30-year period of record in the model. This performance measure was developed to be a surrogate for the health of the Bow River as a whole; in other words, higher flows below Bassano reflect higher flows and better health for the whole river system.

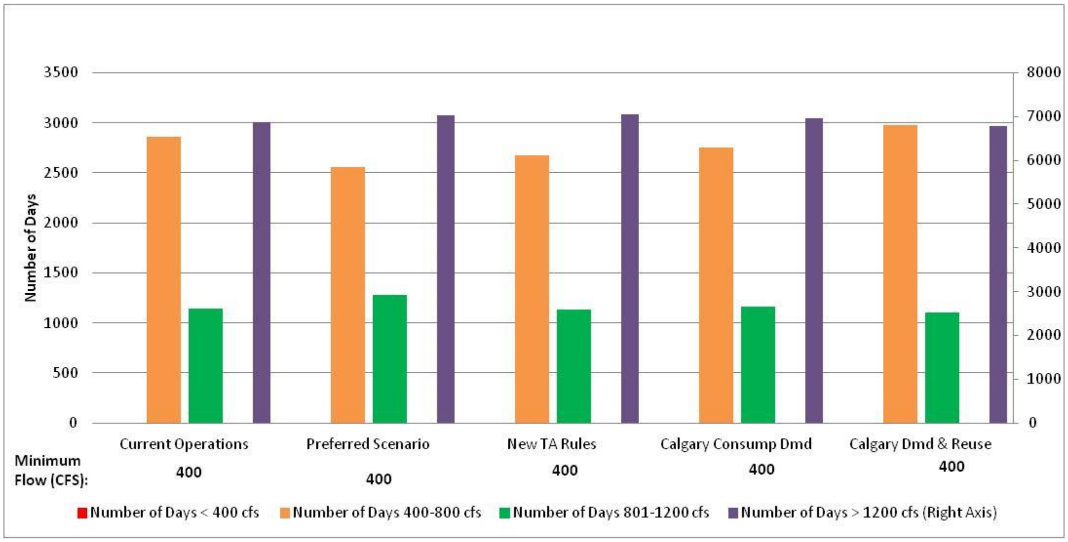

Figure 8: Bassano low flow days

As the probability distribution plot (Figure 9) shows, both versions of the Preferred Scenario trade some of the high flow days (right arrow) for fewer extreme low flow days (left arrow). Cumulative Distribution Function (CDF) plots such as Figure 9 show the percent of time a given flow is at or below a particular level over the period of record. A CDF can clearly show the percent of time a given flow rate happens, indicating if there are increases (higher percentage) to low or high flows or decreases (lower percentage).

For the Preferred Scenario and the Preferred Scenario with trigger, the CDF plot in Figure 9 shows a reduced frequency in the number of low flows (500-1200 cfs), which comes at a cost of supplementation by reducing periods of higher flows in the 1500-3000 cfs range. The objective here was to increase the minimum flow for longer periods using storage, recognizing that this would reduce the percent of time for mid- to higher-flow rates. It is thought that this tradeoff would minimize harm to the river ecology. This is only done in response to extreme conditions, and higher flows would be returned when conditions normalize.

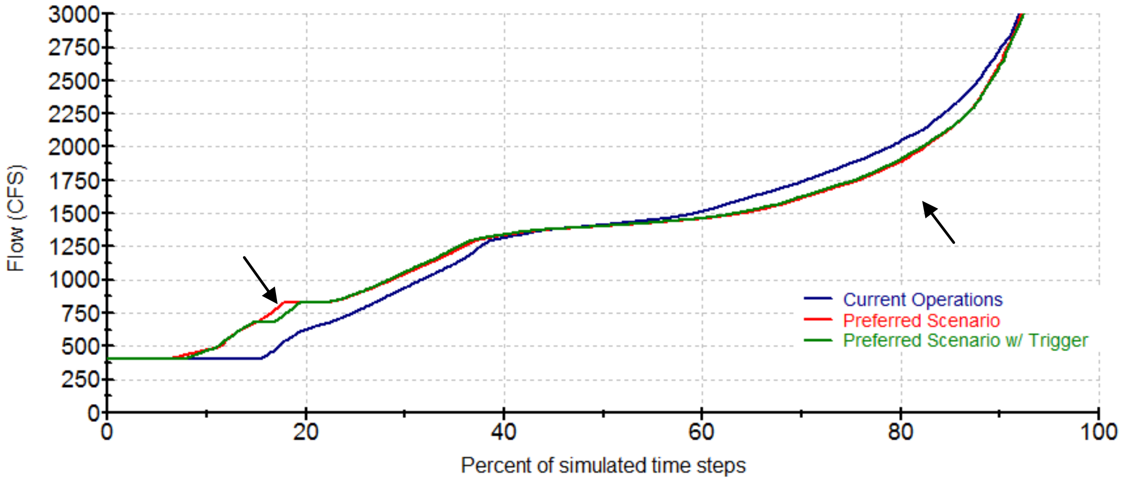

Figure 9: Bassano flow probability distribution

The new Preferred Scenario avoids making excessive releases and, while it does have some small impact on TransAlta storage, it does not have substantial effect on the number of low flow days through Calgary over the 30-year record (Figure 10).

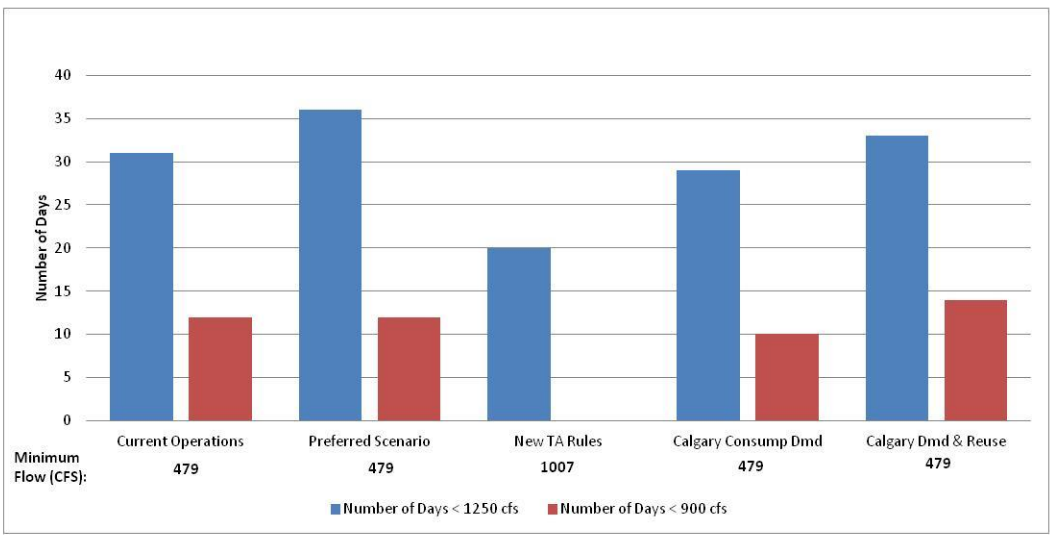

Figure 10: Calgary low flow days

Figures 11 and 12 show the positive impact of the Preferred Scenario on the elevation of Lower Kananaskis Lake.

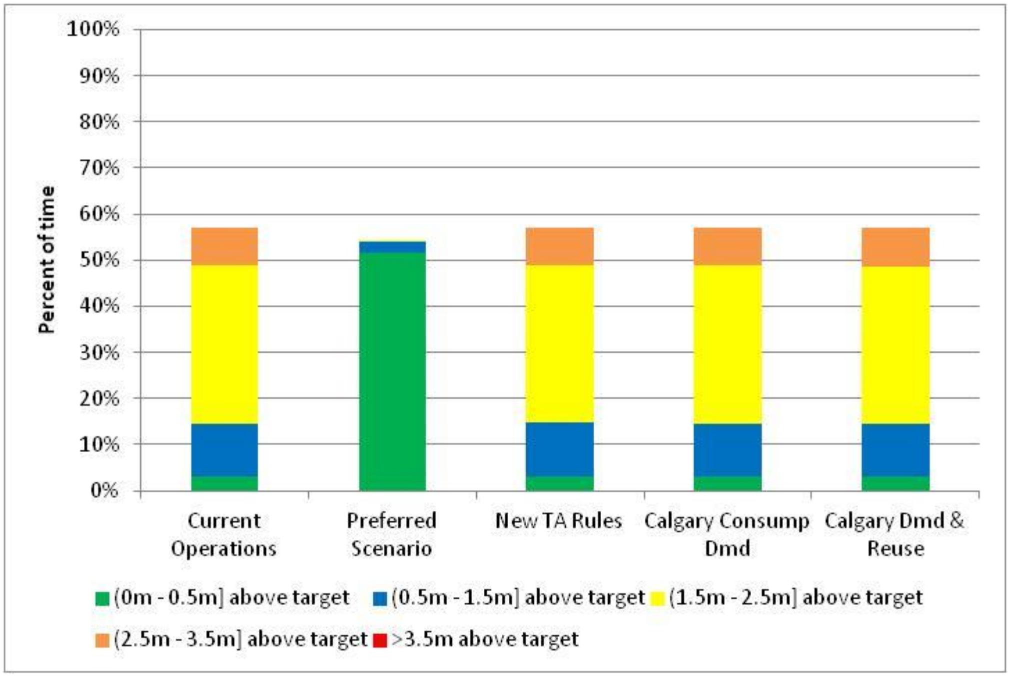

Figure 11: Percent of time above Lower Kananaskis target elevation of 1663.5 m

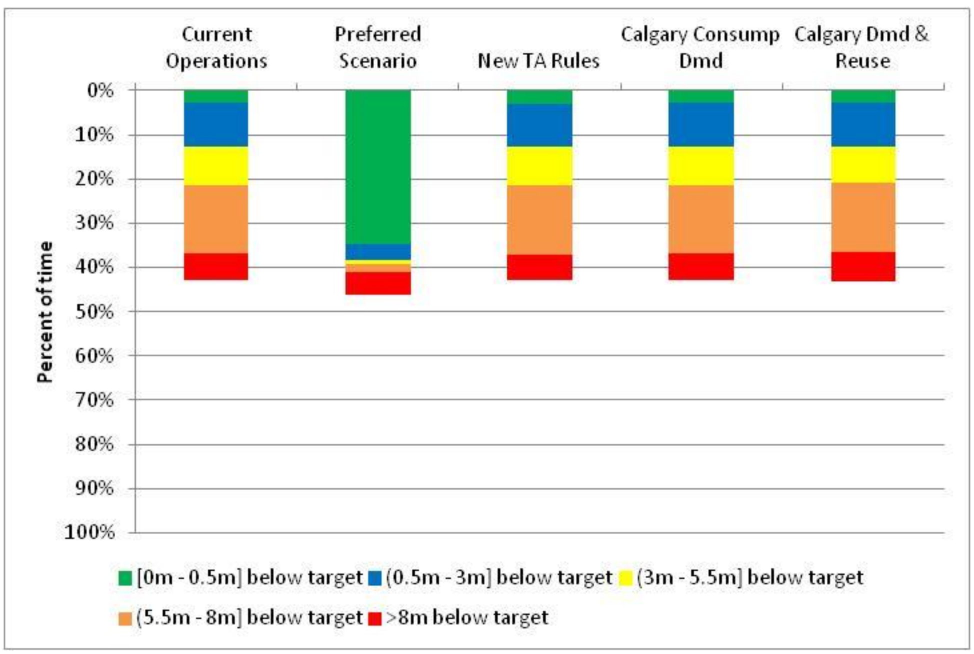

Figure 12: Percent of time below Lower Kananaskis target elevation of 1663.5 m

This strategy stabilizes Lower Kananaskis Lake (LKL) when sufficient water is available but it starts to drain the lake when other TransAlta reservoirs are drained. The rationale for this strategy was that under extreme drought conditions, stabilization of LKL would have to be temporarily abandoned and the lake could be drawn down as a "last resort" measure. It would be first drawn down to its rule curve, then drained only after other reservoirs are drawn down. The intent to stabilize LKL would continue as soon as water supply conditions improved. Under the most extreme drought conditions the lake was always considered available to supplement critically low flows downstream to protect the river ecology and that it would be returned to stabilized operations when the crisis ends.

As envisioned in the original BRP report, intelligent management of the water bank allows this alternative to provide substantial benefit for basic ecological flows in the river with fewer side effects for other users.

Relevant BROM run names

CV_CB8.9_PreferredScenario
CV_CB8.9_PreferredScenarioTrigger

N2. Adjust fill times for three largest TransAlta reservoirs (Minnewanka, Spray and Upper Kananaskis)

At present, the three largest TransAlta reservoirs (Minnewanka, Spray and Upper Kananaskis) are operated according to "normal patterns," with the intent of having elevations match their historical (2001-2010) averages. This situation is not ideal under drought situations and could result in water being captured and released at less than optimal times for non-hydropower generation. This strategy involved changing the rule curves for these three reservoirs so they reach full storage slightly sooner. Under the drier conditions that could result from climate variability, this would avoid the need to fill in August when natural streamflows may be reduced.

With this strategy, the reservoirs would be approximately full by July 31, held full until October 15, and then allowed to make releases according to normal operations. This would leave more natural flow to pass in August and September to meet higher seasonal downstream needs at a time when flows are typically lower. In reality, this basic strategy would be carefully managed within a range to adapt to changing conditions.

The normal patterns for Minnewanka, Spray and Upper Kananaskis reservoirs are shown in Figures 13-15 (blue line), compared to the new rule curve (red line). For this initial modelling, the pattern is more or less the same for all three reservoirs. These reservoirs are located in parks or protected areas, so there could be specific restrictions or requirements with respect to water management.

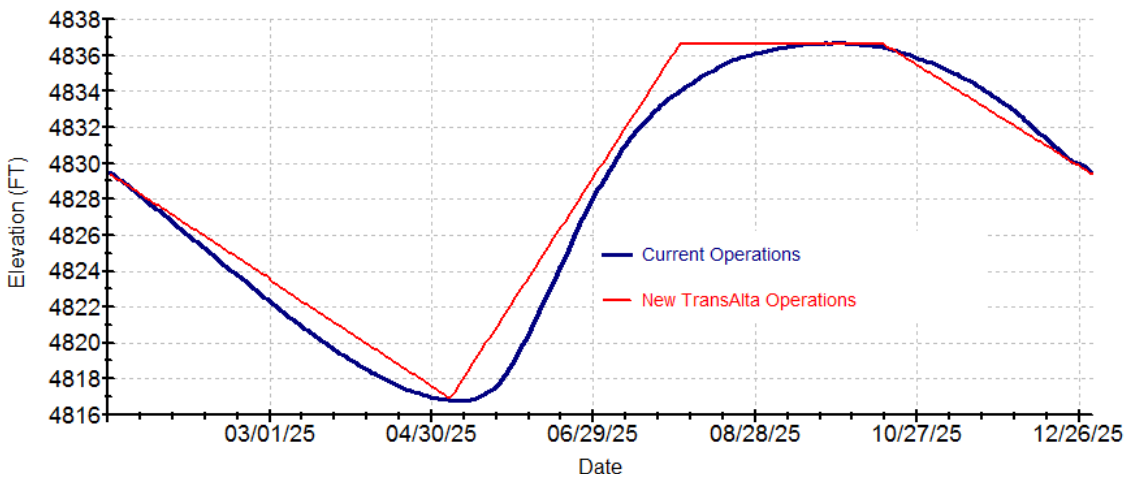

Figure 13: Minnewanka Reservoir normal pattern vs. potential new rule (2025)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

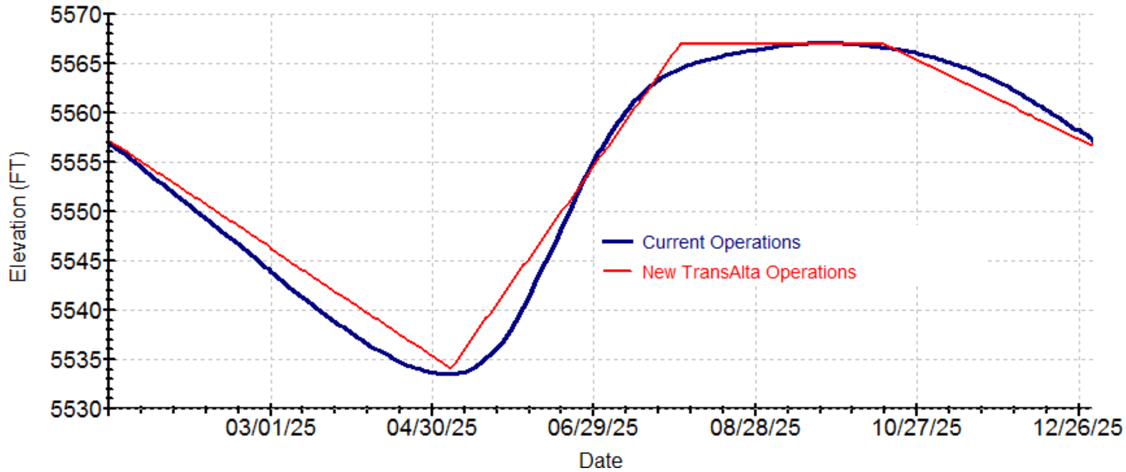

Figure 14: Spray Reservoir normal pattern vs. potential new rule (2025)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

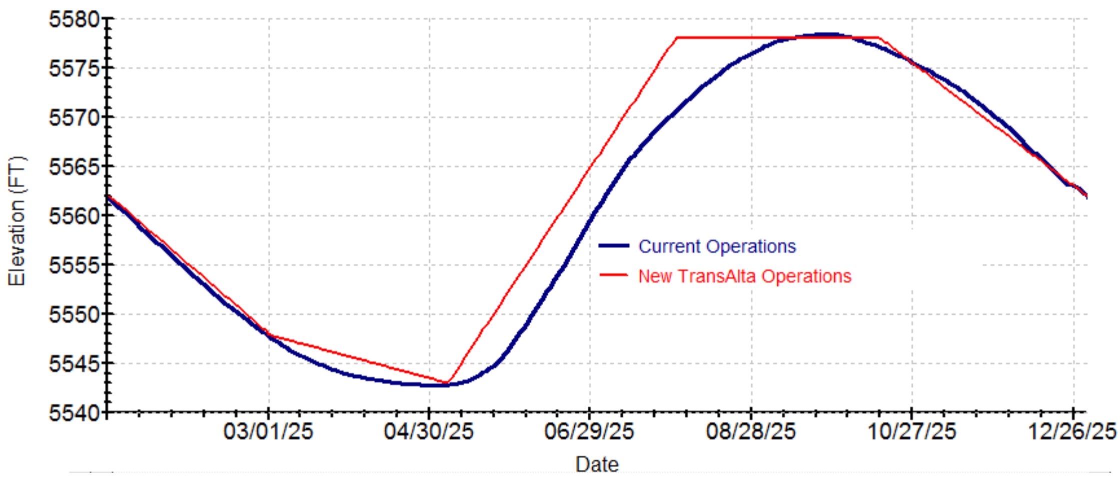

Figure 15: Upper Kananaskis Reservoir normal pattern vs. potential new rule (2025)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

Model results and impacts

Under drought conditions, Figure 16 compares storage at current operations with storage under the new rules. In this situation, the strategy provides about an extra 20,000 AF of storage compared to current operations. This is not enough to offset the most extreme drought events as storage is still depleted under drought conditions, but still suggests a valuable potential benefit to the river system in the more "normal" years.

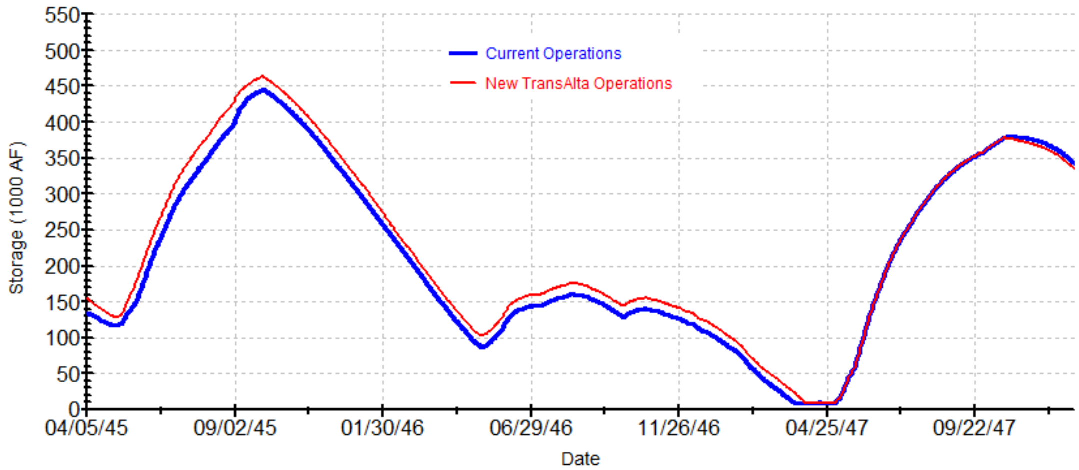

Figure 16: Live storage in all reservoirs under drought conditions (2045-2047)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

Figures 17 and 18 present examples of performance measures for this strategy. The extra storage provided by this strategy does offer some additional flexibility for managing drought. It reduces the number of low storage days for TransAlta, and the extra 20,000 AF (compared to current operations) also substantially improves the number of low flow days through Calgary.

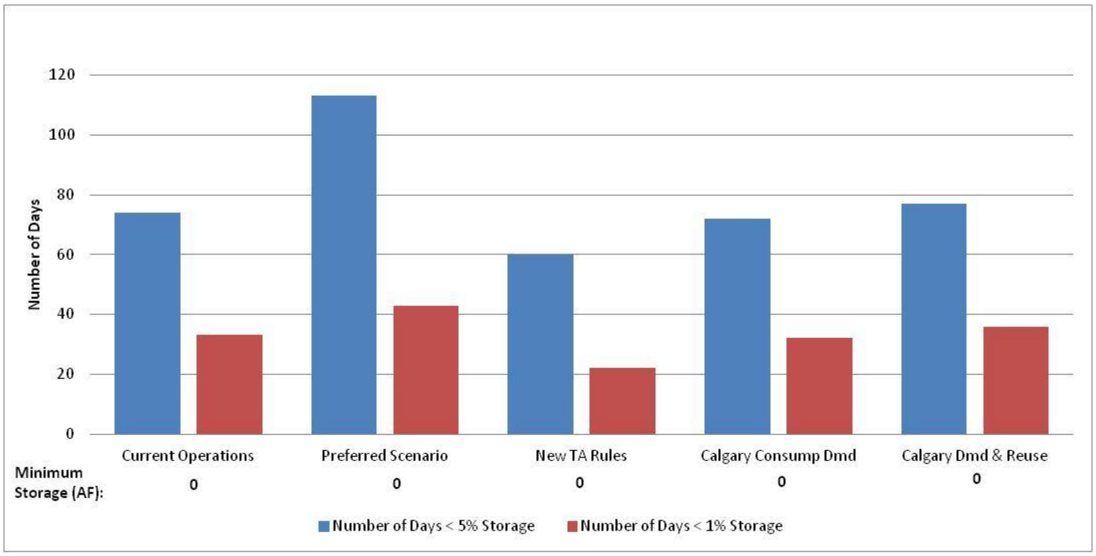

Figure 17: TransAlta system low storage days

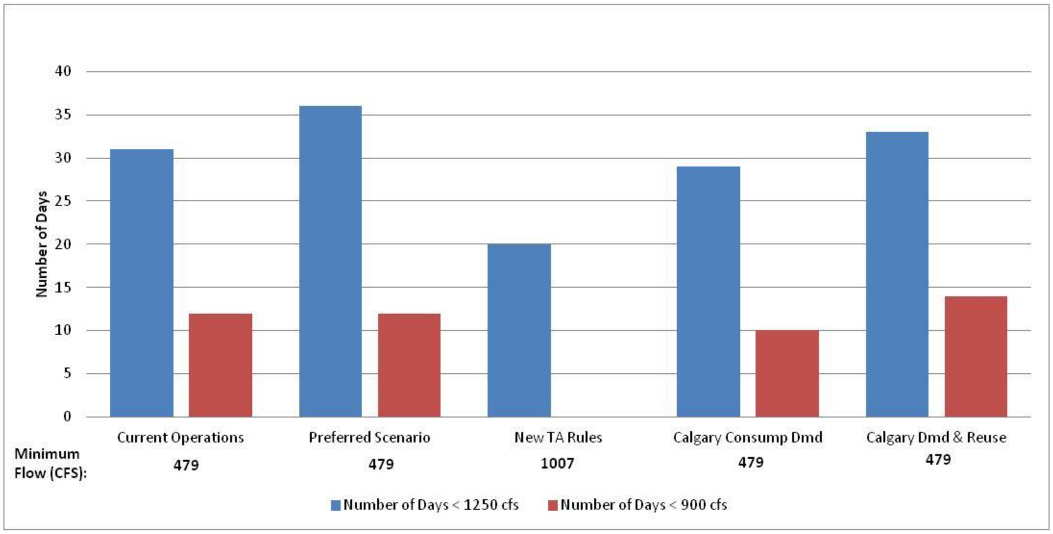

Figure 18: Calgary low flow days

While this is a relatively positive strategy, there is still a flood risk in August due to late summer convective storms that could lead to flooding if reservoirs are full and TransAlta needs to spill. Dam safety related to earlier filling would also likely be a concern. The existing rule curve is designed to address high inflows from convective summer storm events to avoid spillage and reduce flood concerns.. It is also undesirable for TransAlta to have to spill water, as generation revenue would be lost if water must be run down the spillway rather than through the turbines because of high water releases.

Relevant BROM run name

CV_CB8.9_TA-NewRules

N3. Reduce seasonal consumptive demand in Calgary

As a means of protecting basin-wide health and resiliency when demand for water is high, one strategy is for Calgary to reduce seasonal consumptive demand by 30% during the summer, from April 1 to September 30. Figure 19 shows the change made to Calgary demands for this strategy, with the summer portion reduced by 30%.

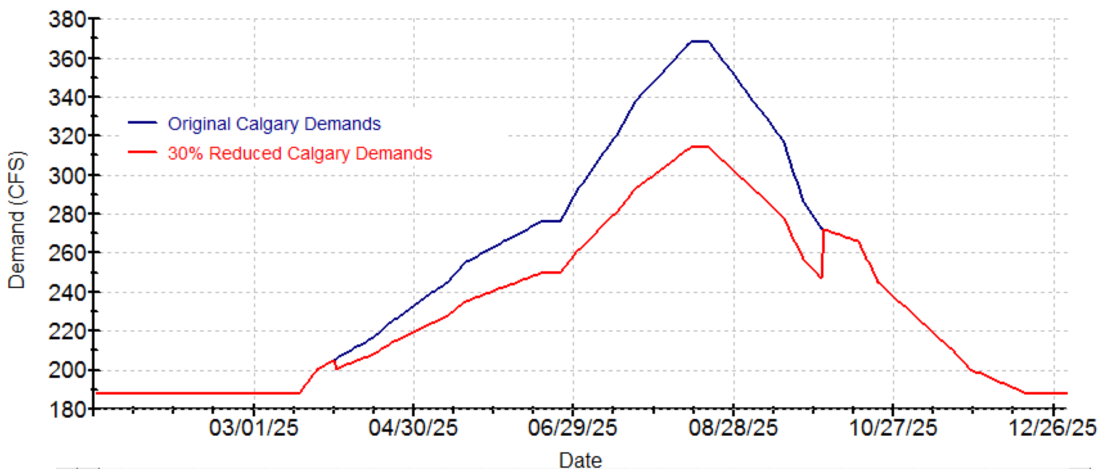

Figure 19: Illustration of the change made to Calgary demands (2025)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

Assuming the conservation measures are targeted at typically consumptive uses, return flow volumes to the river can potentially remain unchanged. In winter, demands are generally flat and were presumed to remain constant under this strategy, representing the traditional steady flow of municipal and industrial use. In summer, demands go up as more water is used for seasonal activities (e.g., watering lawns and golf courses). In this strategy, only demands above winter levels were affected by the 30% reduction; in other words, toilet flushing, laundry and other domestic water uses, for example, are considered to be constant year round and the net return to the river stays the same. Rather than address a specific event, this strategy was intended to improve basin-wide performance measures. Many measures to reduce consumptive demand have been and are being considered by municipalities and this strategy does not specify what measures should be taken, only that the net result is a 30% reduction in summer demand.

Model results and impacts

This reduction in demand does not occur during the winter when Calgary is most susceptible to extreme low flows, and thus Calgary flows are not substantially improved when compared to current operations over the 30-year period (Figure 20).

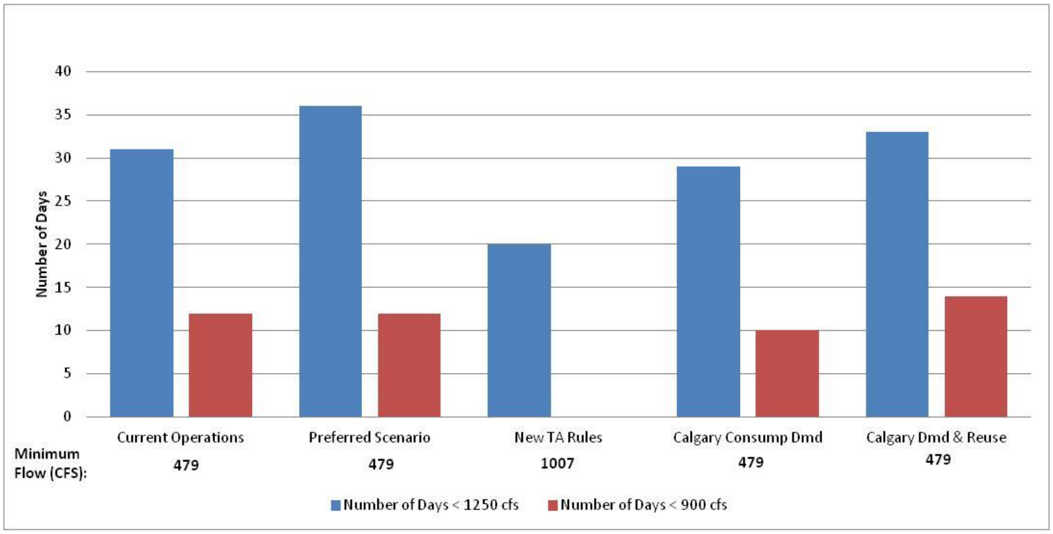

Figure 20: Calgary low flow days

When water is not being withdrawn by Calgary, it stays in the river until it is needed by downstream users, so Calgary's reduced demand does contribute to aquatic ecosystem health and helps to mitigate shortages to other users. However, the effect on downstream shortages is small (Figure 21).

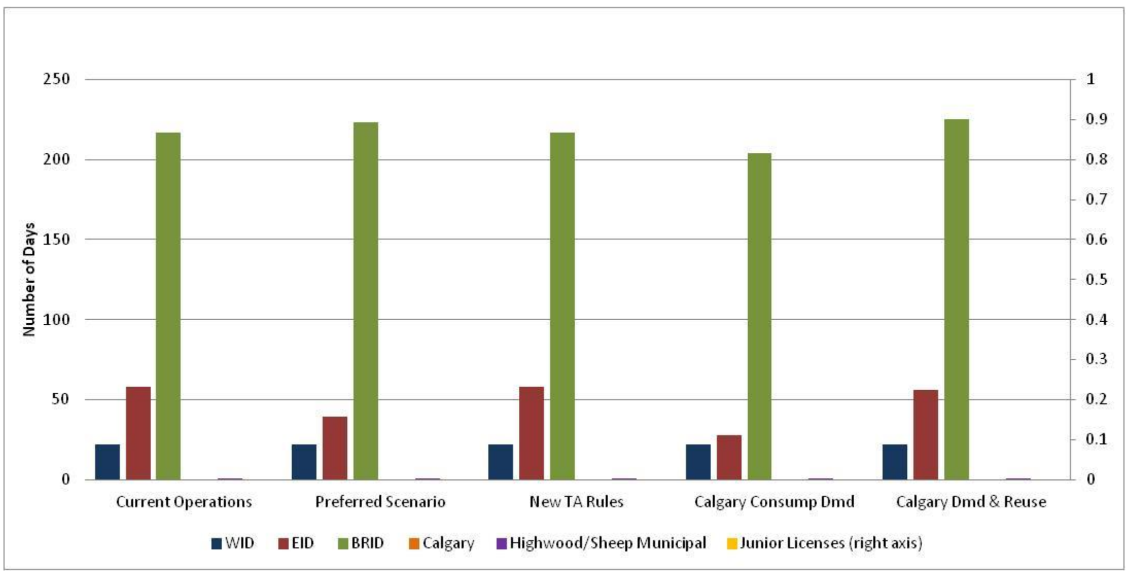

Figure 21: Number of shortage days

The primary advantage of this strategy is that more flow remains in the river downstream of Calgary. As demands are being reduced during the high flow (summer) season the effect is somewhat overshadowed, but the additional water from demand reduction is noticeable. Under drought conditions it is particularly noticeable, as seen in Figure 22, with the blue line representing current operations and the red line representing the flow with reduced Calgary demands.

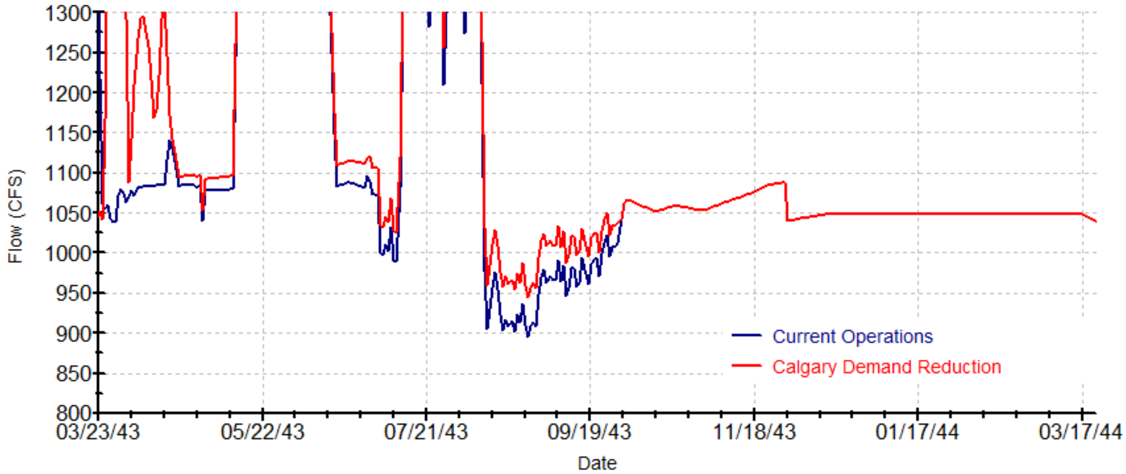

Figure 22: Bow River flow after Calgary withdrawal (2043-2044)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

In summary, the net effect on the river is that less water is taken out when seasonal consumptive demands are reduced and the same amount of water is returned. Leaving more water in the river, especially during droughts, contributes to the health of the downstream aquatic ecosystem. This additional water also provides more flexibility for other users in the basin in their water usage patterns and may slightly reduce withdrawals from the water bank.

Relevant BROM run name

CV_CB8.9_CalgaryCons

N4. Implement seasonal consumptive reuse in Calgary

This strategy also aims to achieve a 30% reduction in Calgary demand; it includes the approach described in strategy N3 to reduce seasonal consumptive demand. In addition, it introduces a 30% reduction in return flow as demand reductions are assumed to come entirely from consumptive reuse. In other words, water that is withdrawn from the river is being used again and consumed rather than being returned to the river; an example would be the application of grey water to golf courses. For the purposes of the model, return flows were reduced by 30% for the summer season of April 1 to September 30.

This strategy was examined to determine the top end of the benefit and the low end of the benefit from Calgary's efforts to reduce demand. If a demand reduction strategy only involves consumptive reuse, it is unlikely to offer many benefits. However, the combination of reduced demands and consumptive reuse is expected to provide positive net benefits.

Figure 23 shows the returns from the Calgary water treatment plant to the Bow River under this strategy, with original returns represented by the blue line, and the reduced flows by the green line.

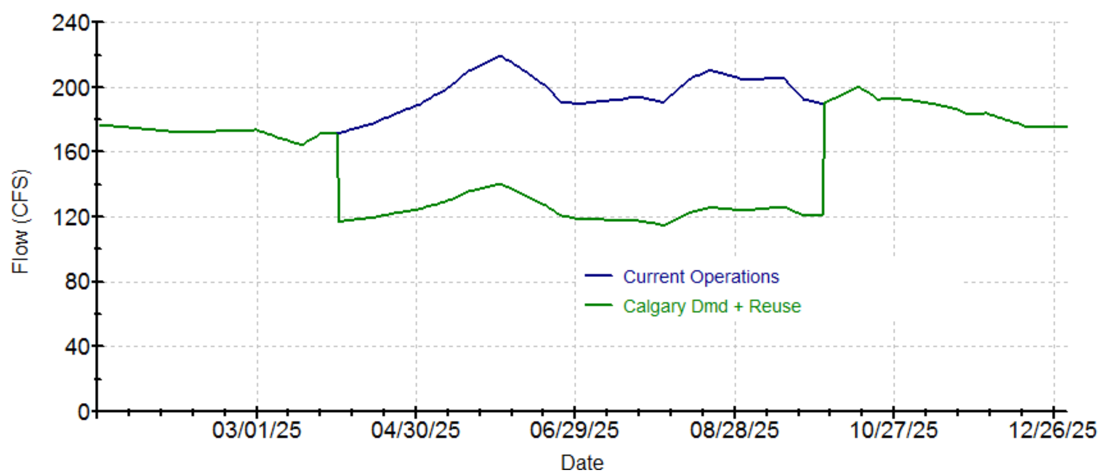

Figure 23: Calgary returns to the river (2025)

Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

Model results and impacts

The main benefit of reduced Calgary demands is an increased flow immediately after their diversion. In Figure 24, which illustrates flow during a drought period, the flow for this strategy is shown as the green line. The extra water in the river from reduced demands remains, and that benefit is not lost immediately below Calgary.

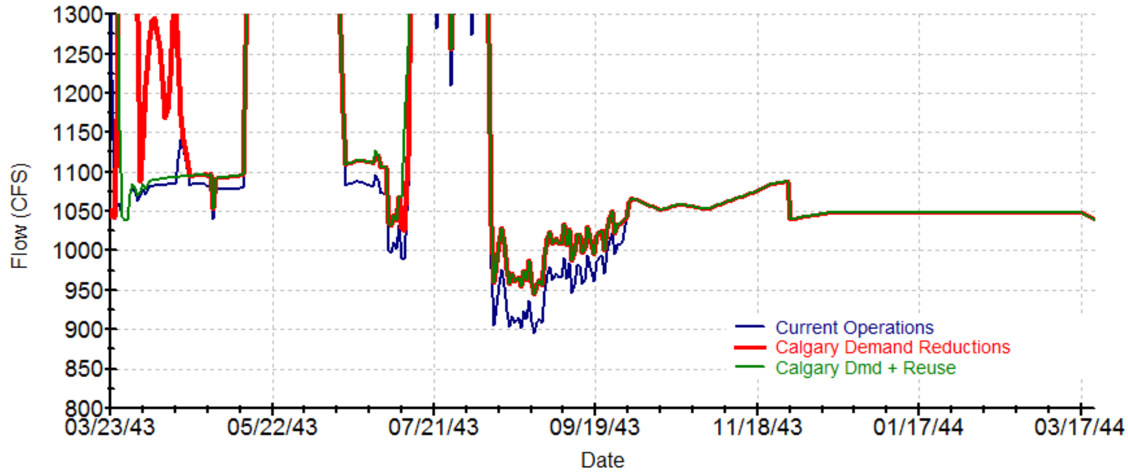

Figure 24: Bow River flow after Calgary withdrawal (2043-2044)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

With Calgary reducing its returns however, there is less water in the river, and the irrigation districts experience more shortages, as shown in Figure 25.

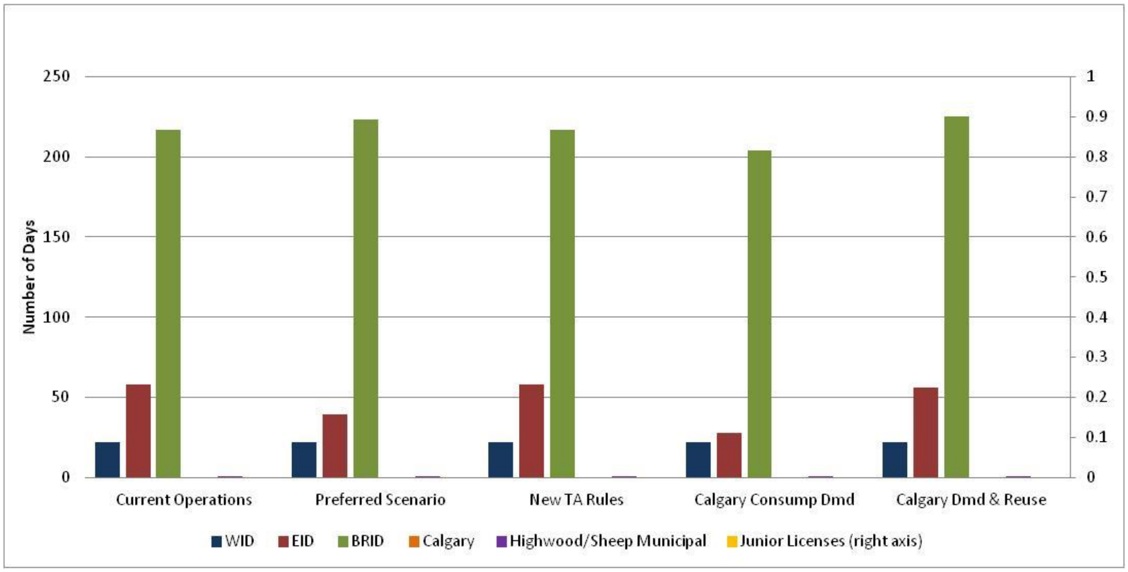

Figure 25: Number of shortage days

The resulting additional river calls under drought conditions cause TransAlta to drain its storage slightly faster (Figure 26). The green line represents the consumptive reuse strategy and it drops just ahead of the red and blue lines by a few days. This is not a lot but it's enough to exacerbate low flow conditions through Calgary, as seen in Figure 27.

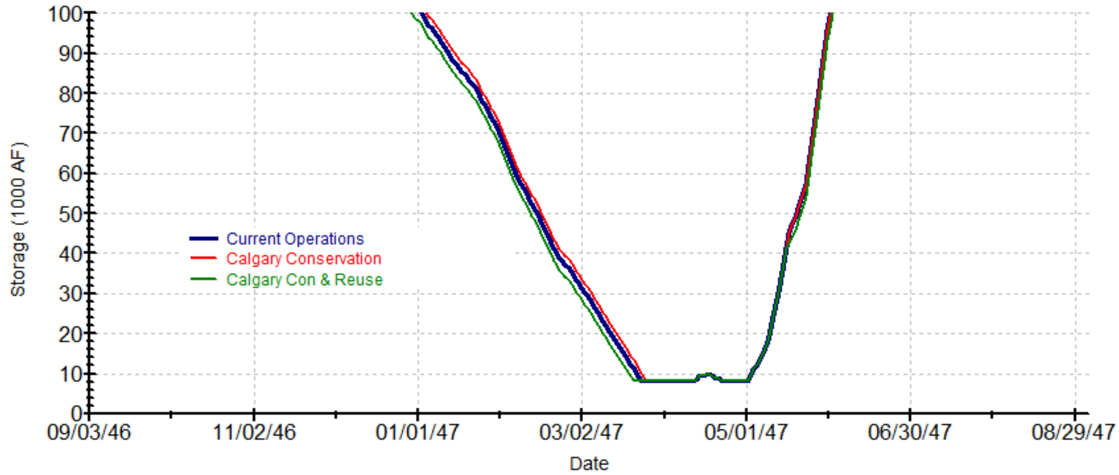

Figure 26: Live storage in all TransAlta reservoirs (2046-2047)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

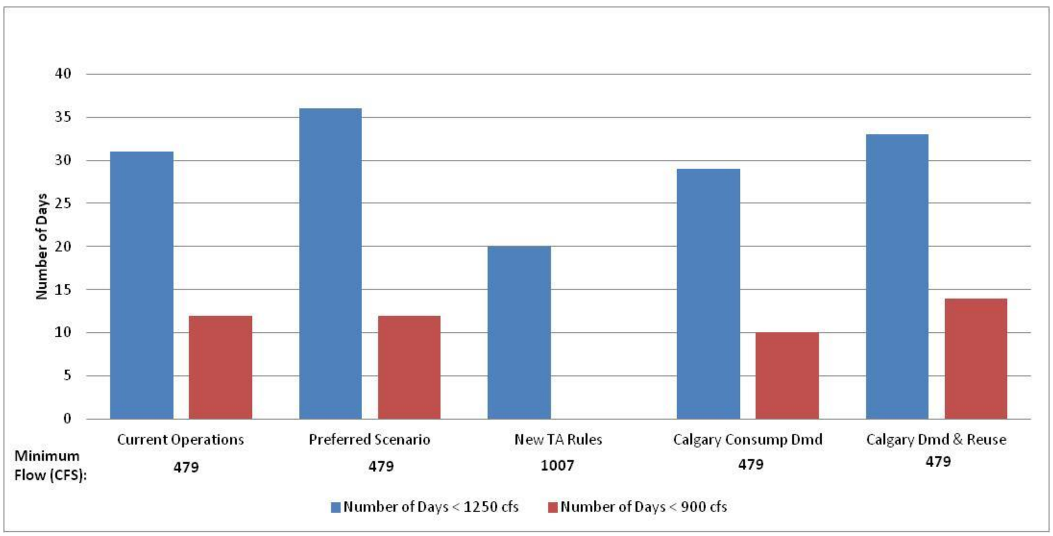

Figure 27: Calgary low flow days

This run, in combination with the previous strategy, seems to indicate that there is potential benefit to the river when Calgary demands are reduced. It should be noted, however, that these benefits may have unexpected costs as downstream users rely on Calgary return flows. A strategy that relies entirely on consumptive reuse may not, in the end, provide a substantial net benefit to the river but may provide some cost reductions to Calgary. Such a strategy is unlikely in the real world, however, but the city's efforts should acknowledge the balance that must be struck.

Relevant BROM run name

CV_CB8.9_CalgaryCons+Reuse

N5. Move municipal licences from Highwood/Sheep system to Bow River

The Highwood River and Sheep River area of the Bow River system is recognized as being environmentally sensitive. It is experiencing considerable pressure and planning for municipal growth, yet has limited options for water supply, due in part to not having any control structures on the rivers. This strategy would increase the likelihood that municipal licences in the Highwood and Sheep system get the water they need while protecting the health of this river system by shifting certain municipal withdrawals from the Highwood and Sheep to the Bow River. Five sites were shifted in this way: Okotoks, Black Diamond, Turner Valley, Longview and High River.

In terms of infrastructure, this strategy would entail installing a 20-40 km pipe to the Bow from where the water is needed and pumping the water to that location. Return flows would go back to the Sheep and Highwood system via existing infrastructure, which would improve the flows and benefit the aquatic ecosystem. This was similar to one of several options evaluated through previous work for purposes of improving municipal water supply in the region.

With this strategy, it is possible that some industrial (non-irrigation) licences may be mixed in with the municipal licences that were moved to the Bow. The demand nodes were chosen based on municipality names from WRMM, which does not delineate what demand data is included in all the nodes (other than irrigation usage).

Model results and impacts

The Highwood and Sheep licences are senior licences on that system. When these demands were moved to the Bow, they were made senior to the irrigation district licences. This was a logical decision because the Highwood and Sheep demands are so small relative to the Bow flow that they are inconsequential. For modelling purposes, all Highwood and Sheep licences were moved to the Bow, but further detailed modelling may show that only some smaller portion of these licences could be relocated with less cost and similar assurance of water availability to these populations. In the model, for Turner Valley, water was taken from the Bow to fill their storage rather than go directly to their use, which is the same way their supply was taken from the Sheep.

Figure 28 shows the impact of this strategy on flow at the mouth of the Sheep River during non-drought conditions. (Note: The top of Figure 28 is deliberately cut off to provide higher resolution for the results in the lower flow portion of the chart.)

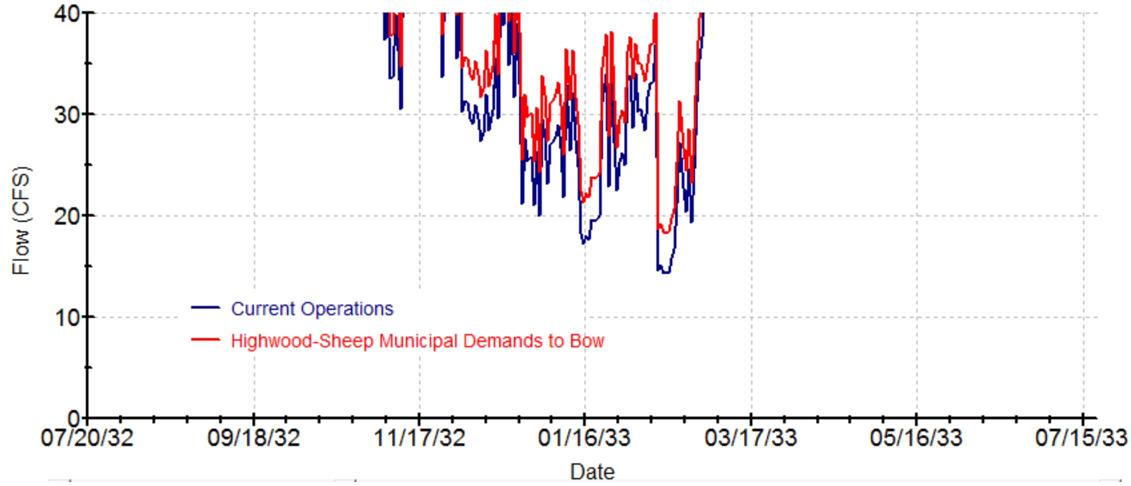

Figure 28: Flow at the mouth of the Sheep River during non-drought conditions (2032-2033)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

The main effect of this strategy is that it benefits the health of the Highwood and Sheep aquatic ecosystem. Specifically, it means a gain of about two cfs at the mouth of the Sheep River during periods of particularly low flow. While this does not appear to be a large absolute gain, it is significant because the total flow at this time is only about 12 cfs.

In-stream flows in the Sheep River were improved with no measurable effect on the Bow, including the flows below Bassano. There were no shortages to municipalities using the Bow and the overall health of the Sheep River is improved. By drawing water from the Bow, the Highwood and Sheep system would benefit significantly, with an improved fishery, better water quality and better ability of the Sheep in particular to assimilate waste. Much less water is being withdrawn from the Sheep and Highwood but treated water is still being returned to this system.

The costs for withdrawing Bow water and pumping back to the Highwood and Sheep system have in part been calculated as part of the Calgary Regional Partnership planning exercise, but are not included for purposes of this study.

Relevant BROM run name

CV_CB8.9_HWShp-MuniDmdsBow

N6. Increase winter carryover in Travers Reservoir

Travers Reservoir was built on the Little Bow River in 1954. It is part of the Oldman River drainage basin but receives most of its water from the Bow River via McGregor Lake and from the Highwood River via a canal to the Little Bow River. The reservoir is owned and operated by Alberta Environment and Sustainable Resource Development as part of the Carseland-Bow River Headworks System. The main purpose of the reservoir is to store water for irrigation in the Bow River Irrigation District (BRID). As well, it serves to minimize flooding of the Little Bow River and to maintain flow in the Little Bow River during low flow periods. Recreation is also an important use.[4]

By not drawing down Travers Reservoir as far as usual during the fall and winter, the BRID could effectively increase its storage capacity by increasing the amount of water carried over the winter. This strategy could be implemented without any infrastructure changes, thus making costs relatively low. To see the effect this strategy might have, the winter storage upper rule for Travers was increased by 3.3 feet (1 metre). Although not considered in this project, McGregor Reservoir is also a potential candidate for increased winter carryover.

Figure 29 shows new rule curves applied to Travers reservoir to enable winter carryover.

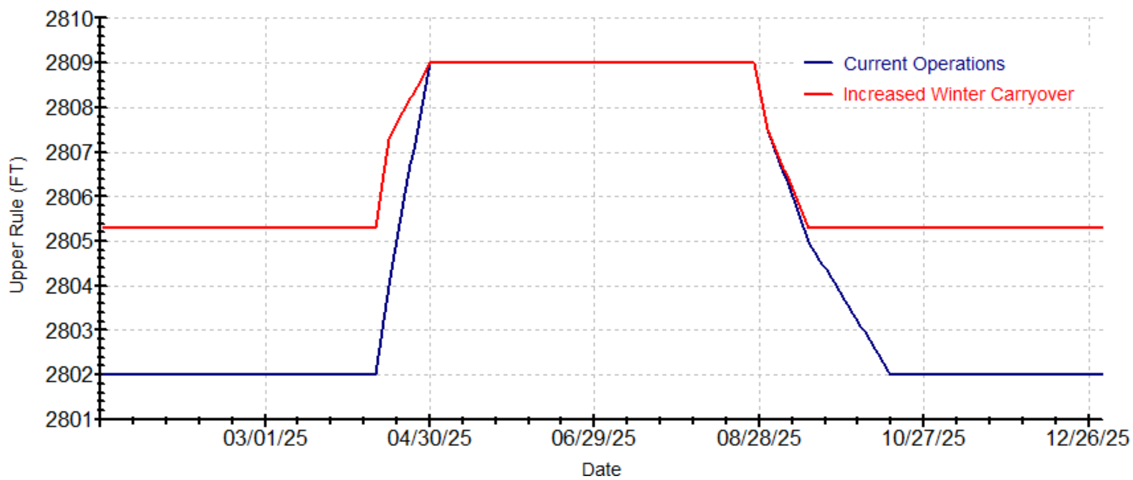

Figure 29: Travers elevation under non-drought conditions (2025)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

Model results and impacts

The current summer storage in Travers Reservoir is sufficient to weather even extreme droughts. As Figure 30 shows, under this strategy Travers would begin the year much closer to its summer level. This means that the BRID needs to withdraw less water from the Bow River to fill during the spring, decreasing its need for river calls. This in turn, allows TransAlta to better fill its reservoirs in periods of drought (Figure 31) and allows minimum flows to be maintained through

[4] This paragraph is adapted from: *Atlas of Alberta Lakes*, online at http://sunsite.ualberta.ca/Projects/Alberta-Lakes/view/?region=South%20Saskatchewan%20Region&basin=Oldman%20River%20Basin&lake=Travers%20Reservoir&number=123

Calgary for longer (Figure 32). This additional storage also frees water for use by other users, and slightly reduces shortages throughout the system (Figure 33).

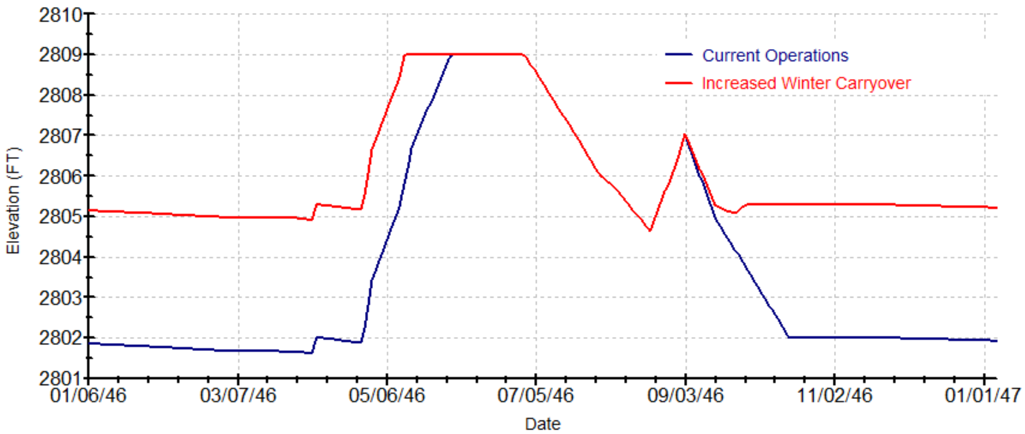

Figure 30: Travers elevation under drought conditions (2046-2047)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

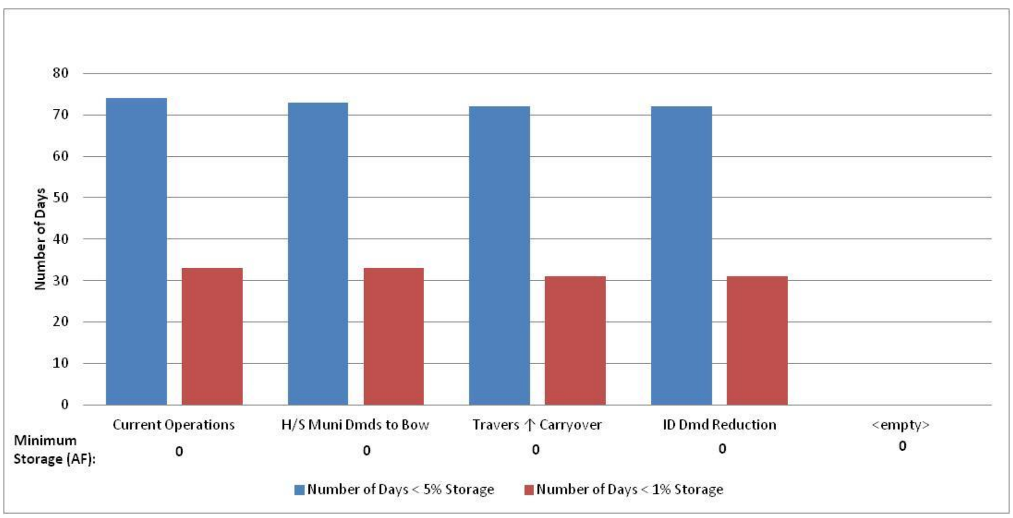

Figure 31: TransAlta system low storage days

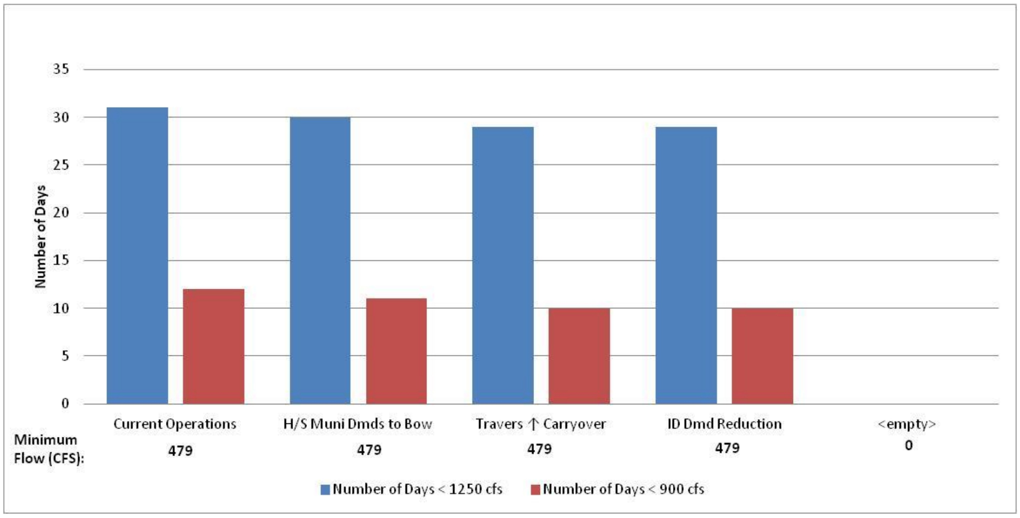

Figure 32: Calgary low flow days

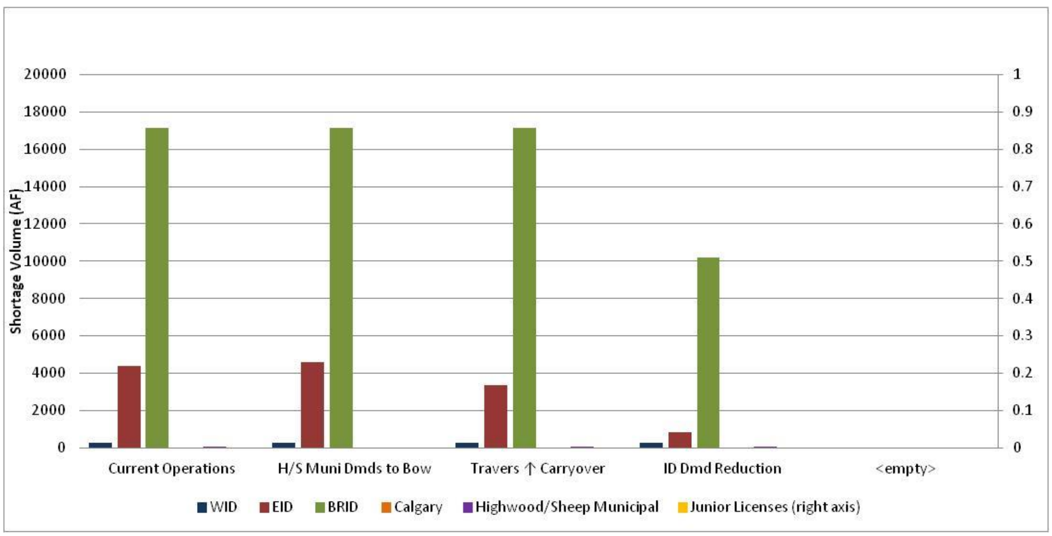

Figure 33: Total volume of shortages

This strategy has benefits across the system as it enables Travers to retain water that would otherwise be released at a time when little benefit can be gained from it. It also enables water to be drawn from storage rather than from the river. However, higher winter carryover could increase slightly the risks of erosion and downstream flooding.

Relevant BROM run name

CV_CB8.9_TraversCarryover

N7. Implement additional demand reduction in irrigation districts

Faced with growing water shortages due to climate change and variability, further demand reduction by irrigation districts (IDs) could represent one potential adaptation strategy. This idea was suggested to determine how much reduction in water use would be needed to achieve the same impact as the water bank. This specific strategy reduced irrigation demands by 30% and return volumes by 30%.

Due to data limitations, all climate scenarios assume the same level of demands for users. These demands are monthly averages based on the pre-existing data in the BROM. It would be expected that under drought conditions, demands would, in fact, be much higher than the monthly average. IDs in particular would likely ask for substantially more water if there was a lack of precipitation.

Given this understanding, properly reflecting irrigation demands under the 3yr Min climate scenario would probably entail increasing the existing monthly average demands by 50%. With this in mind, if the IDs were to reduce their demands by a third from what they would expect to need, the demands would return to the currently modelled levels (150% x 1/3 = 100%). As such, it could be considered that the base current operations already assume irrigation demand reduction and conservation.

To keep alternatives comparable, however, a run was introduced in which IDs reduce their demands by 30% relative to the base current operations (100% - 30% = 70%). Assuming that the ID demands are already understated, these demands become *extremely* low. As the results below indicate, it is clear that reducing demand alone is insufficient to adapt to potential extreme multi-year droughts.

Model results and impacts

Reducing irrigation demands has the obvious effect of decreasing the number of river calls placed on TransAlta reservoirs, which led to increased storage in the TransAlta system (Figure 34). In an extreme drought, however, the additional reductions in demand are still not enough to prevent near-constant river calls. Thus TransAlta still empties its reservoirs, and Calgary flows are not substantially improved (Figure 35).

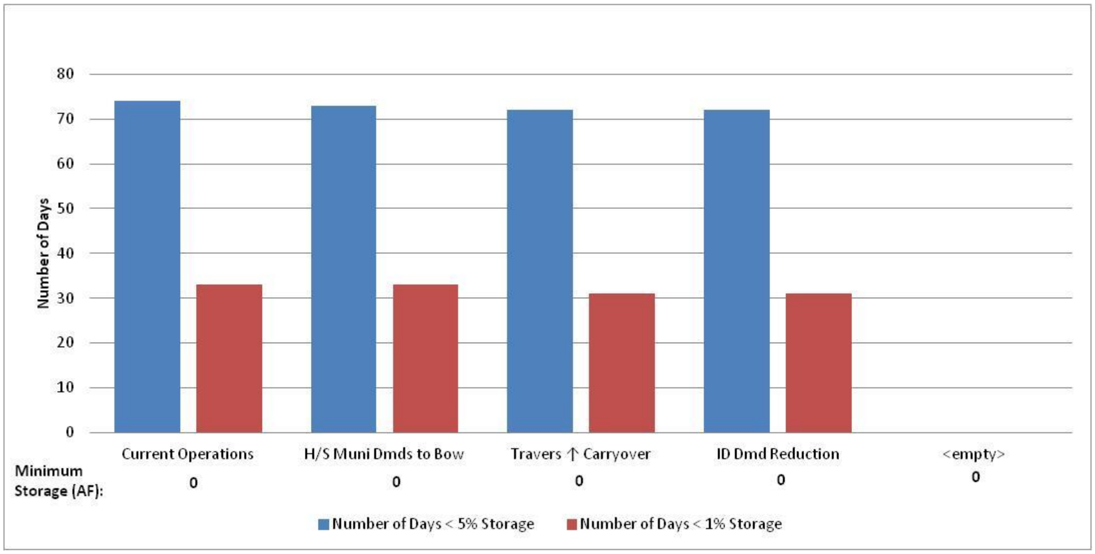

Figure 34: TransAlta system low storage days

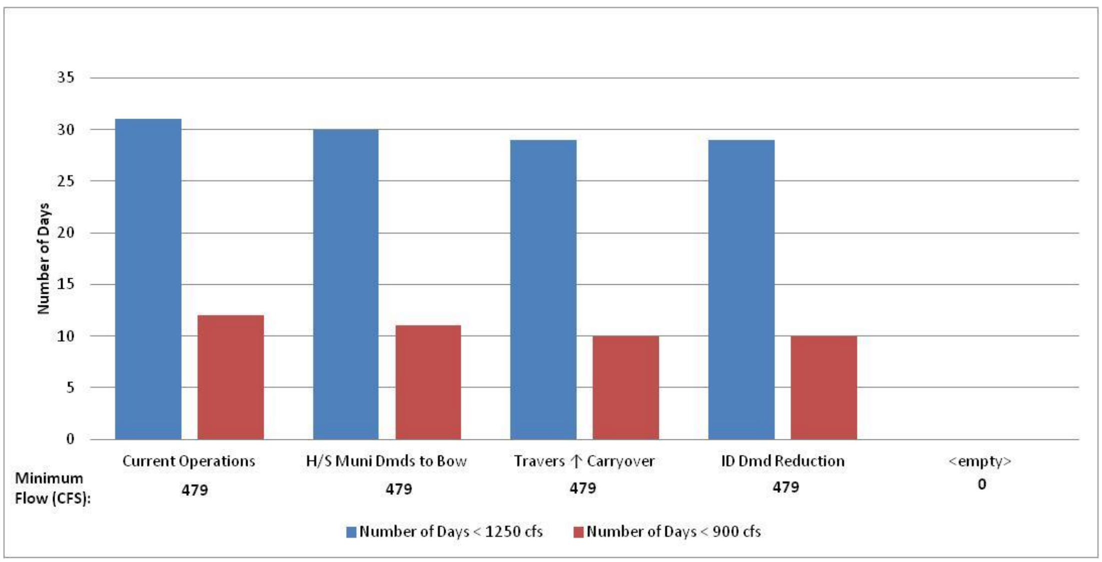

Figure 35: Calgary low flow days

Bassano flows, which indicate the overall health of the river, are somewhat improved (Figure 36), thanks to smaller requests for water by the IDs, but the improvement is questionable considering the extreme levels of demand reduction the IDs would have to attain.

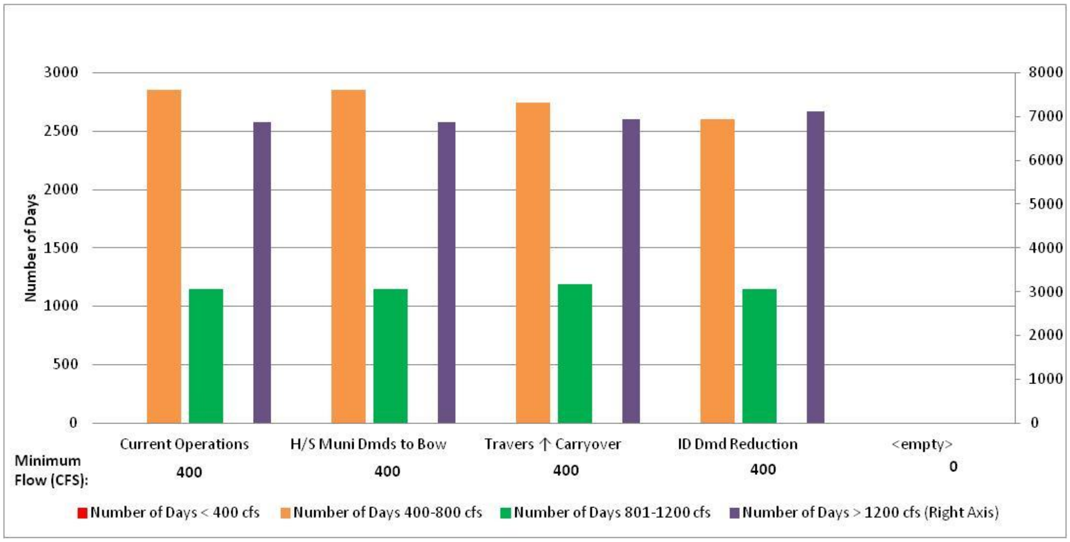

Figure 36: Bassano low flow days

Demand reductions can offer a number of benefits and, used in combination with other strategies, can perhaps help to offset the effects of changed hydrology due to climate impacts. However, if climate impacts and low flows are as severe as suggested in some years of the model, it is likely that irrigators would consider a wide range of responses including more aggressive conservation measures, changes in crop types, and emergency drought relief programs or crop insurance.

Relevant BROM run name

CV_CB8.9_IDConservation

4.1.1 Most Promising Strategies to Benefit the Watershed under Normal Conditions

Four specific strategies and one more general approach were suggested as having the most promising benefits to the watershed under the "normal" conditions that occurred over most of the years of the 30-year period for the chosen climate scenario. These strategies could be considered or implemented now to improve aquatic ecosystem health and create opportunities for economic development in the watershed. They would also be valuable in building resilience and helping the basin adapt to more severe climate conditions should these conditions arise. The five approaches for improving the existing situation focus on changing demands and management rather than building new infrastructure.

N1: Implement preferred scenario

The two primary aspects of the Preferred Scenario as proposed in the BRP are 1) the water bank, and 2) the approximate stabilization of Lower Kananaskis Lake and river system for ecological improvements throughout that series of parks and protected areas. The water bank amounts to approximately 10% of TransAlta storage and capturable inflows in any given year. For purposes of this study, some of the Preferred Scenario priorities were altered to better adapt to the extreme drought conditions of supply and demand modelled under the 3yr Min scenario. As envisioned in the original BRP report, intelligent management of the water bank allows this alternative to provide substantial benefit for basic ecological flows in the river with few side effects for other users.

N2: Adjust fill times for three largest TransAlta reservoirs (Minnewanka, Spray and Upper Kananaskis)

This strategy changes the normal operational patterns so the three TransAlta reservoirs would be approximately full by July 31, held full until October 15, and then allowed to fall normally. This would leave more natural flow to pass in August and September to meet higher seasonal downstream needs when flows are typically lower. The extra storage offers some additional flexibility for managing drought, reducing the number of low storage days for TransAlta, and improving the number of low flow days through Calgary. However, there is still a risk that late summer convective storms could lead to flooding if reservoirs are full and TransAlta needs to spill.

N5: Move municipal licences from Highwood/Sheep system to Bow River

This strategy would increase the likelihood that municipal licences in the Highwood and Sheep system get the water they need while protecting the health of this river system by shifting certain municipal withdrawals from the Highwood and Sheep to the Bow. A 20-40 km pipe would be installed to pump water from the Bow to where it is needed, and return flows would go back to the Sheep and Highwood system via existing infrastructure, which would improve the flows and benefit the aquatic ecosystem. In-stream flows in the Sheep River were improved with no measurable effect on the Bow, including the flows below Bassano. There were no shortages to municipalities using the Bow and the overall health of the Sheep River was improved.

N6: Increase winter carryover in Travers Reservoir

By raising the winter storage upper rule for Travers Reservoir by 3.3 feet, the BRID could effectively increase its storage capacity. This strategy could be implemented without any infrastructure changes, thus making costs relatively low. This strategy enables Travers to retain water that would otherwise be released at a time when little benefit can be gained from it. It also enables water to be drawn from storage in the spring before the freshet begins rather than from the river during this low flow period. However, higher winter carryover could increase slightly the risks of erosion and downstream flooding.

Conservation and demand reduction

Several strategies to reduce demand were examined, with a focus on large licence holders: the City of Calgary and irrigation districts. Reducing Calgary demands left more water in the river, thereby contributing to the health of the downstream aquatic ecosystem and providing more flexibility for other water users. Reducing irrigation demands decreases the number of river calls placed on TransAlta reservoirs, which increases storage in the TransAlta system. In an extreme drought, however, the additional reductions in demand are still not enough to prevent near-constant river calls. Conservation and demand reductions can offer a number of benefits and, used in combination with other strategies, can perhaps help to offset the effects of changed hydrology due to climate impacts.

4.2 Strategies for Adapting to Severe Drought Conditions

D1. Restore Spray Reservoir to full design capacity

This strategy was initially identified in the Bow River Project. It envisions restoring the capacity of Spray Reservoir to its original design specifications, thus increasing storage by about 60,000 AF. The original hypothesis was that this storage would be used to offset lower streamflows caused by stabilizing Lower Kananaskis Lake and used in combination with the other reservoirs to increase flow capacity at the upper end of the Bow system and provide benefits throughout the basin.

The new storage in Spray was subject to the same rules as existing TransAlta storage in that water is stored only when there is no senior licence demand in the basin, but downstream users could not call on it once it became stored water. For the purposes of this project, a node was added to the system to represent the additional capacity of a restored Spray Reservoir.

Model results and impacts

During non-extreme portions of the 3yr Min climate scenario, water was stored in the restored Spray Reservoir and drawn on regularly, as seen in Figure 37. However, during truly extreme droughts the inflows to restored Spray were insufficient to allow it to fill (Figure 38).

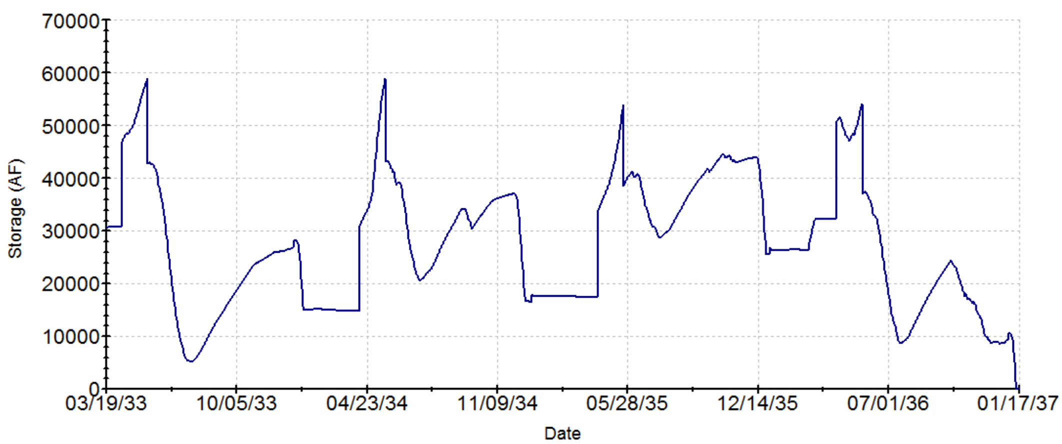

Figure 37: Restored Spray Storage during non-extreme drought conditions (2033-2037)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

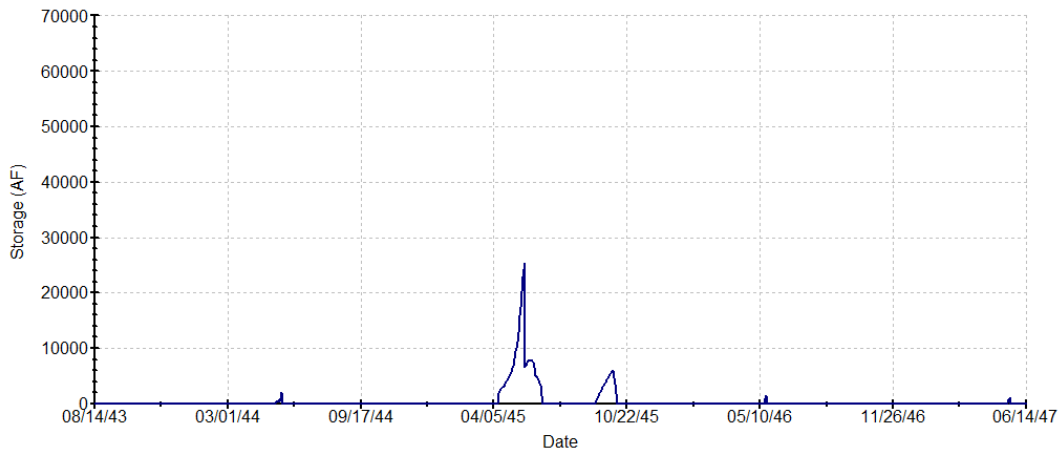

Figure 38: Restored Spray storage during extreme drought (2043-2047)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

Several reasons were suggested as to why Spray does not fill during drought conditions:

- It is filled from a relatively small watershed.
- The naturalized flow data used to generate climate scenarios may not be entirely representative and TransAlta may have historical data that imply Spray would fill better.
- The model draws down Spray ahead of other reservoirs in the system to meet licence needs.

There is some benefit to this strategy in that it could help extend the time that a drought could be withstood; it offers modest benefits to TransAlta storage (Figure 39), which in turn improves flows through Calgary.

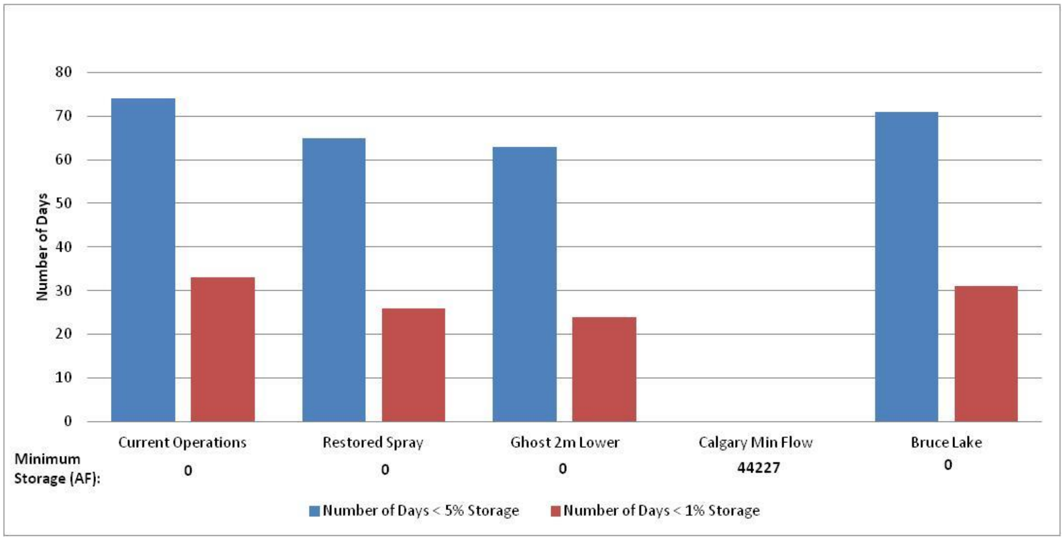

Figure 39: TransAlta system low storage days

The overall benefits from this strategy do not appear large, compared with those derived from Strategy N2, which proposes adjustments to TransAlta reservoir fill rules. For this strategy to succeed and for Spray to carry water over in dry years, the operating rule curves for the

TransAlta reservoirs would need to be changed. A disadvantage of this strategy is the uncertain capital cost associated with restoring Spray to its original design specifications.

Relevant BROM run name

CV_CB8.9_RestoredSpray

D2. Draw Ghost Reservoir down preferentially to 6.6 feet (2 m) below normal pattern

Ghost Reservoir is the most downstream reservoir in TransAlta's system, excluding Bearspaw. Bearspaw has a relatively small capacity, which means that Ghost has the most ability to capture large "spike" inflows to the entire system, such as heavy rains or very rapid melt. In the BROM, Ghost operations adhere as strictly as possible to the "normal" curve, which provides very little empty space to catch such pulse flows. Consequently, such flows pass through Bearspaw and usually contribute to flows well in excess of 1,250 cfs past Bearspaw and, accordingly, higher flows downstream past Bassano.

Drawing down Ghost by up to 6.6 feet (two metres) before taking water from any other reservoir enables Ghost to capture these pulse flows and leverages its position as having the greatest catchment area. Once Ghost is 6.6 feet below its normal pattern, all reservoirs are drawn down equally. In this strategy, Ghost was removed from reservoir deficit balancing and was preferentially accessed as long as its storage remained within 6.6 feet of the normal pattern.

Model results and impacts

As Figure 40 shows, the new operations that reflect this strategy (red line) provide some benefit as long as there are inflows to be captured. Under non-drought winter conditions, the captured flows are due to releases from upstream storage; in this case, Upper Kananaskis Reservoir was at its upper storage limit and released water that could then be captured in Ghost (between 01/22/43 and 03/23/43 in Figure 40). Later, in the spring (starting about 05/22/43 on the graph), Ghost captured the usual additional inflows that occur seasonally under non-drought conditions. Without the additional capacity in Ghost, all of these flows would have passed by.

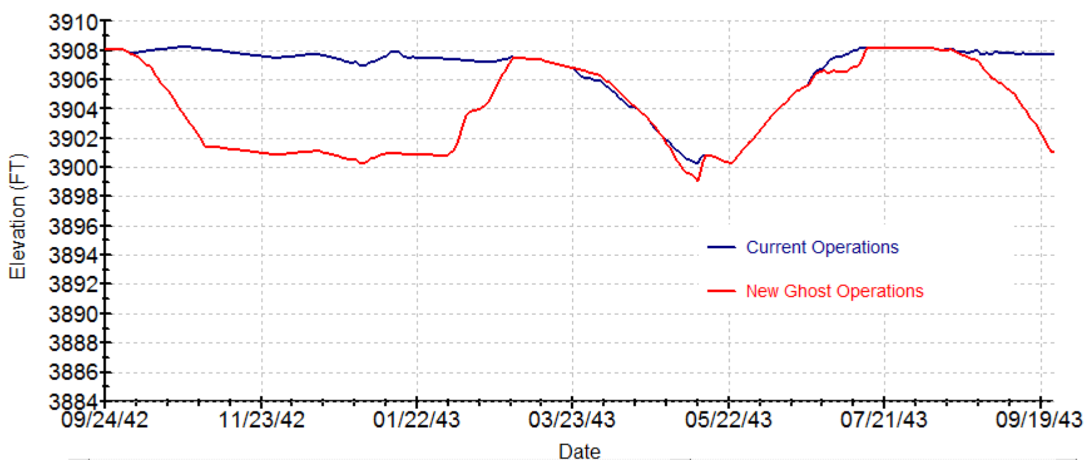

Figure 40: Ghost Reservoir elevation under non-drought conditions (2042-2043)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

However, during severe drought conditions, these spikes simply do not occur, as seen in Figure 41; if there are inflows, they get captured at any point in the system. During severe drought, Ghost levels drop along with those of other reservoirs in the TransAlta system.

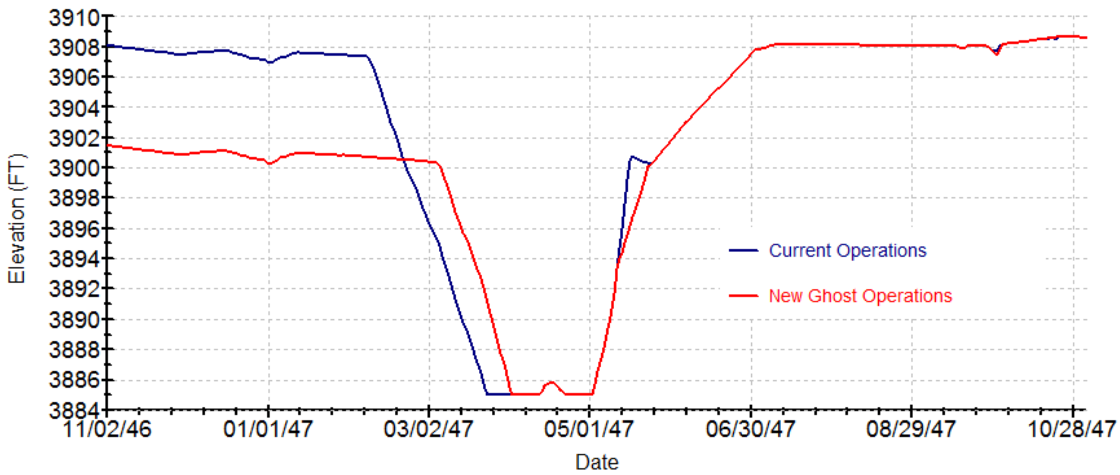

Figure 41: Ghost Reservoir elevation under drought conditions (2046-2047)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

Figure 42 illustrates the potential for this strategy to result in fewer low storage days in the TransAlta system compared with current operations.

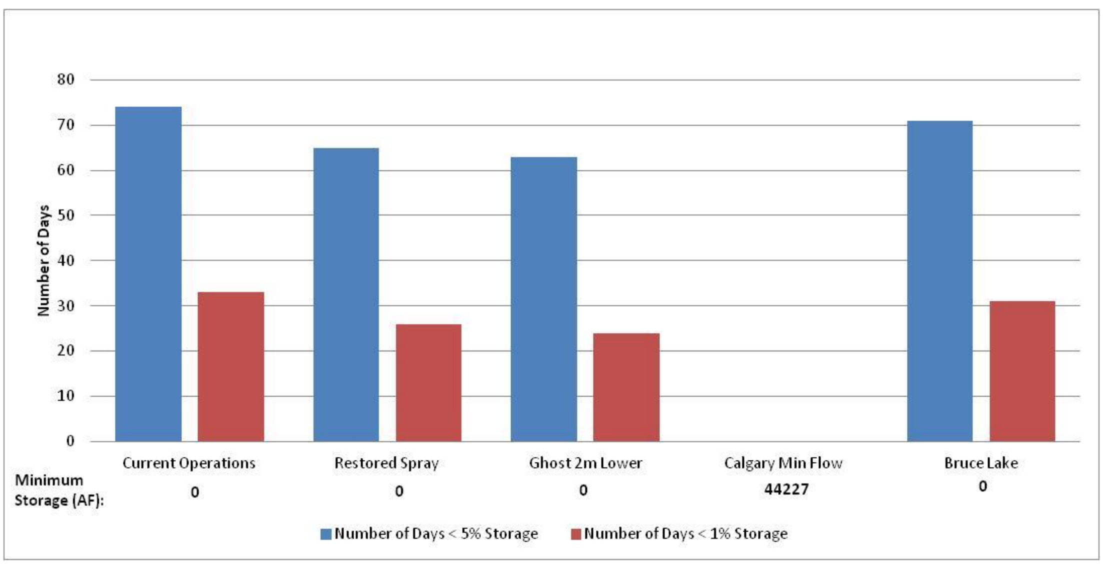

Figure 42: TransAlta system low storage days

Preferentially drawing down Ghost yields similar benefits to restoring Spray but without the capital costs. This strategy would generally be more beneficial than restoring Spray as it is easier and more efficient to fill a small reservoir in a large watershed (Ghost) than to fill a large reservoir in a small watershed (Spray). Using Ghost in this manner could also allow it to mitigate downstream flooding, particularly in Calgary.

However, lower reservoir levels could have some negative impacts. Recreational activities on the reservoir could be affected, particularly boating and its associated infrastructure such as marinas and docks. Lower water levels could also affect property owners along the reservoir with negative recreational and aesthetic impacts.

One other potential issue is the impact on power generation. TransAlta requires a minimum gross operating head for the Ghost units of 75 to 80 feet, below which it is not possible to generate power from them. Thus the acceptable minimum elevation for Ghost for power generation purposes is 3,880 feet. Although Figure 41 suggests that under non-drought conditions, this strategy would easily maintain the minimum elevation for power generation, TransAlta would be more exposed to the risk of being unable to operate its turbines at Ghost. Under drought conditions, levels approach those needed to produce power regardless of the operating rules.

Another strategy considered for enabling Ghost to take advantage of pulse flows was to raise the reservoir's full supply level (FSL) by two metres. This would enable water to be captured during spikes, but the reservoir could still be operated at 6.6 feet below FSL most of the time (that is, at its current FSL). This approach would reduce the generating risk to TransAlta and would still improve ability to mitigate floods. However, it could pose risks related to local flooding along the reservoir shoreline, with occasional impacts on the community, railway, and First Nations land during extreme drought or flood conditions.

Relevant BROM run name

CV_CB8.9_Ghost2mLower

D3. Reduce minimum river flow through Calgary

Current operations ensure that the minimum flow through Calgary (i.e., via Bearspaw releases) of 1,250 cfs year round is met to ensure water quality standards continue to be met. This is especially important during the summer periods when dissolved oxygen can become a concern for aquatic ecosystems. The strategy to reduce minimum flow through Calgary was proposed as a means, when drought conditions are expected, to conserve more water in upstream storage and mitigate the exceptional low flows through Calgary when TransAlta storage was completely exhausted.

Several approaches were suggested, but the strategy that was modelled saw a reduced minimum flow through Calgary to 900 cfs from October 1 to December 31 with the following parameters:

- TransAlta storage is assessed on October 1 each year.
- If total live storage is less than 400,000 AF (about 80% of the seasonal full level), Calgary minimum flow is set to 900 cfs through to December 31.
- If total live storage is greater than 400,000 AF, Calgary minimum flow remains at 1,250 cfs.
- The flow through Calgary between January 1 and October 1 remains unchanged at 1,250 cfs.

Model results and impacts

As seen in Figure 43, reducing minimum flow through Calgary allowed a little extra storage to be maintained in TransAlta reservoirs during a critical period in 2047. This in turn allowed the flow to Calgary to be maintained for longer at a slightly lower flow, without causing a severe low flow event, as Figure 44 illustrates.

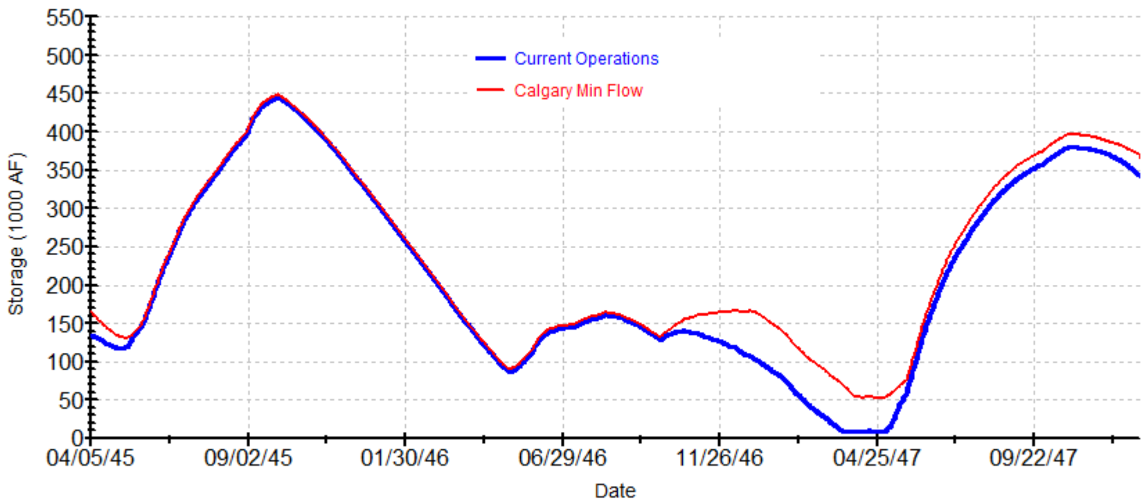

Figure 43: Comparison of live storage in TransAlta reservoirs under drought conditions, with and without the trigger (2045-2047)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

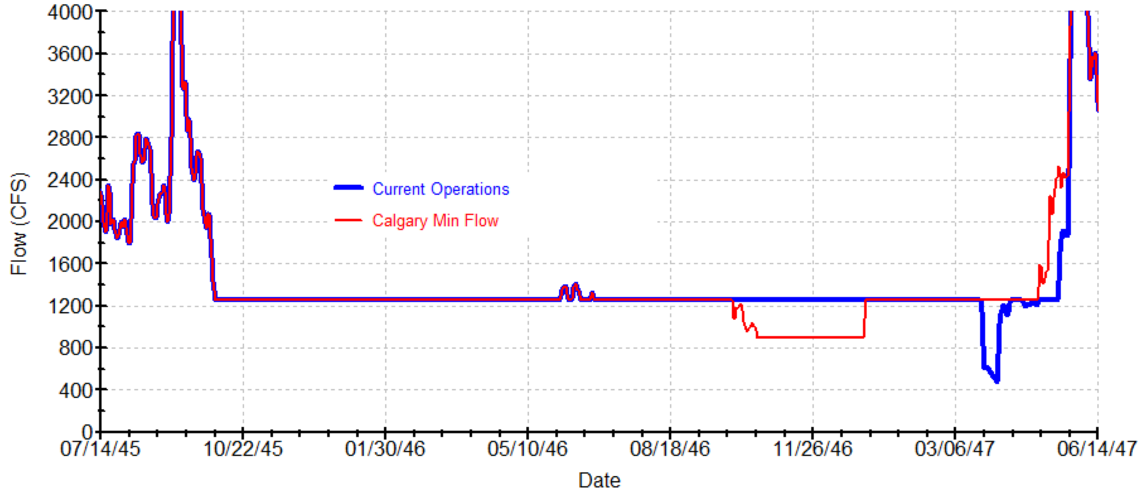

Figure 44: Flow out of Bearspaw to Calgary under drought conditions, with and without the trigger (2045-2047)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

As seen in Figure 45, this strategy essentially removes all the low storage days for TransAlta over the 30-year period compared with current operations.

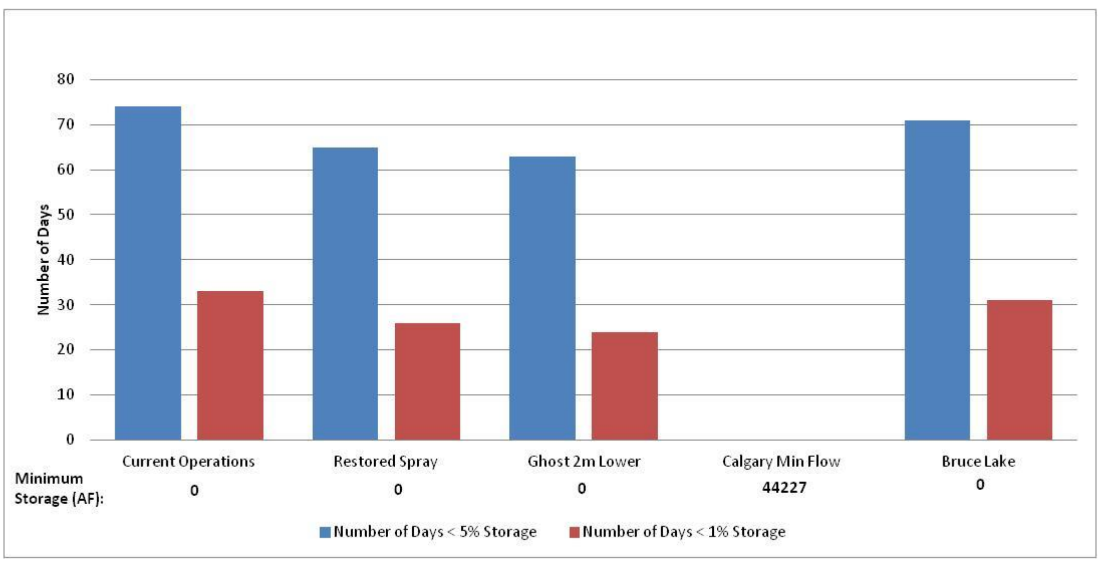

Figure 45: TransAlta system low storage days

This strategy would protect upstream storage. However, because less water is in the river and Calgary's return flow becomes a higher proportion of total flow, assimilative capacity may be reduced which could affect water quality, also leading to higher wastewater treatment costs. This strategy could negatively affect brown trout spawning due to lack of stable water levels and temperature concerns.

Field conditions would be a critical consideration for this strategy. River ice cover often forms in Calgary in December and it can happen quickly if there is a significant cold snap. If ice formed at a 900 cfs flow, that would be the flow limit until March or April. Flow could be reduced to 900 cfs for October and November but may not be advisable past mid-December.

Relevant BROM run name

CV_CB8.9_CalgaryMinFlow

D4. Increase off-stream storage in the WID (Bruce Lake)

Bruce Lake is envisioned as a way to increase off-stream storage in the Western Irrigation District (WID) by providing 41,400 AF of live storage (Figure 46). Bruce Lake would fill based on WID's licence, subject to those licence limitations. For this project, Bruce Lake was modelled as an adaptation strategy in terms of how it could be managed to meet both WID needs and the needs of others in the basin.

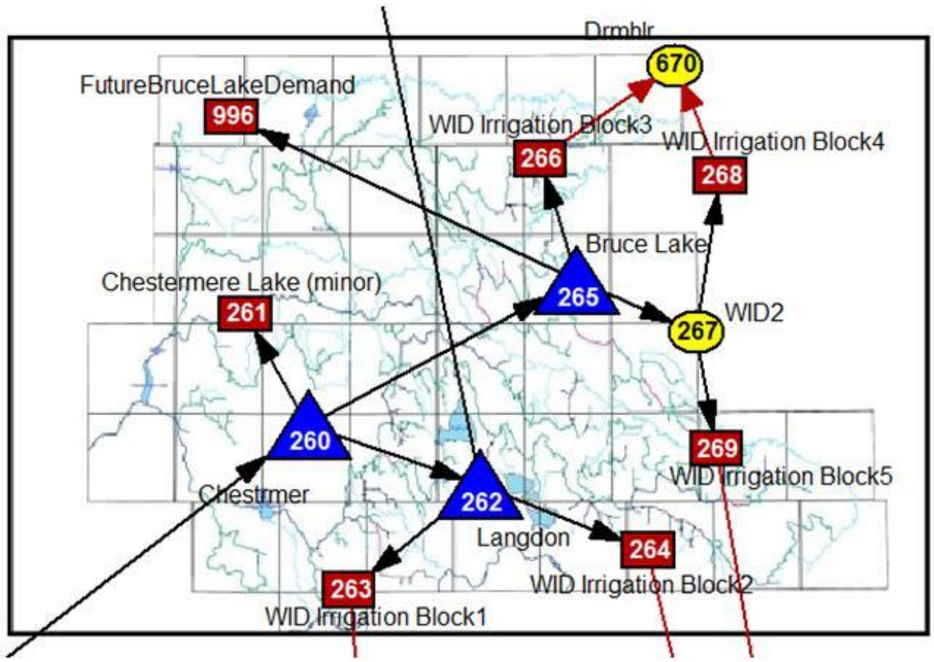

Figure 46: Location of Bruce Lake (blue triangle 265) for potential off-stream storage

The reservoir could benefit the river, as WID could reduce its diversion from the Bow River by meeting part of its irrigation needs from Bruce Lake storage instead, although the licensed right to divert from the river would be retained. Bruce Lake would fill during high flow periods and then later, less water would be needed from the river when this reservoir is tapped instead. Leaving this additional water in the river would be particularly valuable in low flow periods.

In addition, the concept of Bruce Lake has always included using some of the storage capacity to meet local municipal needs. Specifically, this strategy included an additional 10 cfs to meet year-round municipal demand that would be serviced by Bruce Lake. A side benefit of this new off-stream storage is the potential for enhanced regional economic development opportunities as well as recreation benefits for the region.

In this model run, WID would withdraw exclusively from Bruce Lake when the reservoir is more than 50% full and when Bassano flow averages for the three previous days are below 800 cfs. When these criteria are not met, WID would take water from the river in accordance with its licensed allocation. To demonstrate the maximum possible benefit to the river, flows that the WID did not take (i.e., demands that were instead met by Bruce Lake) became protected in the same way as water bank releases. The model ensured that these additional flows passed downstream of Bassano.

Model results and impacts

As Figure 47 illustrates, Bruce Lake would be used extensively during drought events such as those projected in the 3yr Min climate scenario used for this project. The very large drop of about 20,000 AF in 2046 is the worst year; inflows are exceedingly low at that time as TransAlta storage is depleted, and Bruce Lake alone meets those demands in full for nearly the entire year.

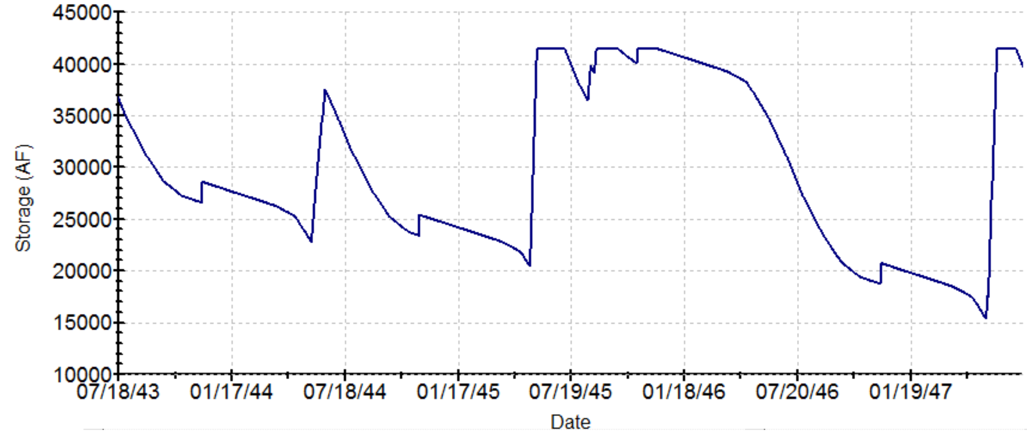

Figure 47: Live storage available in Bruce Lake during drought conditions (2043-2047)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

The most obvious benefit from the addition of Bruce Lake is to the WID, as Figure 48 shows. Since the water saved by using Bruce Lake is protected through Bassano, however, no substantial benefits accrue to the other IDs.

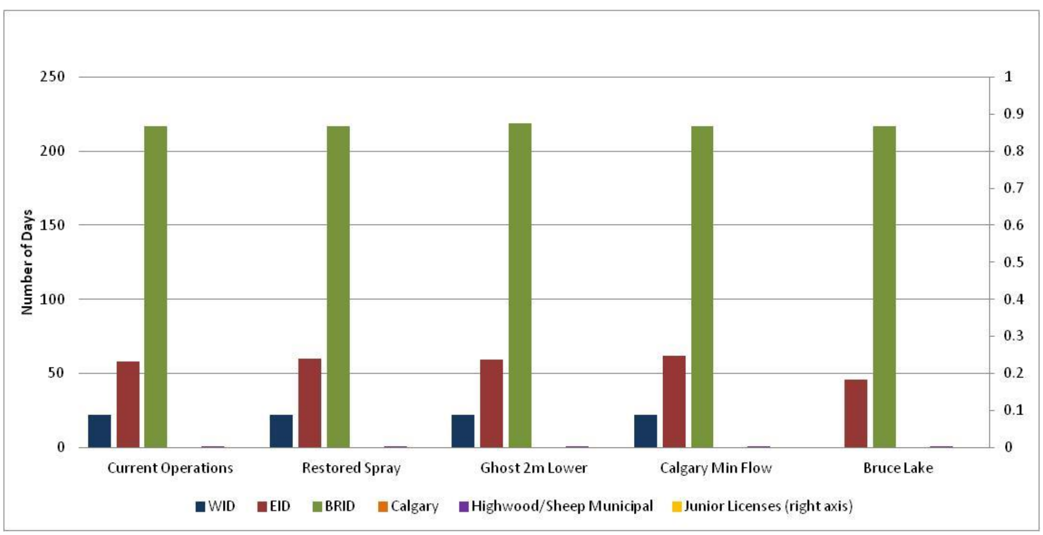

Figure 48: Number of shortage days

Although Bruce Lake does not directly supplement flows below Bassano, the water that WID forgoes is "protected" until it passes downstream of Bassano Dam; that is, no other users can divert it. This does improve Bassano flows (Figure 49), though not to the 800 cfs threshold of the primary performance measures. Flow improvement is much more modest (<100 cfs) but worth noting as it occurs even in the worst year of the three-year drought.

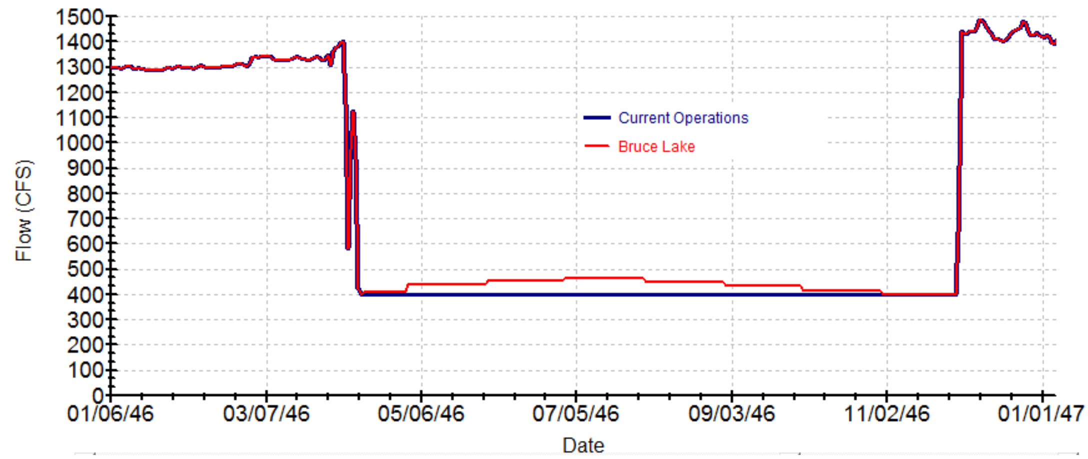

Figure 49: Flow below Bassano Dam (2046-2047)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

As the irrigation demands served directly by Bruce Lake never exceed 75 cfs, with average annual demand at 22,900 AF, the maximum supplementary flow is insufficient to substantially increase Bassano flows, which are used as a surrogate for overall river health. In the model, however, TransAlta will release flows to meet the 400 cfs requirement at Bassano and downstream junior licences if need be. In the 3yr Min scenario, this situation arises. As such, the additional water foregone by WID allows TransAlta to occasionally store a little extra water, which helps to ameliorate some drought circumstances (see Figure 50).

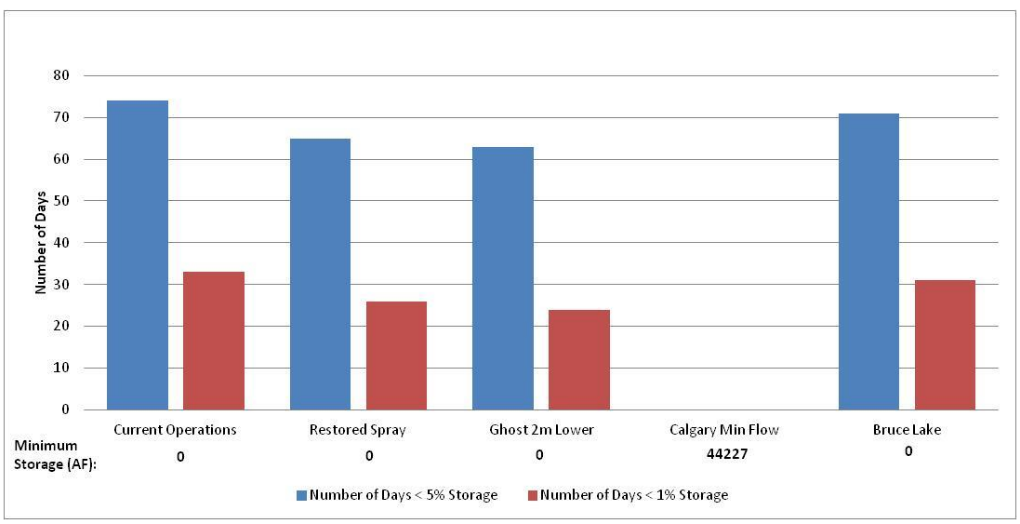

Figure 50: TransAlta system low storage days

Since normal operations resume when Bruce Lake falls below 50% full, WID reasserts its licence priority once that occurs. This leads to longer periods of river calls during and after a drought event. Although the effect is minor (<1% of total days), this causes some small increase in the number of 400-800 cfs flow days, as seen in Figure 51.

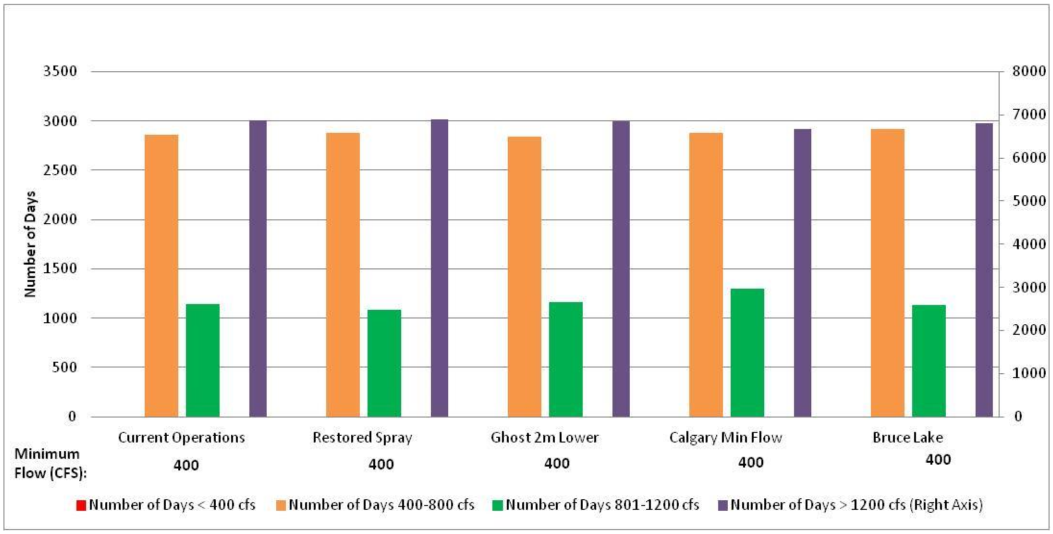

Figure 51: Bassano low flow days

This CDF plot (Figure 52) of current operations and Bruce Lake shows that with Bruce Lake there is a slightly reduced frequency of low flows (400-500 cfs range), which comes at a cost of supplementation by reducing periods of higher flows in the 750-1000 and 2000-3000 cfs range.

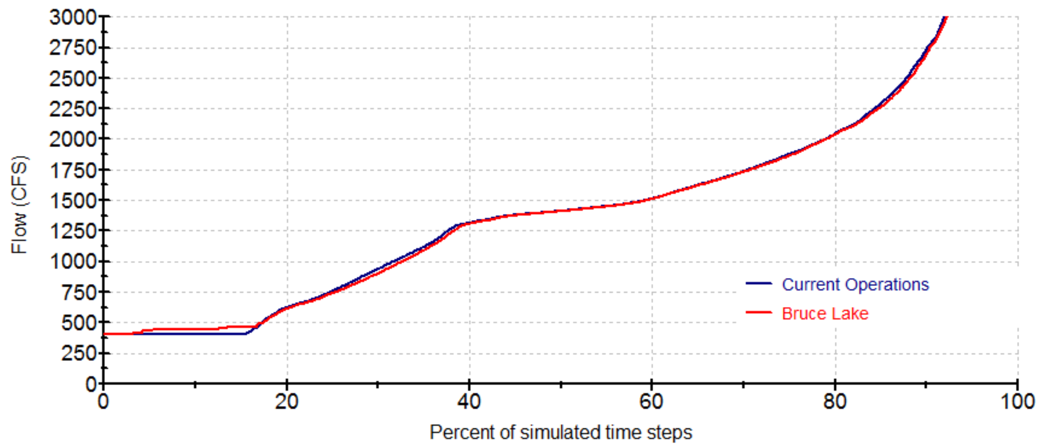

Figure 52: Bassano flow probability distribution

The addition of a 10 cfs year-round municipal demand could be met with few ill effects even under the severe drought conditions in the modelled climate scenario.

The WID shortages addressed in the model are probably understated, which means that Bruce Lake will likely have a bigger impact than the model shows.

Capital costs and time required for construction represent potential disadvantages.

Relevant BROM run name

CV_CB8.9_BruceLake

D5. Manage return flows from WID through Crowfoot Reservoir

Another strategy involving increased off-stream storage is the addition of a reservoir on Crowfoot Creek to capture flows through portions of the WID (see Figure 53). This area was viewed as a suitable location for a reservoir, so this strategy was examined to see if it could provide substantial benefit to the river. Its location allows it to capture most of the returns from the WID, but it would also be possible (through the construction of spillways) for the WID to route extra water through their system with the express intent of filling Crowfoot Reservoir. Crowfoot would then return its flows to the Bow River directly above Bassano Dam.

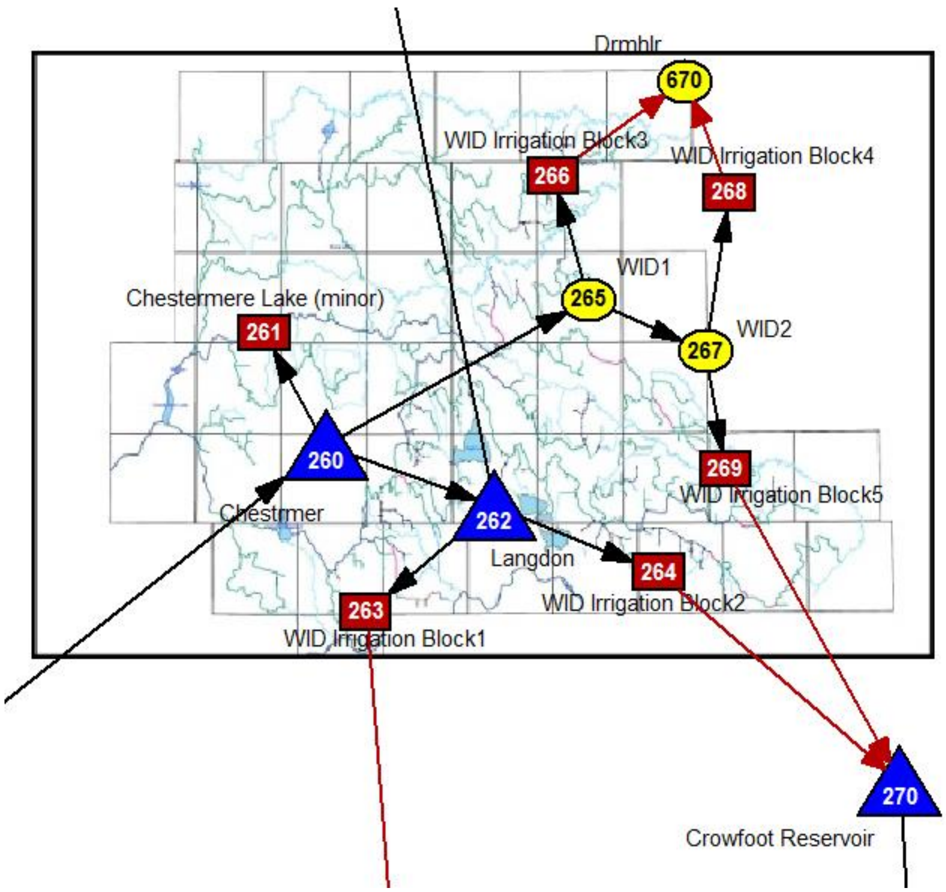

Figure 53: Location of potential Crowfoot Reservoir (blue triangle 270)

Several assumptions were needed to model the reservoir. Capacity was arbitrarily modelled at 30,000 AF, and water would only be released to supplement flows to 650 cfs below Bassano any time flow past Carseland dropped below 650 cfs. Filling of the reservoir was limited to excess capacity in WID's canals – at most 500 cfs. Its window for filling was also limited by the typical diversion season, but it was thought that seasonal flows would allow the reservoir to fill for an additional two weeks past the irrigation season. To prevent harm to other users or the river, Crowfoot was granted a maximally junior storage licence and was not allowed to store water when flows below Carseland fell below 800 cfs or when a river call had been placed on the river. Further, when a river call was on, all return flows from the WID were passed on to ensure the Eastern Irrigation District (EID) suffered no additional hardship.

Model results and impacts

Crowfoot Reservoir saw regular use in most years of the record, drawing down primarily any time IDs used river calls and drew the Bow down to its 400 cfs limit (Figure 54).

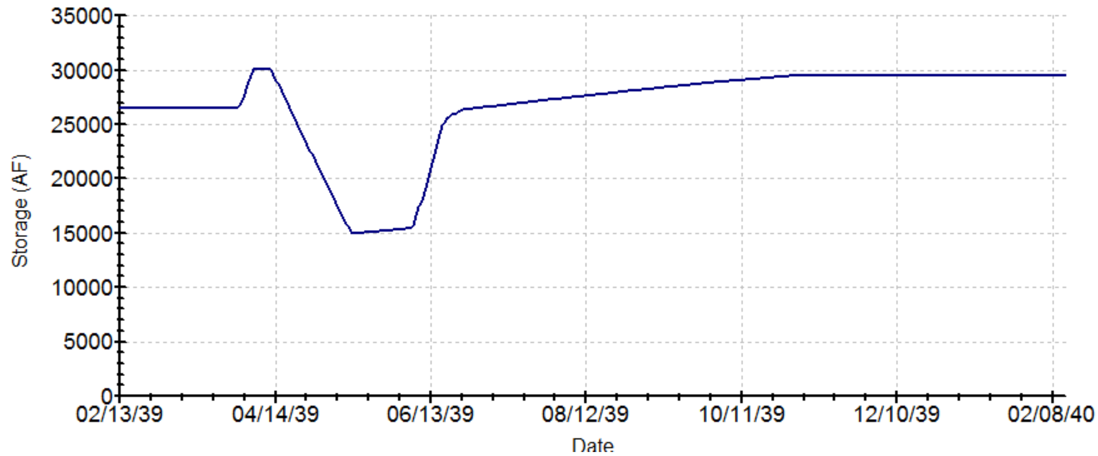

Figure 54: Crowfoot Reservoir storage (2039-2040)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

During the most extreme events, however, near-constant river calls prevented Crowfoot Reservoir from filling. In the three-year drought situation the reservoir emptied and remained at or near empty for several years (Figure 55).

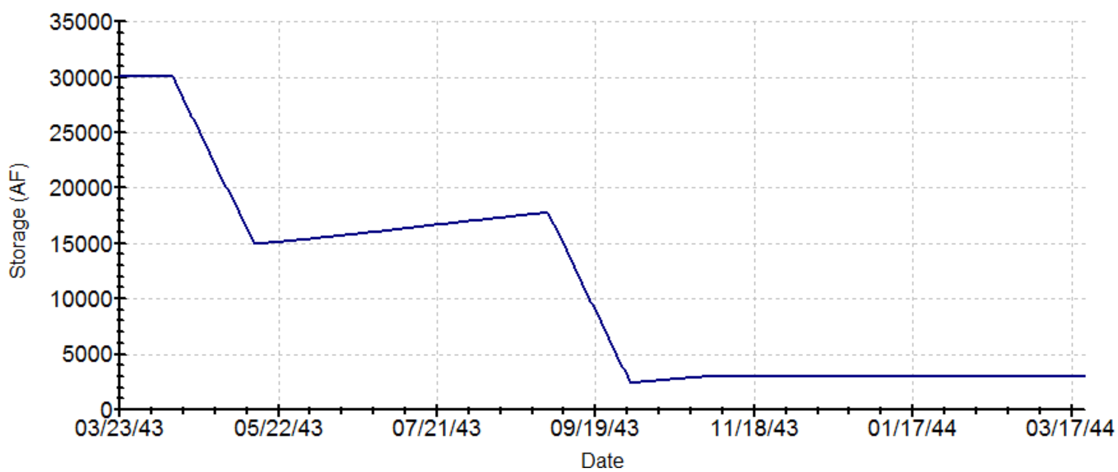

Figure 55: Crowfoot Reservoir storage (2043-2044)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

As implemented, Crowfoot had few impacts on the system as a whole outside of Bassano flows. As it targeted a 650 cfs flow, it was largely invisible to the primary Bassano flow performance measure. Under closer examination, however, supplementation did show an effect. The number of days where flow was below 650 cfs was reduced by roughly 1%, largely being replaced by 650-800 cfs days (Figure 56).

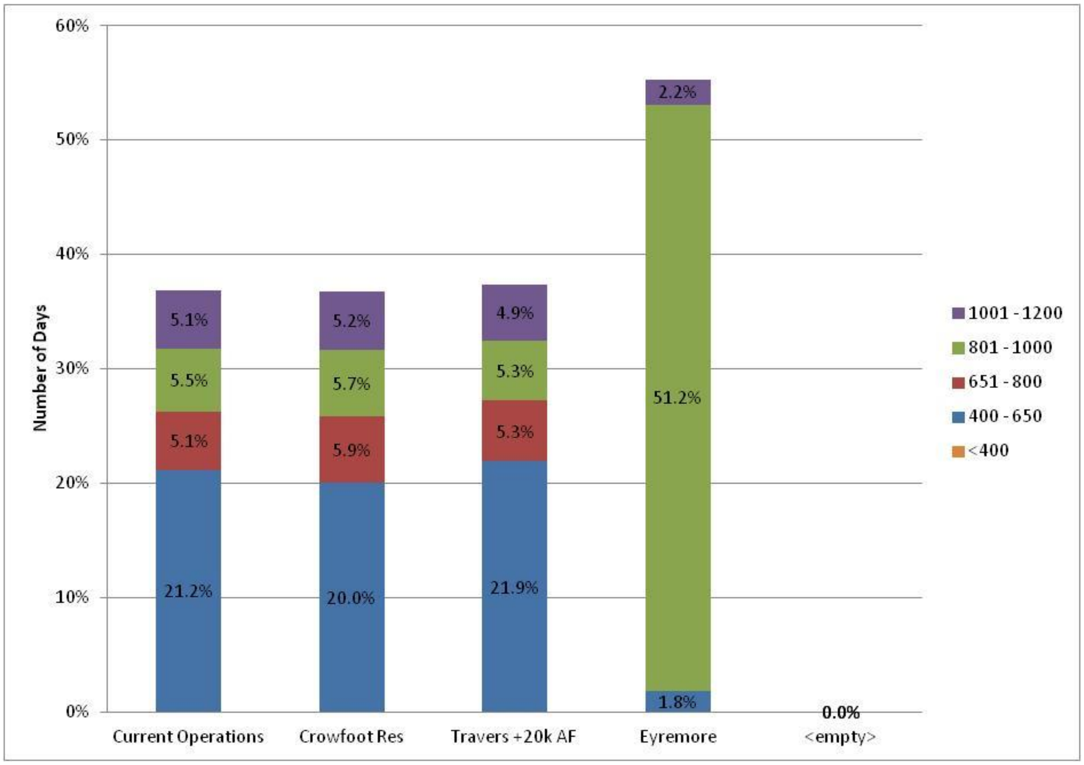

Figure 56: Percent of days with low flows past Bassano

Similar to the Preferred Scenario, this was accomplished by trading some of the very high flow days for supplementation at low flows, as shown in the CDF in Figure 57.

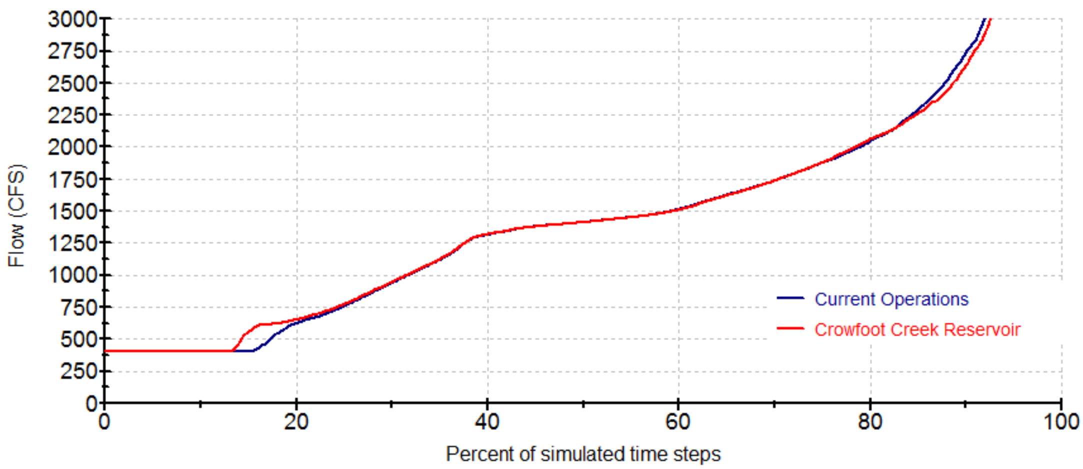

Figure 57: Bassano flow probability distribution

Although the benefit to Bassano flow seemed underwhelming compared to the Preferred Scenario, Crowfoot Reservoir only emptied in a few years of the record. This would suggest that there is room to be a good deal more aggressive with its releases. The limitation on filling during droughts means it probably cannot serve as an effective adaptation to multi-year droughts, but it could have potential for single year droughts or for alleviating pressures during lower flow years. It's also worth noting that, although Crowfoot can supplement flows at Bassano, it has no ability to improve performance in the upstream portion of the Bow.

Relevant BROM run name

CV_CB8.9_CrowfootRes

D6. Increase Little Bow/Travers storage capacity

Increasing Little Bow/Travers capacity is envisioned as a way to help the BRID, and consequently the river system as a whole, deal with shortages. Although the additional storage would likely come from combining Little Bow and Travers Reservoirs into one "super reservoir," for modelling purposes, the 20,000 AF of additional storage was simply added to Travers. Because of the way the model is constructed, both approaches will yield identical results. For this strategy, Travers winter levels remained at pre-expansion levels, while summer levels were increased to accommodate the extra storage. The BRID is actively considering this strategy.

Model results and impacts

Figure 58 shows the elevation of Travers Reservoir during severe drought conditions under current operations and with the additional storage.

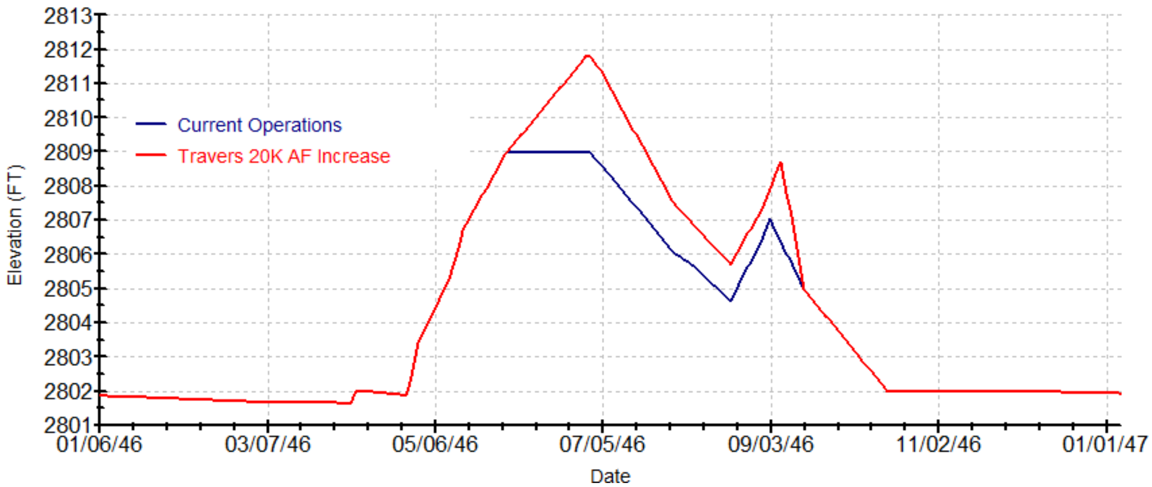

Figure 58: Travers storage during drought conditions (2046-2047)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

Figure 59 shows the impact of the additional 20,000 AF of storage on shortage volumes.

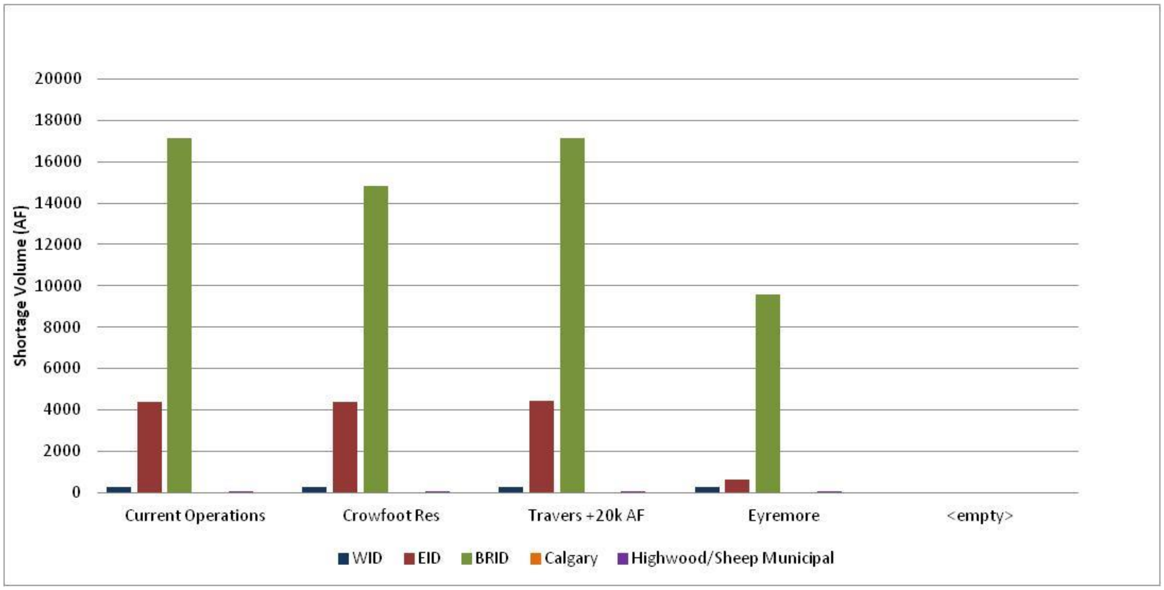

Figure 59: Volume of shortages

Figures 60 and 61 show the impact of the additional 20,000 AF of storage on TransAlta system storage and on Calgary low flow days respectively.

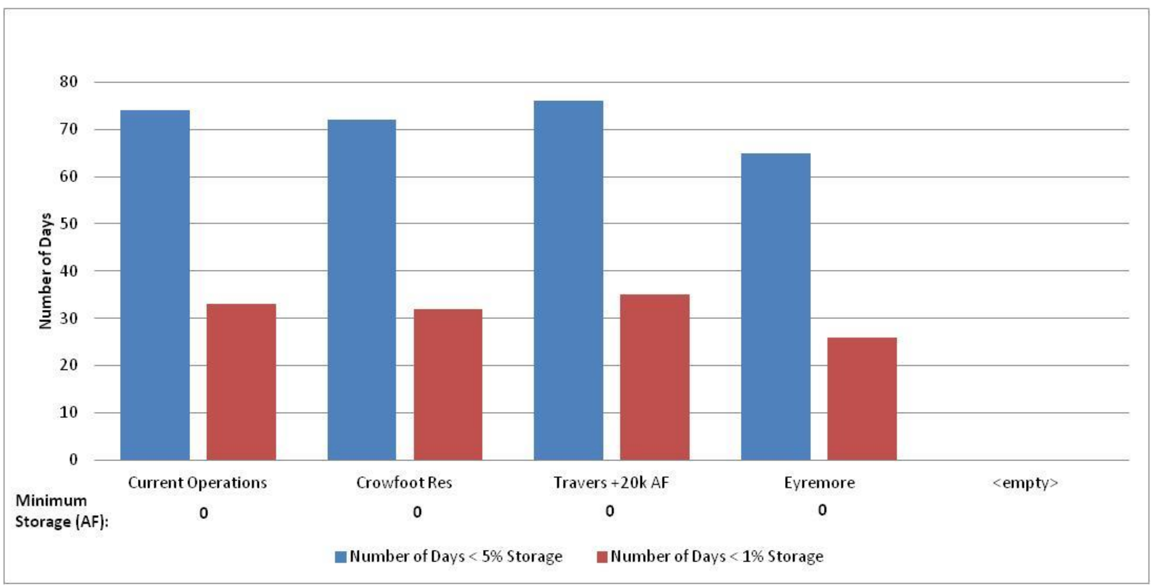

Figure 60: TransAlta system low storage days

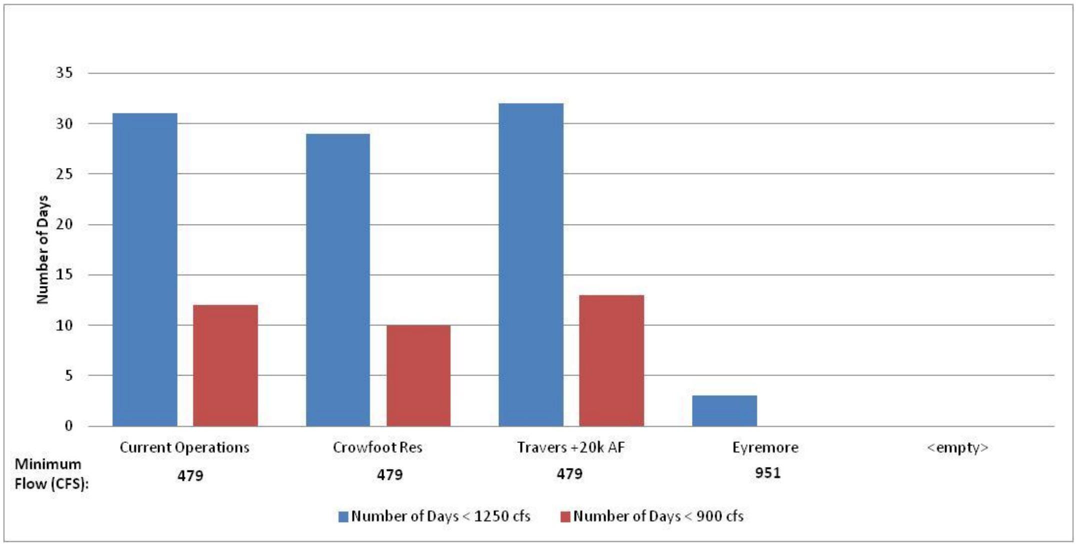

Figure 61: Calgary low flow days

As modelled, the extra 20,000 AF of storage is of very little help to the BRID, but the value of this strategy is likely understated as the modelling does not fully capture how this change in the system would actually be operated by experienced managers. Even under severe drought conditions, as it is currently modelled, Travers Reservoir has excess storage remaining that it is required to release by the end of the irrigation season. Any further storage in Travers only seems to increase the volume of releases the BRID makes at the end of the season to drain down to winter levels. In fact, the extra storage in Travers (without raising the winter levels) is somewhat detrimental to the system as it causes BRID to hold a river call for longer as it attempts to fill its additional 20,000 AF in the reservoir. This prevents TransAlta storage from filling as much in the spring, and exacerbates the low flows through Calgary as the TransAlta system drains sooner.

However, there would be substantial benefit to adding the extra 20,000 AF of storage if the winter carryover level in Travers Reservoir were increased. This would allow for the extra storage to be held in the reservoir rather than releasing the water at the end of the season to drain down to current winter levels. Although not modelled specifically, even if Travers winter level was not raised, the winter level in Travers is 2,800 feet (854 m), which would raise the winter level in Little Bow by about 4 feet (1.2 m), providing roughly 4,000 AF of storage for winter carryover. This benefit was not modelled, but would occur based on the physical reality of the system if the 20,000 AF of storage were added by combining Little Bow and Travers Reservoirs into one “super reservoir.”

Relevant BROM run name

CV_CB8.9_Travers+20kaf

D7. Increase on-stream storage downstream of Bassano (Eyremore Reservoir)

In 1977, the former Prairie Farm Rehabilitation Administration, a federal government agency, examined the option of on-stream storage at the Eyremore dam site about 10.5 km north of secondary highway 539.[5] Storage capacities considered at the time (from 627,000 AF to 1.6 million AF) would have made this reservoir far larger than any existing reservoirs in the Bow Basin.

In this project, Eyremore was raised as a potential strategy to capture flows at the lower end of the Bow system which could then be released to meet the environmental needs of the lower river as well offer potential flow augmentation and flood mitigation benefits to downstream users.

For the purpose of this project, the model assigned to Eyremore:

- Maximum live storage of 250,000 AF,
- A minimum flow of 1000 cfs leaving the reservoir when storage is available (400 cfs if Eyremore is emptied), and
- A 100 cfs requirement that must be passed to Eyremore from Bassano Dam.

Although the BROM assumes that the EID does not draw directly from Eyremore because the reservoir is located downstream from the EID canal, the fact that the EID would no longer be responsible for ensuring 400 cfs minimum Bassano flows means that more water would be available to the EID.

Located downstream of Bassano Dam, Eyremore would provide the water for the "below Bassano" reaches directly under this strategy. Thus Bassano flows can no longer be used as a surrogate for "whole river" ecological health and, for this strategy, they become a proxy for downstream river health. A new performance measure (Carseland flow) was developed to serve as a surrogate for upstream river health when comparing alternatives that include Eyremore. The arrow pointing to the section between nodes 290 and 319 in Figure 62 is the new stretch of interest rather than the section below node 326.

[5] The exact location considered by PFRA was Section 14, Twp 18, Range 18, W4M, at 50 deg, 31 min Lat, 112 deg, 23 min Long.

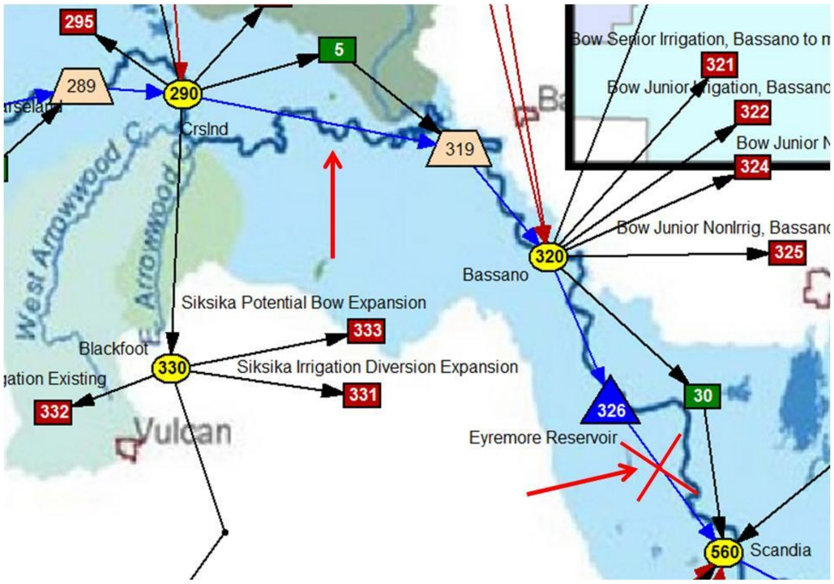

Figure 62: Location of river reach of interest (surrogate for river health)

Model results and impacts

As Figure 63 shows, during particularly severe droughts, Eyremore is fully utilized and drained to maintain a minimum 1000 cfs flow.

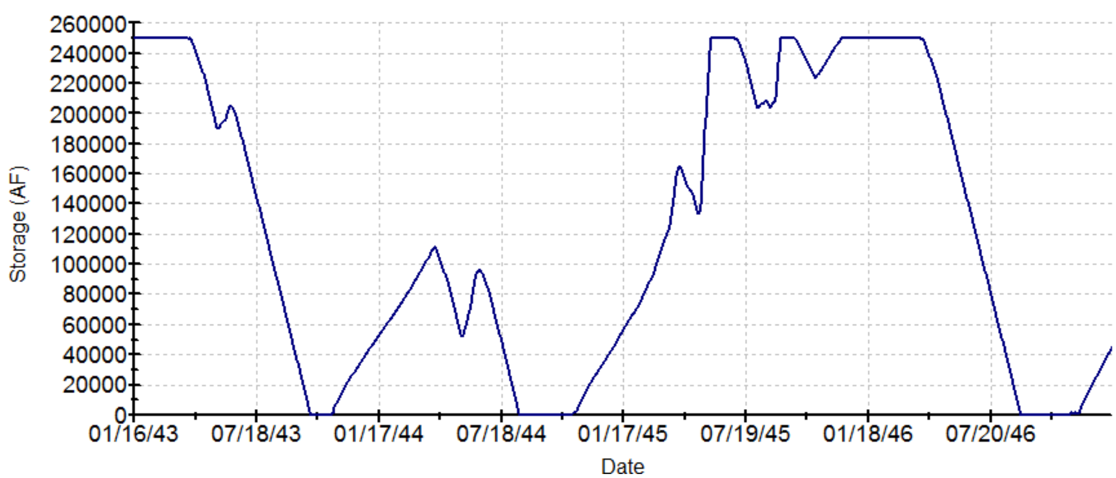

Figure 63: Eyremore Reservoir storage during severe drought conditions (2043-2046)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

Eyremore had a number of benefits to the river system and to water users. It reduced the number of days of shortage for all IDs across the 30-year period of record (Figure 64) and substantially improved the flows below Bassano (Figure 65), which in this strategy is now the surrogate for river health downstream, by the release from Eyremore of 1,000 cfs flows.

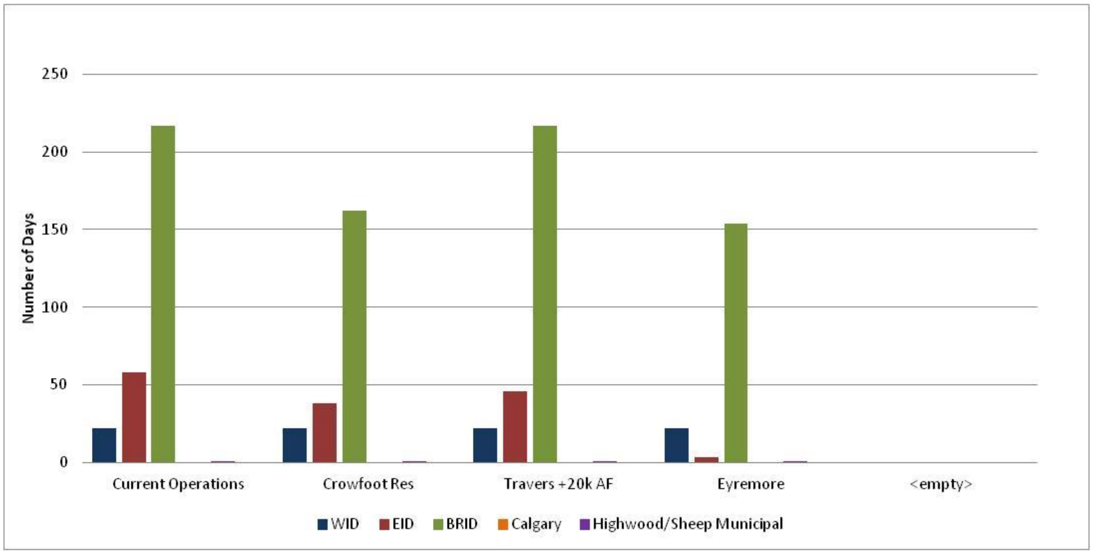

Figure 64: Number of shortage days

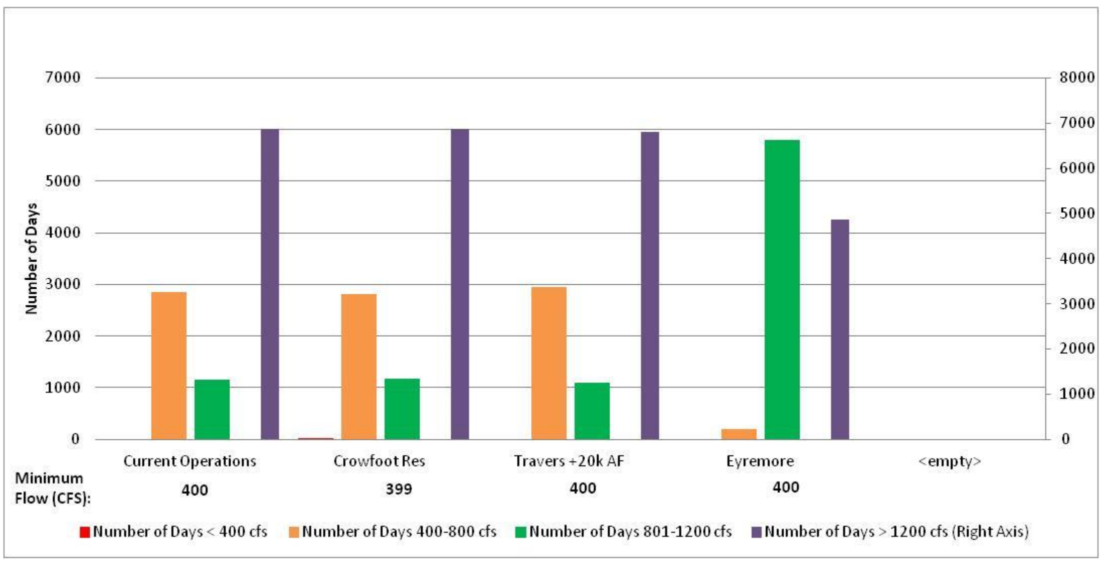

Figure 65: Bassano low flow days

With Eyremore positioned below Bassano, it eliminates EID's responsibility for ensuring the 400 cfs flows below Bassano are met. The flow below Bassano can now be met with stored water. Eyremore also affects BRID, which no longer needs to pass as much water through to EID. This strategy also reduces the number of river calls, which increases the amount of time TransAlta can store water, and similarly reduces the number of low flow days for Calgary.

As expected, the addition of Eyremore Reservoir does not affect Carseland flows (Figure 66).

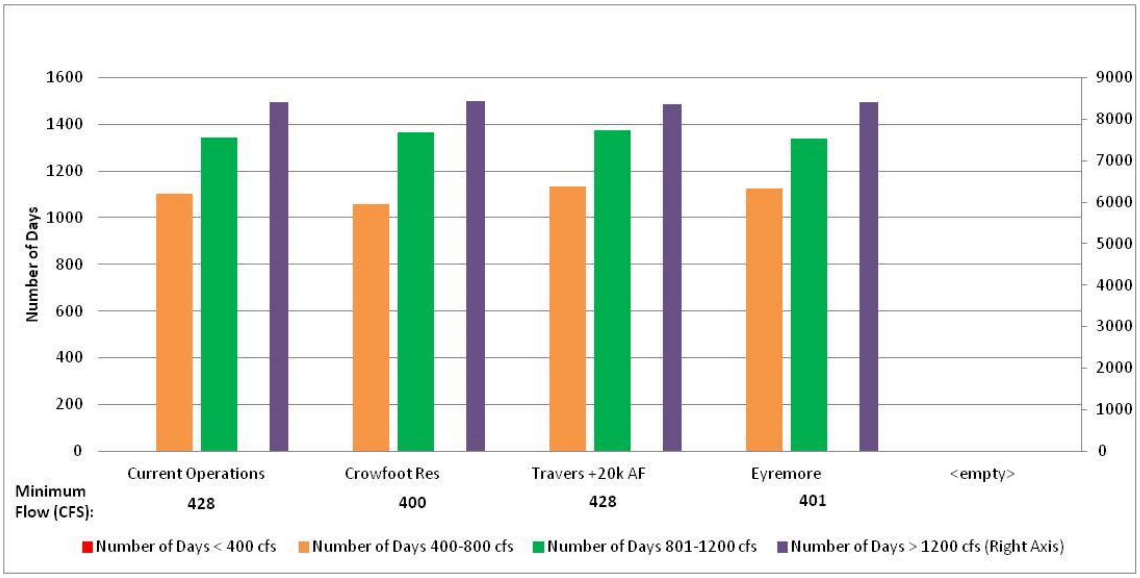

Figure 66: Carseland low flow days

The CDF plot in Figure 67 shows that with Eyremore Reservoir operations there is a reduced frequency of low flows in the 400-750 cfs range compared with current operations.

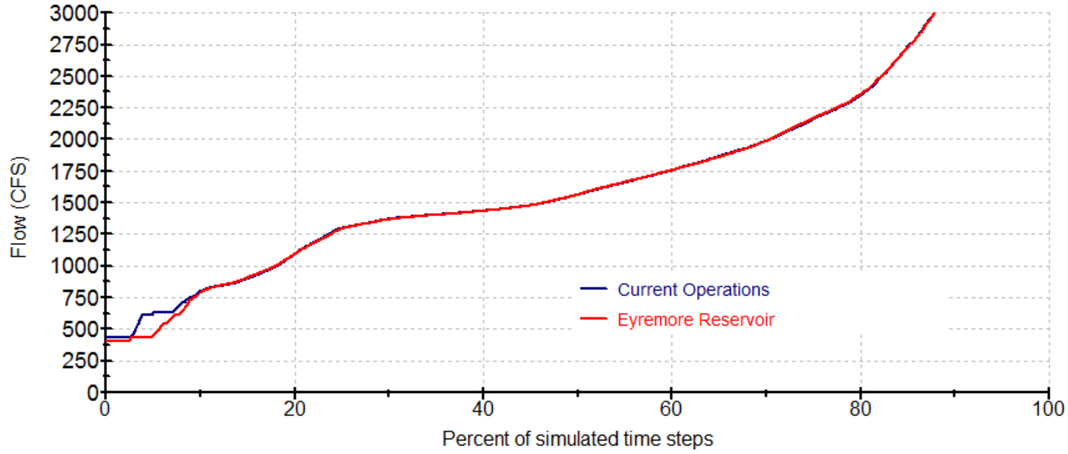

Figure 67: Bassano flow probability distribution

Eyremore is drawn down in a few extreme years, which would potentially improve the downstream aquatic ecosystem. The water bank could still play a role if Eyremore is very low, but if environmentally required flows are more than Eyremore can deal with, the water bank will suffer. Current performance measures do not capture the value of high stochastic flows, but introducing a new reservoir with managed flows will certainly reduce it. This effect would need more analysis from ecologists.

Eyremore Reservoir would capture water further downstream, levelling out peaks and eliminating the need to calculate time of travel from Bearspaw in keeping downstream flows healthy. It would catch any additional releases by TransAlta, thus creating opportunities and flexibility to use this water below the reservoir, for example, to pulse flows in support of riparian health. Eyremore could potentially assist with flood control at Medicine Hat and could benefit the Oldman system by a) relieving pressure to supply minimum flows through Medicine Hat, and b) helping to meet the 50% apportionment requirement in dry years. Eyremore would be expected to substantially mitigate the impacts of both drought and floods if the worst effects of climate change and variability materialize.

Potential disadvantages to this strategy are a) it represents additional on-stream storage which, among other environmental impacts, disrupts aquatic ecosystem function, and b) the capital costs and time required for construction would be significant.

Relevant BROM run name

CV_CB8.9_Eyremore

D8. Operate ID reservoirs to protect Junior licences

Under Alberta's current water allocation system, licences are regarded as being "senior" or "junior" with respect to each other in a basin, based on when the licence was originally issued. In the Bow Basin, the total volume of junior licences is very small in comparison with the senior licences, such as those held by TransAlta, the City of Calgary and the three irrigation districts (EID, WID, and BRID).

Because of the amount of storage in the BRID and the EID, the IDs have typically been able to manage their reservoirs to meet both their needs and those of other licence holders in the basin as well as support the in-stream flow needs of the Bow River; in fact, junior licences have never been shorted in the history of the basin. The ability to do this is due in part to the basin being closed to new allocations. If allocations had continued to be given out, the total volume of demands of the junior licences would continue to increase gradually, making it harder for the IDs to cover them.

Under the climate variability scenarios developed for this project, water shortages could be so severe that many junior licences frequently would not be met if the usual allocation procedure was followed. Changes were made in the model to determine the impact of meeting junior licences under all conditions or alternatively to cut off junior licences under extreme low flow conditions in accordance with their priority. This had not been done before in the Bow Basin either in reality, or under the modelled conditions.

Model results and impacts

Currently in the BROM, all junior licences are met all the time. The model run demonstrated how the existing irrigation reservoirs are operated to continue to ensure that junior licences will always be met (Figures 68 and 69). These figures illustrate the impact on two large irrigation reservoirs of protecting junior licences (blue line) and calling on them (red line). Operating the reservoirs in this manner does result in them being drawn down more than otherwise, but even in the worst drought conditions modelled, the drawdown may be acceptable to ID operators.

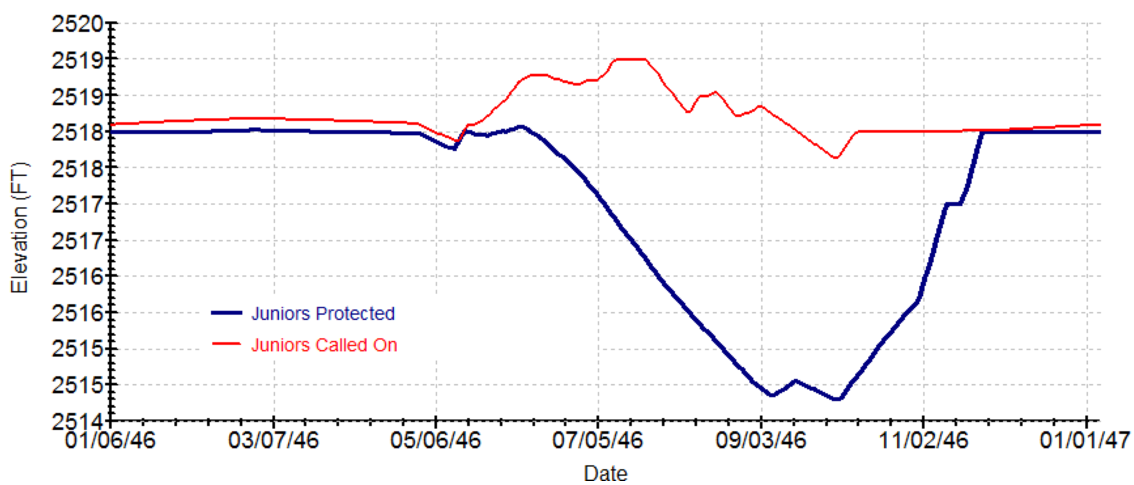

Figure 68: Newell Reservoir elevation during drought conditions (2046-2047)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

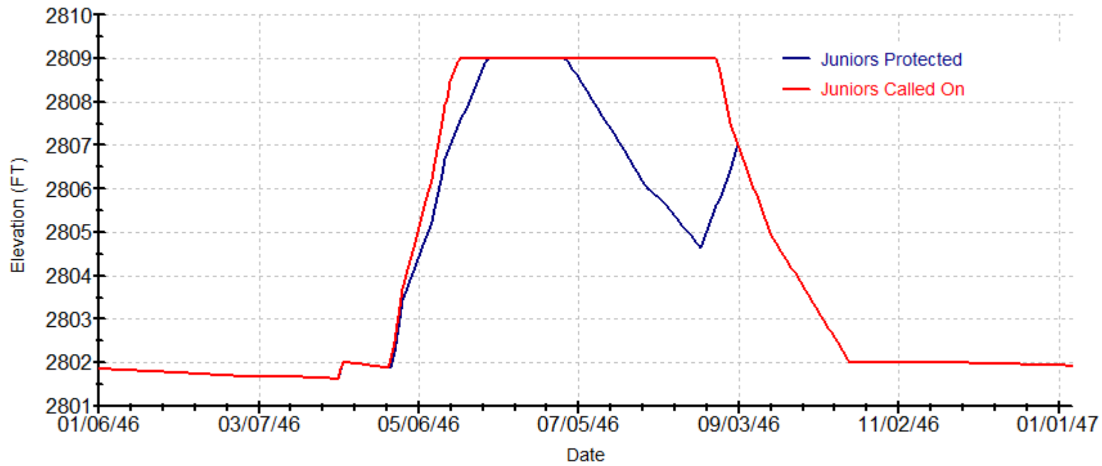

Figure 69: Travers Reservoir elevation during drought conditions (2046-2047)
Scenario: 3yr Min (CGCM 3T47 3B1), 30-year record

The model run also determined shortages that accrued to junior licensees and to IDs if junior licences were kept as the lowest priority (that is, unprotected), and compared those with shortages to both parties if junior licences were always met (that is, current operations). The results are shown in Figures 70 and 71.

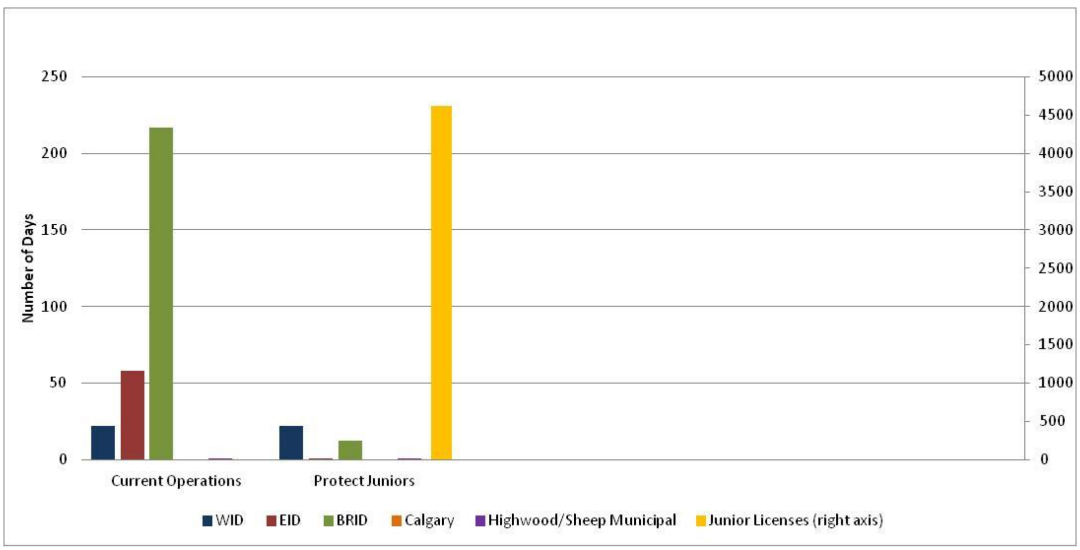

Figure 70: Number of shortage days

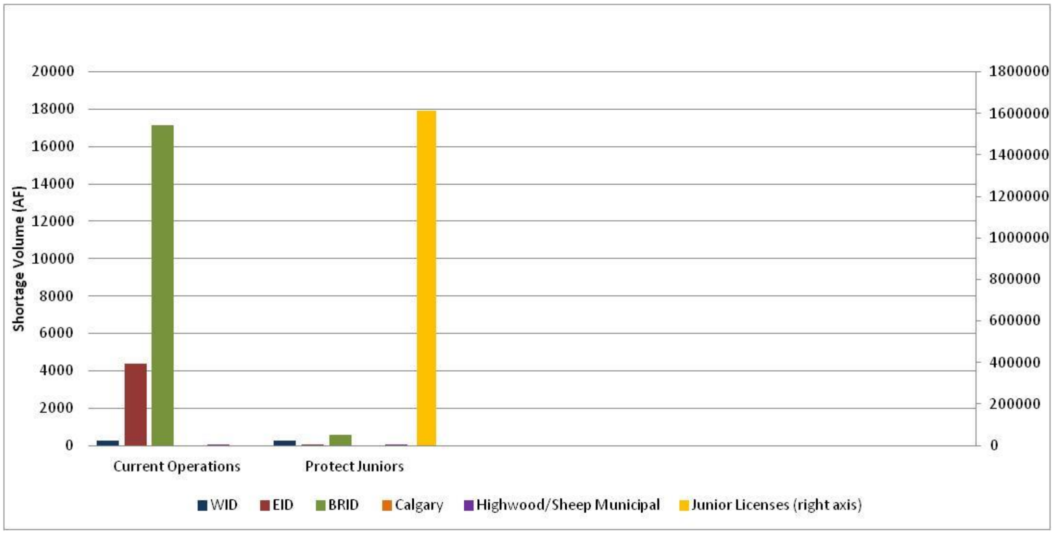

Figure 71: Volume of shortages

Figure 70 shows that when the junior licences were unprotected, their shortages were very large – just over 4,600 days over the 30 years of the 3yr Min climate scenario. Under the same conditions (that is, the junior licences are unprotected), the three IDs experience about 45 days of shortages over the same period. Figure 70 also shows as "current operations" what happens if the junior licences are all met. There is no shortage to the junior licensees, while the total shortage to the IDs amounts to about 300 days. This is a difference of some 255 days of shortage for the IDs; in other words, ensuring junior licences are met creates an additional 255 days of shortages for the IDs over the 30-year period. BRID is most affected, followed by EID; shortages for the WID do not change.

Similarly, as Figure 71 shows, shortage volumes for junior licensees when their licences are unprotected amount to 1.6 million AF over the 30-year period, while volume shortages to the IDs under the same circumstances amount to about 875 AF. On the other hand, if junior licences are protected (current operations), the IDs would experience a total volume shortage of about 22,000 AF over the 30-year period, again with BRID and EID most affected. This shortage is a small fraction (0.2%) of the total volume of 9.6 million AF used by BRID and EID over the 30-year period.

These results suggest that water users in the basin can effectively decide how to allocate water in times of shortage. They show that the IDs in the Bow Basin can indeed do what they committed to in the March 2012 Declaration: that should severe water shortages occur, the IDs will work with communities in southern Alberta to ensure people have water for their needs. The model results reflect the current reality that differs from how the allocation system theoretically works under a strict legal interpretation. There is little incentive for IDs to short junior licences in times of drought, as the impact on ID needs is projected to be minimal because of the large amount of reservoir storage available to the BRID and EID. The results confirm that there are collaborative opportunities to maintain and support economic growth while meeting social and environmental needs in the basin.

Relevant BROM run name

CV_CB8.9_JuniorLicPriority

4.2.1 Most Promising Strategies for Adapting to Severe Drought Conditions

Three strategies were suggested as having the most promise for adapting to the most severe drought conditions that occurred over three years of the 30-year period for the chosen climate scenario. Two of these involved new infrastructure to expand storage capacity – one reservoir off-stream and one on-stream. Any new infrastructure and storage would need to consider both positive and negative environmental impacts as well as impacts on the land and landowners, and recognize that there are tradeoffs. These "drought" options, once in place, would also be expected to benefit the region if and when conditions returned to normal.

D3: Reduce minimum river flow through Calgary

The strategy was proposed as a means, when drought conditions are expected, to conserve more water in upstream storage and mitigate the exceptional low flows through Calgary when TransAlta storage was completely exhausted. It would protect upstream storage, but because less water is in the river and Calgary's return flow becomes a higher proportion of total flow, assimilative capacity may be reduced which could affect water quality and also lead to higher wastewater treatment costs. This strategy could negatively affect brown trout spawning due to lack of stable water levels and temperature concerns. Field conditions and the formation of river ice cover would be critical considerations for this strategy, but may be manageable for short periods.

D4: Increase off-stream storage in the WID (Bruce Lake)

Bruce Lake would provide 41,400 AF of live storage and would fill based on WID's licence. The most obvious benefit from the addition of Bruce Lake is to the WID, but it would also benefit the river by enabling WID to reduce its diversion and meet some of its needs from storage under a prearranged agreement. This strategy also included an additional 10 cfs to meet year-round municipal demand that would be serviced by Bruce Lake. A side benefit of this new off-stream storage is the potential for enhanced regional economic development opportunities as well as recreation benefits for the region. Capital costs and time required for construction represent potential disadvantages.

D7: Increase on-stream storage downstream of Bassano (Eyremore Reservoir)

Eyremore Reservoir could capture flows at the lower end of the Bow system, creating opportunities and flexibility to use this water below the reservoir in various ways to improve aquatic ecosystem health. Eyremore could potentially assist with flood control at Medicine Hat and could benefit the Oldman system by a) relieving pressure to supply minimum flows through Medicine Hat, and b) helping to meet the 50% apportionment requirement in dry years. Eyremore would be expected to substantially mitigate the impacts of both drought and floods if the worst effects of climate change and variability materialize. Potential disadvantages to this strategy are a) it represents additional on-stream storage which, among other environmental impacts, disrupts aquatic ecosystem function, and b) the capital costs and time required for construction would be significant.

4.3 Strategies Suggested but not Modelled

Two strategies were suggested but not modelled. These are described very briefly below.

Raise full supply levels in Barrier and/or Upper Kananaskis Reservoirs

Strategies to raise the full supply level at TransAlta's Barrier and Upper Kananaskis Reservoirs were considered as ways to capture more inflow and generally improve river management. However, it was decided that changes to Ghost Reservoir offered more potential because its theoretical catchment includes all the reservoirs above it.

Change land use and/or cover upstream of Calgary

Potential changes in land use and land cover upstream of Calgary could affect water management. Focusing on natural water storage, protecting and restoring wetlands, and alluvial aquifers could all contribute to improved water management. Demand management strategies for Calgary could consider opportunities for different upstream land use management that may be less expensive than infrastructure changes, and offer considerable additional ecological benefits.

4.4 Combined Strategies

Recognizing that the Bow River Basin is a complex, dynamic system, it is expected that potential adaptation strategies would be implemented in combination, reflecting the needs of the basin and the appropriate degree of risk management. To examine how adaptation strategies might be layered to produce cumulative and offsetting impacts, the project modelled six strategy combinations. Because the BRP Preferred Scenario benefits Bassano flows (the surrogate for overall river health), it was combined with various individual adaptation strategies. As described in Strategy N1 (section 4.1), a trigger was proposed for the water bank component of the Preferred Scenario and the rules for the trigger were noted in that strategy. Reference to the Preferred Scenario in these combinations infers the added trigger for the water bank.

The numbers of the individual strategies are shown below the title for easy reference back to those strategies, their descriptions and modelling results. The Preferred Scenario is abbreviated as “PS.” Performance measure charts can show a maximum of four strategies plus current operations; thus C1-C3 measures appear in one series of charts, and C4-C6 measures appear in a different series. The first segment includes descriptions and modelling results and impacts for strategies C1-C3, followed by the same content for strategies C4-C6. The performance measure for Carseland flow is not shown for strategies C1-C3 as it pertains only to Eyremore Reservoir, which is not included in C1-C3.

Consistent with assessment of individual strategies, the 3yr Min climate variability scenario was used to compare the combined strategies and results are similarly shown over the 30-year period of record.

For easy reference, the table below shows the combined strategies plus their short form titles, which are used in the performance measure charts.

Combined Strategies	
C1. Preferred scenario (water bank + stabilized LKL) + reduce minimum flow through Calgary (from Oct to Dec, with low storage trigger)	PS + Calgary min flow
C2. Preferred scenario (water bank + stabilized LKL) + adjust fill times for three largest TransAlta reservoirs + increase winter carryover in Travers Reservoir	PS + reservoir changes
C3. Preferred scenario (water bank + stabilized LKL) + move municipal licences from Highwood/Sheep system to Bow River + implement additional demand reduction measures in Calgary and in Irrigation Districts	PS + demand reduction
C4. Preferred scenario (water bank + stabilized LKL) + adjust fill times for three largest TransAlta reservoirs + increase winter carryover in Travers Reservoir + increase off-stream storage in the WID (Bruce Lake)	PS + on- and off-stream storage
C5. Combination 4 + increase on-stream storage downstream of Bassano (Eyremore Reservoir)	C4 + Eyremore
C6. Stepwise combination for maximum drought adaptation	High potential strategy

C1. Preferred Scenario (water bank + stabilized LKL) + reduce minimum flow through Calgary (from Oct to Dec, with low storage trigger)

(N1 + D3)

This strategy does not include any capital infrastructure additional to the Preferred Scenario. One of the key issues during a drought, such as the models forecast for one-, two-, and three-year minimums, is how best to retain water in the upstream and downstream reservoirs for release during extreme low flow periods. This can protect environmental conditions to some degree, and yet retain sufficient water in the reservoirs for later use during winter or to carry over a certain amount of water for use the following spring to mitigate risk against a continuing drought. One of the means for accomplishing these goals under stressful conditions of low snowpack and drought conditions is to reduce the streamflow to a lower level than has been considered optimal, but still retain sufficient flow to protect environmental and fish habitat conditions, albeit at a somewhat lower level. This strategy involves a reduction in the minimum flow released from Bearspaw Reservoir on the western edge of Calgary to 900 cfs to test the effects on reservoir storage quantities remaining for release in the dry spring period. The original PS set a minimum of 1,250 cfs for release at Bearspaw which could be met under the historic period, but not for some of the dry climate change scenarios.

In this scenario, flows through Calgary are adjusted downward to 900 cfs only between October 1 and December 31, and only if the total storage in the upstream TransAlta reservoirs is low (less than 400,000 AF as of October 1). The hypothesis is that this relatively small reduction in flow in this period will enable TransAlta reservoirs to be maintained at a slightly higher level and thus provide adequate flows in the coming year, even with a low snowpack over the winter.

C2. Preferred Scenario (water bank + stabilized LKL) + adjust fill times for three largest TransAlta reservoirs + increase winter carryover in Travers Reservoir

(N1 + N2 + N6)

This strategy has two components in addition to the Preferred Scenario. The additional components focus on what can be done using existing reservoirs to build the adaptive resiliency of the system. With Strategy N2, TransAlta reservoirs would be approximately full by July 31, held full until October 15, and then allowed to make releases according to normal operations. This would leave more natural flow to pass in August and September to meet higher seasonal downstream needs at a time when flows are typically lower. The higher winter carryover (using Travers Reservoir as an example in Strategy N6) enables the IDs to release more water in the spring to meet their demands from their full reservoirs without drawing from the Bow River, thus enabling a lower withdrawal from TransAlta's storage in the low flow period each spring.

C3. Preferred Scenario (water bank + stabilized LKL) + move municipal licences from Highwood and Sheep system to Bow River + implement additional demand reduction measures in Calgary and in irrigation districts

(N1 + N5 + N3 + N7)

This strategy has two purposes. The first is to address the significant impact of drought on the in-stream flow needs of the Sheep and Highwood Rivers (N5). There are no reservoirs on either the

Sheep or Highwood to retain some portion of high flows for use at other times of the year. Without such a control mechanism the licensees on these rivers have to make do with the natural flow. In significant drought, the model showed substantial periods of low flow in an area known to be environmentally sensitive, and shows shortages to many junior (or non-municipal) licences drawing from these rivers. Relocating all the Sheep and Highwood licences to the Bow and transporting water to the licence holders via pipeline eliminated all the shortages during the drought periods without changing the flow in the Bow to any extent that would create shortages for other users on that river downstream of the Highwood confluence with the Bow.

The second purpose of this strategy is to determine how much benefit to the environmental flow on the Bow downstream of Calgary during low flow periods could be achieved by reducing summer demands in Calgary and in the irrigation districts (N3 and N7). Summer demands were reduced by 30% in Calgary and the IDs. This was considered to be an achievable reduction under extreme drought and low natural flow conditions in the Bow especially when the upstream reservoirs are no longer able to meet optimal flow due to low snowpack or a drought lasting more than one year.

Model results and impacts, C1-C3

Performance measures for combination strategies C1-C3 appear in Figures 72-76, followed by commentary and observations for each combination.

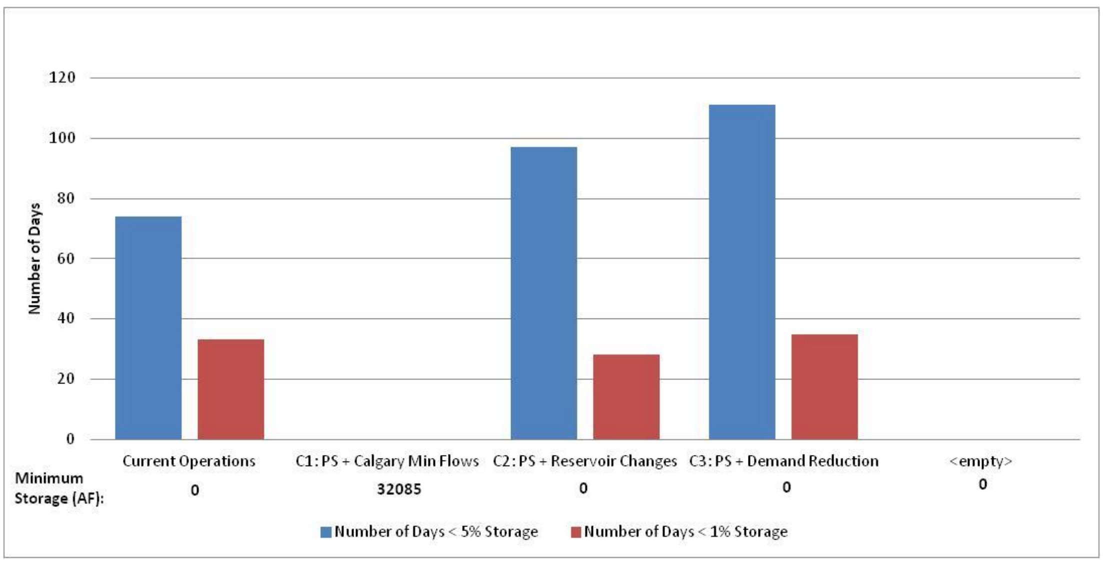

Figure 72: TransAlta system low storage days, combinations C1-C3

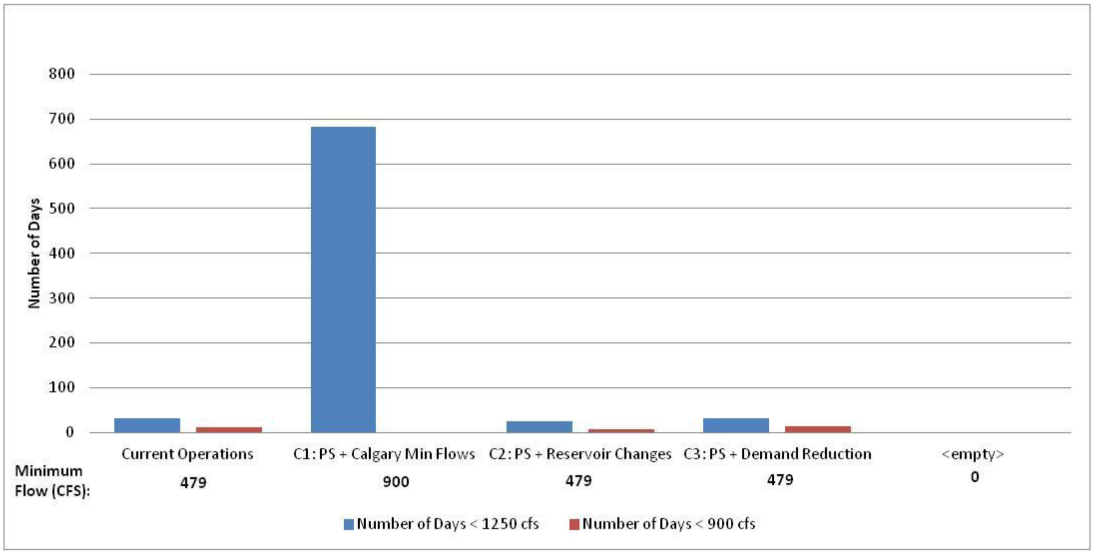

Figure 73: Calgary low flow days, combinations C1-C3

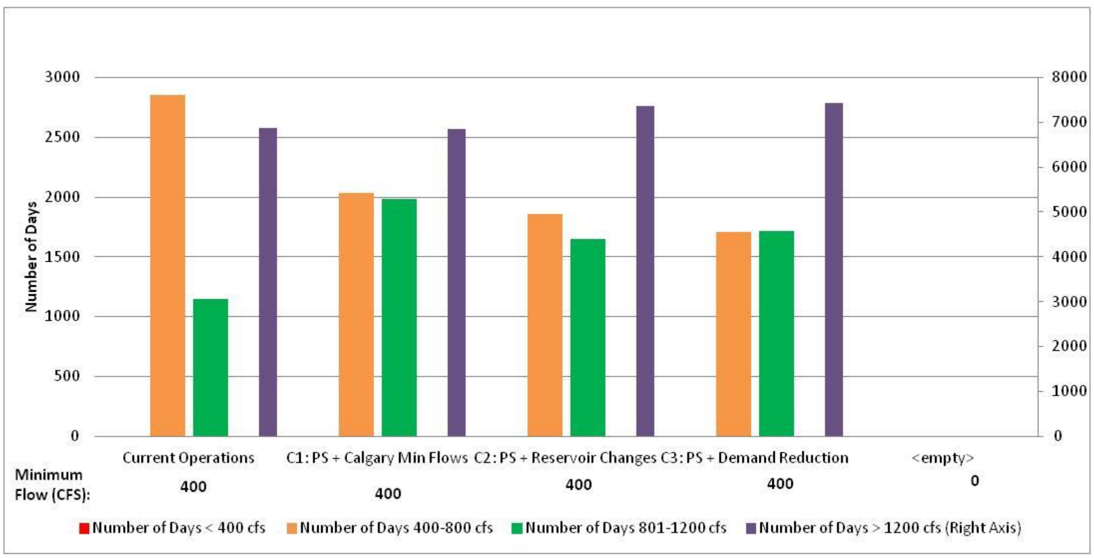

Figure 74: Bassano low flow days, combinations C1-C3

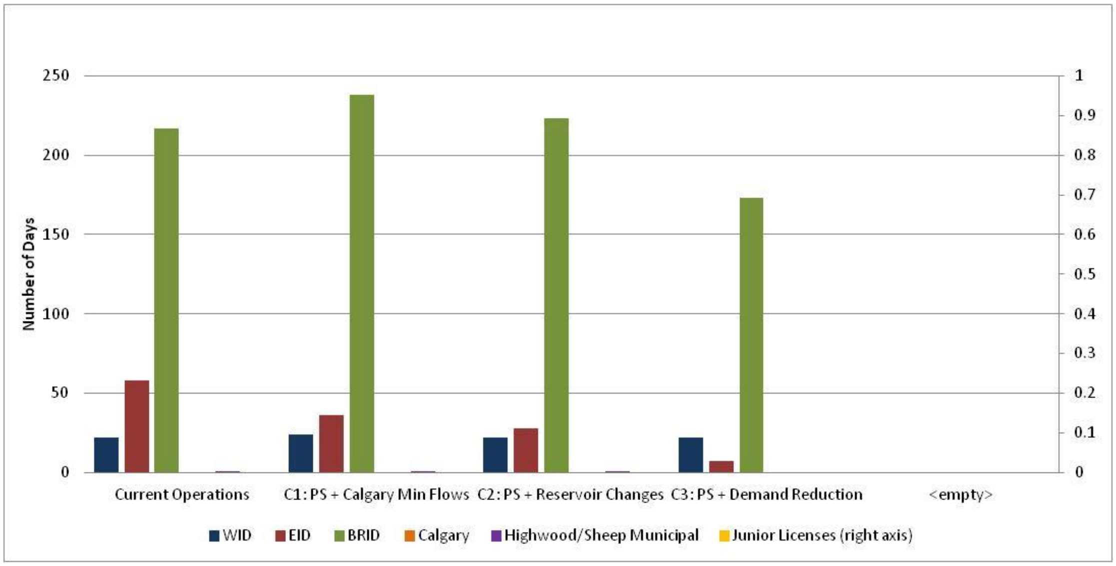

Figure 75: Number of shortage days, combinations C1-C3

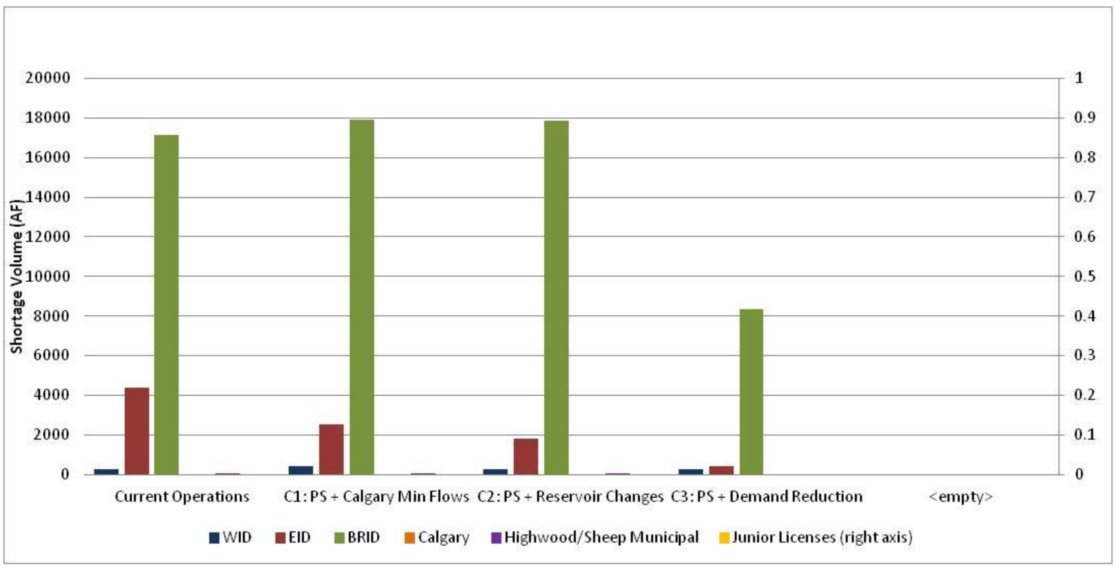

Figure 76: Total volume of shortages, combinations C1-C3

Combination 1: Preferred Scenario + Calgary minimum flow

Preferred scenario (water bank + stabilized LKL) + reduce minimum flow through Calgary (from Oct to Dec, with low storage trigger)

The Preferred Scenario does a very good job of supplementing Bassano flows, but this comes with a cost to TransAlta storage. Reducing Calgary flows for three months with the trigger eliminates the impact on TransAlta storage. The extreme low flow days (<900 cfs) through Calgary are also eliminated but there is a big increase in the number of days below 1,250 cfs. This combination still produces good flows below Bassano, which are an indicator of the health of the whole river. The Carseland PM is not relevant to this combined strategy because it does not include Eyremore. There is essentially no difference in the number of shortage days for this combination compared with current operations over the 30 years, and total volume of shortages is slightly less for this combination vs. current operations. This combination is attractive in extreme drought conditions because the PS ensures overall river health and stabilizes Kananaskis; the cost comes as Calgary takes more days of lower flow so as not to empty the TransAlta storage. Under the normal historical scenario, TransAlta storage does not drop down and Calgary flows need not be reduced. This is an adaptation strategy that allows the water bank to operate in a way that is not damaging to the system in a drought.

Combination 2: Preferred Scenario + reservoir changes

Preferred scenario (water bank + stabilized LKL) + adjust fill times for three largest TransAlta reservoirs + increase winter carryover in Travers Reservoir

The intent of this combination was to use only adaptation strategies that were possible without major infrastructure requirements (such as building a new reservoir). It combined the Preferred Scenario with adjusted “normal patterns” for TransAlta’s main reservoirs and increased winter carryover in Travers Reservoir. Considering that all of these operations could be implemented in the near term if necessary, the improvement from the combination is quite impressive. Extreme low flow days at Calgary are reduced by half over the 30-year period, extreme low flow days at Bassano are reduced by approximately 35%, and even shortages are slightly reduced. This is all accomplished with only a small increase in the number of TransAlta storage days below 5%; at the same time, however, the number of severe low storage days (<1%) is reduced.

Combination 3: Preferred Scenario + demand reduction

Preferred scenario (water bank + stabilized LKL) + move municipal licences from Highwood and Sheep system to Bow River + implement additional demand reduction measures in Calgary and in irrigation districts

This combination demonstrates that while demand reduction measures should always be part of a basin’s management practice, they alone cannot free up enough water to benefit the river in times of drought; other strategies are needed. TransAlta storage is negatively affected compared with current operations because the reservoirs are being drained faster to maintain river health, while the demand reduction measures are not a sufficient offset. Calgary low flow days are unchanged from current operations and flows at Bassano are improved. Carseland flows are covered by the higher Bassano flow in this combination. Over the 30-year period, demand reductions by the irrigation districts combined with reduced demands by Calgary lower the number of days of shortage from nearly 300 days under current operations to 200 days, while volume shortages fall substantially from almost 22,000 AF to just over 9000 AF. The Highwood and Sheep strategy does not have much impact on the Bow, but it does help the flows in the Highwood and Sheep system.

The next segment presents descriptions and modelling results and impacts for combination strategies C4-C6.

C4. Preferred Scenario (water bank + stabilized LKL) + adjust fill times for three largest TransAlta reservoirs + increase winter carryover in Travers Reservoir + increase off-stream storage in the WID (Bruce Lake)

(N1 + N2 + N6 + D4)

This strategy has several components in addition to the Preferred Scenario. Fill times for TransAlta reservoirs would be adjusted so they are approximately full by July 31, held full until October 15, and then allowed to make releases according to normal operations (N2). This would leave more natural flow to pass in August and September to meet higher seasonal downstream needs at a time when flows are typically lower.

Higher winter carryover (using Travers Reservoir as an example, N6) enables the IDs to release more water in the spring to meet their demands from their full reservoirs without drawing from the Bow, thus enabling a lower withdrawal from TransAlta's storage in the low flow period each spring. The final component (D4) is a proposed reservoir of 41,400 AF in the WID (Bruce Lake), filling during the high flow period and holding water over winter. This reservoir could similarly reduce the WID demand on the Bow during spring, thereby increasing the flow available to the environment. For this strategy, Bruce Lake was additionally used to completely meet WID demands any time the water bank made releases.

C5. Combination 4 + increase on-stream storage downstream of Bassano (Eyremore Reservoir)

(N1 + N2 + N6 + D4 + D7)

The Eyremore Reservoir immediately downstream from the Bassano Dam is intended to increase the environmental flows in the reach of the Bow River from Bassano to the confluence with the Oldman River. Operationally it would fill during the high flow period when the irrigation districts can take all the water their diversions will allow and flows in the Bow are still at near flood levels. The Eyremore Reservoir would capture that high flow to fill in the peak runoff period while controlling flood flows downstream to the confluence. If the reservoir were licensed to operate for environmental purposes it could be managed for functional flows to enhance willow and poplar growth in the riparian areas, provide adequate flow during any spawning periods that may require minimum flows, and support adequate flow for the reported sturgeon population in that reach of the Bow. Theoretically, it could also restrain flow rates during the relatively short periods when floods are forecast for the downstream regions of Medicine Hat and Cypress County.

Because of the addition of Eyremore Reservoir, the water bank now made releases to target flows downstream of Carseland. If the water bank makes releases and Eyremore is less than 50% full, any extra water is stored in Eyremore (although Eyremore still maintains a minimum 1,000 cfs outflow as long as it can). If the water bank makes releases and Eyremore is more than 50% full, the extra water is not forced downstream and EID can take that additional water, although Eyremore still maintains a minimum 1,000 cfs outflow.

C6. Stepwise combination for maximum drought adaptation

Preferred scenario (water bank + stabilized LKL) + implement seasonal consumptive demand reduction in Calgary + adjust fill times for three largest TransAlta reservoirs + increase on-stream storage downstream of Bassano (Eyremore Reservoir)
(N1 + N3 + N6 + N2 + D7)

Combination 6 was the last set of alternative operations developed. It was intended to take lessons from both the individual operations and pre-existing combinations (C1-C5) and create a theoretical plan of implementation that would show maximum benefit. As such, it was examined in a stepwise manner. The stepwise analysis is included in the detailed discussion of Combination 6 results, following the broader analysis of all combination runs together.

The first step recommended would be the implementation of the Preferred Scenario. The operations included the Preferred Scenario (and described in Strategy N1) are recommended independent of climate variability. The second adaptation step includes seasonal consumptive demand reduction efforts by the city of Calgary (N3). Even though this strategy did not show benefits on the same scale as many other options, it is likely that Calgary would lead the way in such adaptation efforts. Following Calgary's efforts, the next step would be to consider allowing BRID to carry additional water in Travers Reservoir over the winter period (N6). Although further analysis is needed, this strategy could likely be implemented at very low cost, and thus seemed a reasonable and simple next step. The fourth step would be altering the storage "Normal Patterns" of the three major TransAlta reservoirs to be more adaptive (N2). This step would require additional negotiations with TransAlta, but such negotiations could be undertaken while the first three steps were in progress. The final piece of Combination 6 is the construction of Eyremore Reservoir (D7). As the most costly and time-consuming part to implement, it was included in recognition of the need for long-term adaptation to climate variability. The benefits of the Eyremore strategy, described in Strategy D7, are substantial enough to merit further consideration in combination with simpler options.

Model results and impacts, C4-C6

Performance measures for combination strategies C4-C6 appear in Figures 77-82, followed by commentary and observations for each strategy. Additional analysis and charts are presented for C6 to show the impact of the stepwise combining of other strategies.

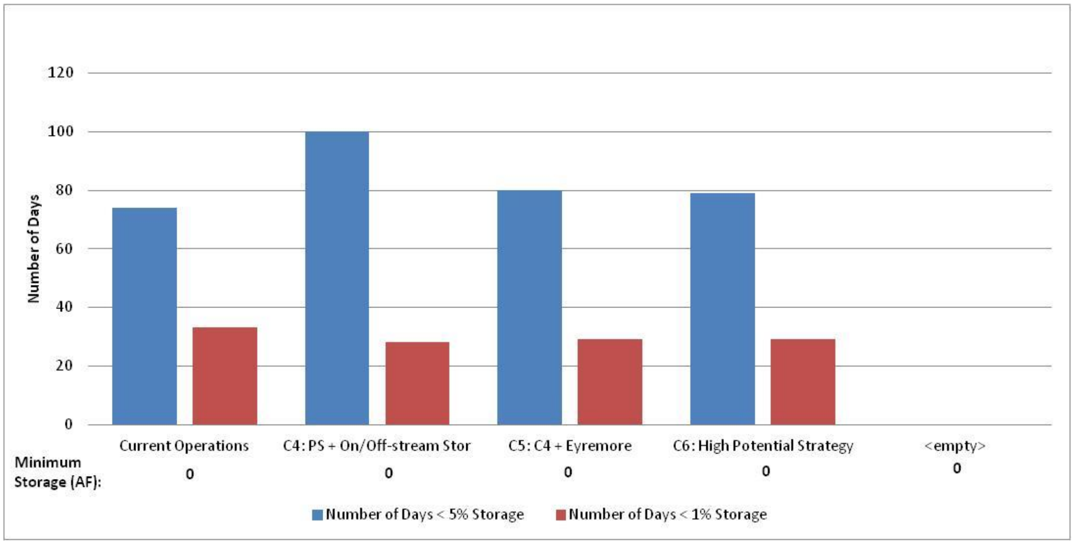

Figure 77: TransAlta system low storage days, combinations C4-C6

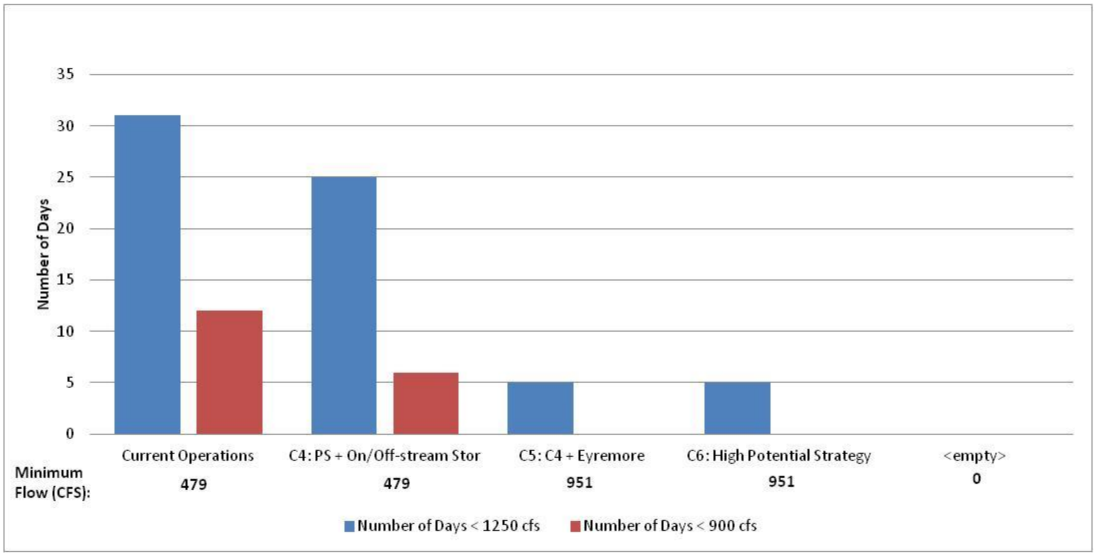

Figure 78: Calgary low flow days, C4-C6

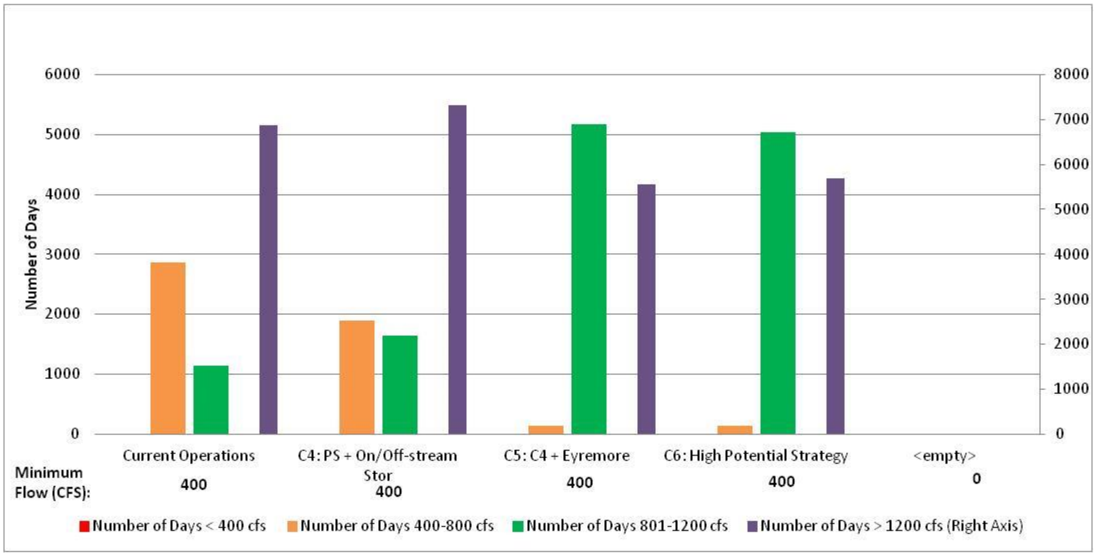

Figure 79: Bassano low flow days, C4-C6

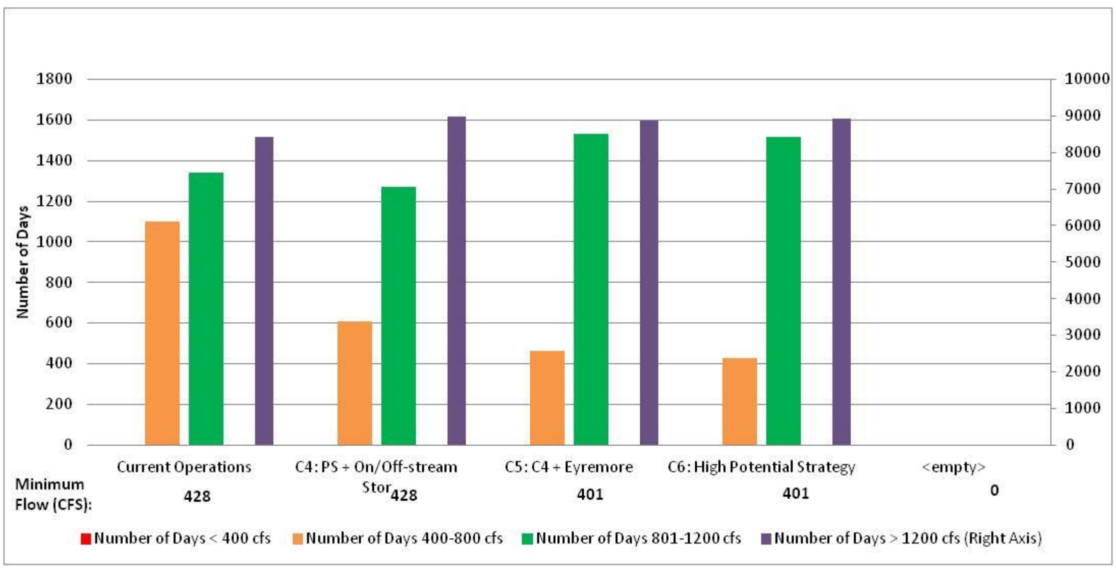

Figure 80: Carseland low flow days, C4-C6

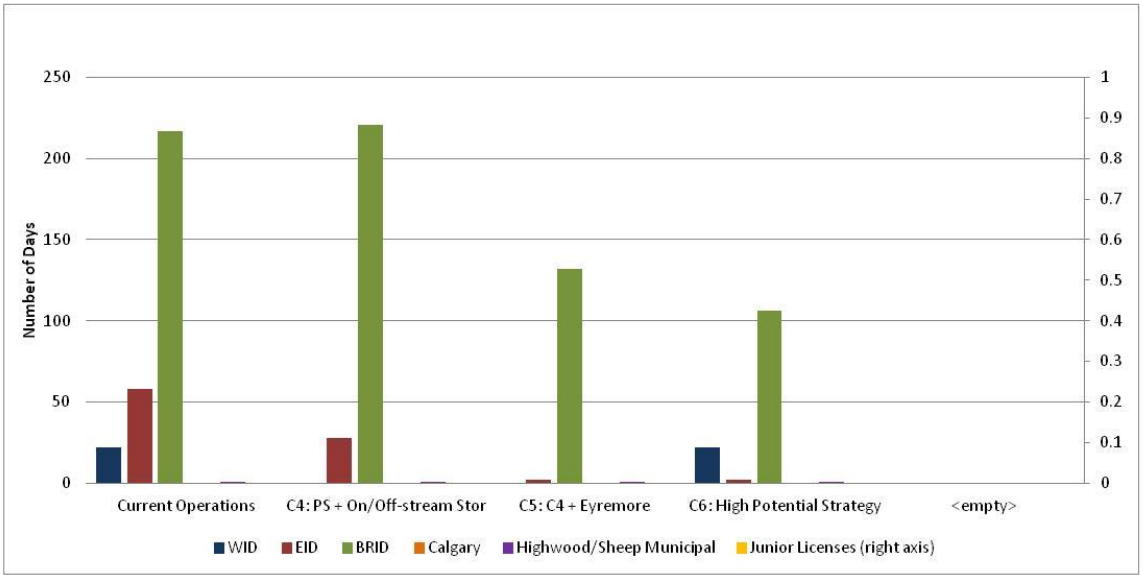

Figure 81: Number of shortage days, combinations C4-C6

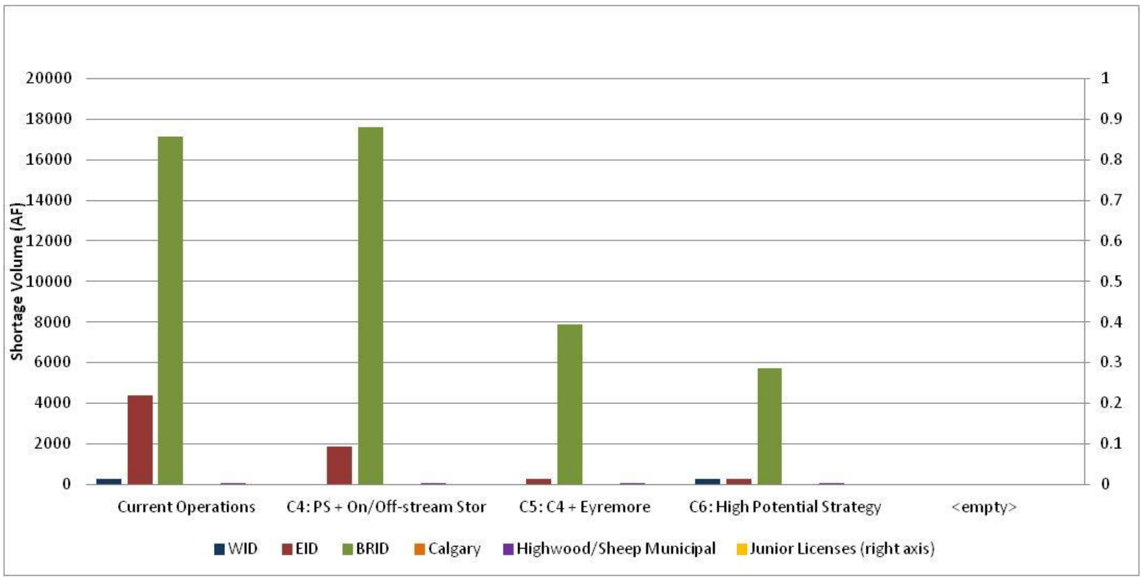

Figure 82: Total volume of shortages, combinations C4-C6

Combination 4: Preferred Scenario + on- and off-stream storage

Preferred scenario (water bank + stabilized LKL) + adjust fill times for three largest TransAlta reservoirs + increase winter carryover in Travers Reservoir + increase off-stream storage in the WID (Bruce Lake)

Again, the Preferred Scenario provides a very big benefit to Bassano flows. From that starting point, some on- and off-stream storage was added (Bruce Lake, and higher winter level for Travers). This combination adds adaptation strategies to assist BRID and WID with additional storage, as well as changes to TransAlta reservoir management to optimize capture and release of water. This combination increased the number of low storage days for TransAlta and slightly increased Calgary's low flow days over the 30-year period, but the strategies in this combination did not yield as many climate adaptation benefits as some other combinations.

Combination 5: Combination 4 + Eyremore Reservoir

Preferred scenario (water bank + stabilized LKL) + adjust fill times for three largest TransAlta reservoirs + increase winter carryover in Travers Reservoir + increase off-stream storage in the WID (Bruce Lake) + increase on-stream storage downstream of Bassano (Eyremore Reservoir)

When Eyremore Reservoir is added to the strategies in Combination 4, a number of benefits are realized. TransAlta storage is slightly better than under current operations, Calgary flows are improved, and Bassano flows (representing downstream health of the river) are improved substantially. With the addition of Eyremore, the Carseland performance measure comes into effect to represent the upstream condition of the river, which still shows a very large improvement. This combination has addressed flow issues for Calgary and throughout the system. It does appear to increase shortages to EID but this is because the flows coming from Bruce Lake are protected as it is operated for the health of the river. These shortages represent about 30 days over the 30-year period; realistically, this is another situation where human operators would probably make decisions that would result in a better balance between BRID and EID shortages. This combination does reflect the addition of two new reservoirs to the system (Bruce Lake and Eyremore), which has a separate suite of issues, but it opens up possibilities for further investigation and modifications.

Combination 6: High potential strategy

Preferred scenario (water bank + stabilized LKL) + implement seasonal consumptive demand reduction in Calgary + adjust fill times for three largest TransAlta reservoirs + increase on-stream storage downstream of Bassano (Eyremore Reservoir)

The single greatest improvement as a result of this combination is in the health of the Bow River. Most of the benefit is captured by implementing the Preferred Scenario, but each additional adaptation strategy improves river flows, although these are small in some cases. The addition of Eyremore Reservoir in particular (step 5) eliminates nearly all low flow days below Bassano, despite severe drought conditions for three years in this climate scenario. Figures 83-92 show the results of the step-wise layering of the specific strategies.

Although the Preferred Scenario does not specifically target river flows between Carseland and Bassano, it naturally improves them as well (see Figures 83-86). Steps 2 and 3 also result in substantial improvement to those flows. Although this improvement is only to one segment of the river, each step in this process adds noticeable value. With the addition of Eyremore Reservoir, the effect is particularly important as Carseland flows become the indicator for upstream river health.

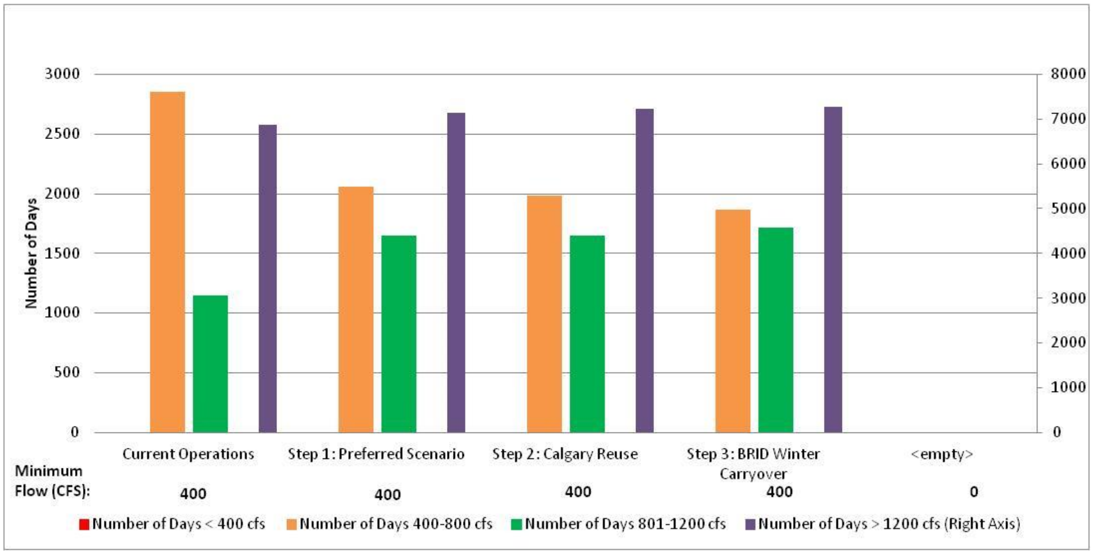

Figure 83: Bassano low flow days, steps 1-3

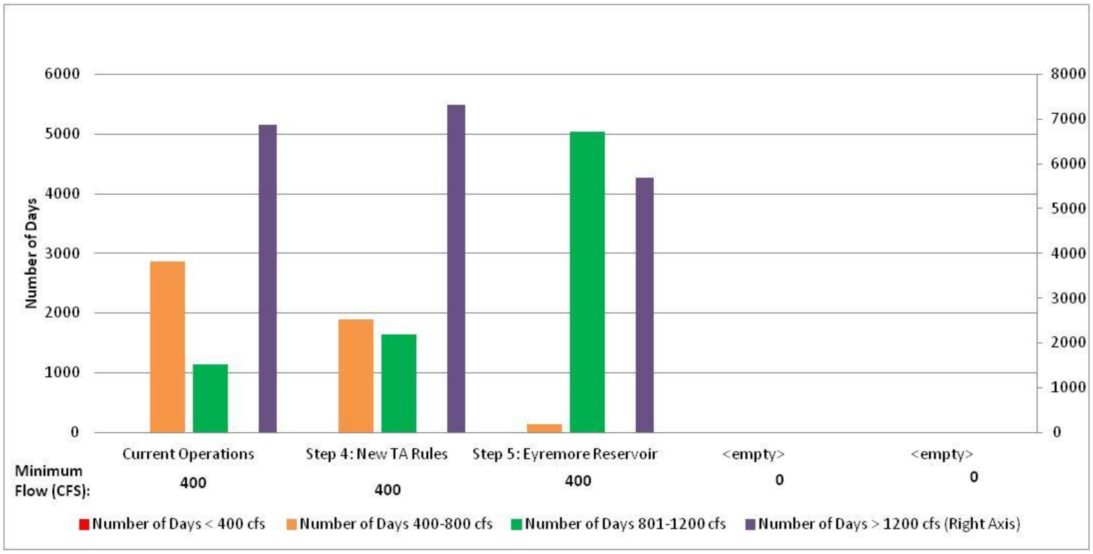

Figure 84: Bassano low flow days, steps 4-5

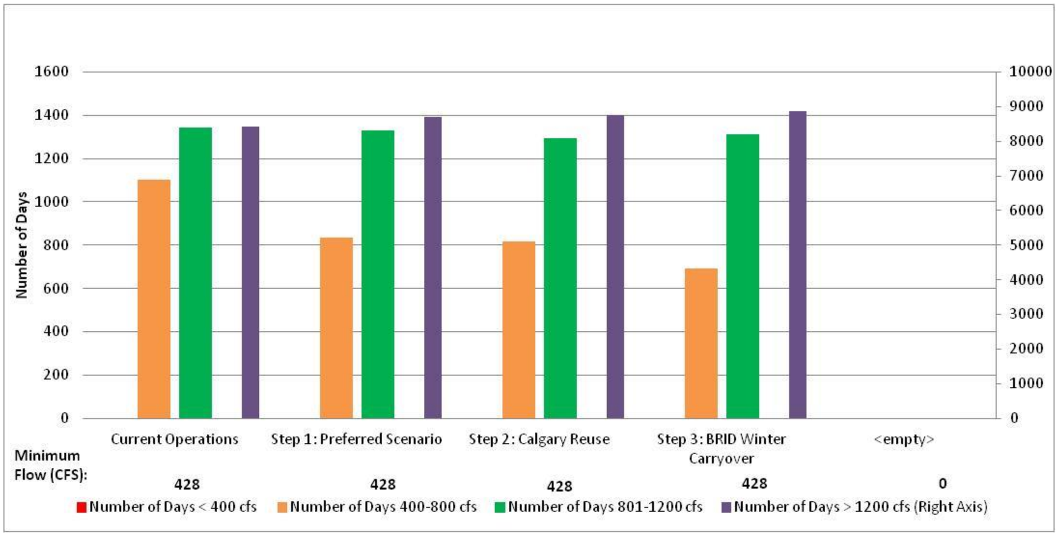

Figure 85: Carseland low flow days, steps 1-3

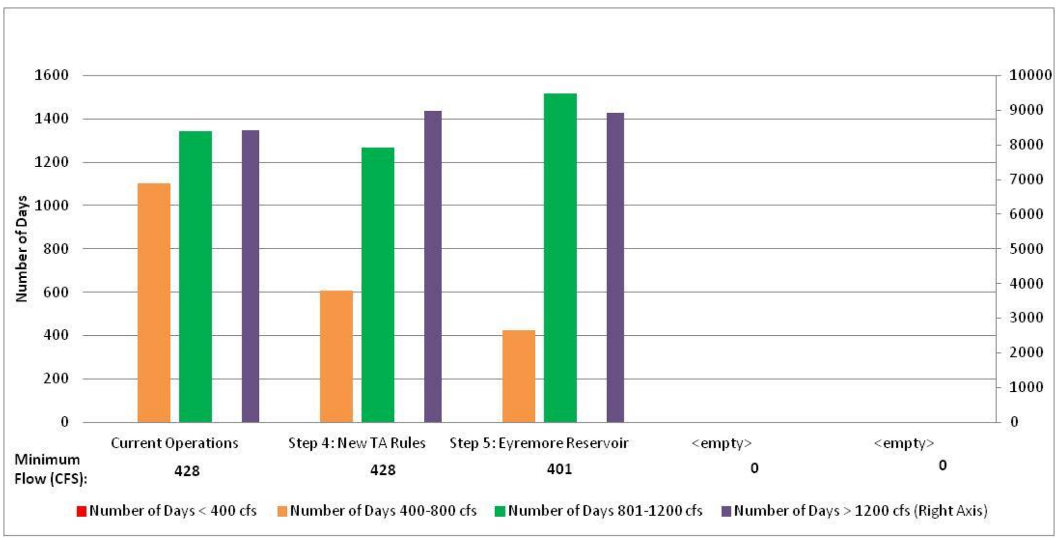

Figure 86: Carseland low flow days, steps 4-5

As steps 1 and 2 specifically target downstream operation, it is not surprising that they have less effect in improving upstream flows at Calgary (Figures 87 and 88). They do not make it noticeably worse, however, and under the more flexible operations recommended for the Preferred Scenario, adjustments would no doubt be made to further reduce low flow occurrences through Calgary. The Preferred Scenario includes a collaborative approach to flow management, which during a previous exercise was shown to provide much better results than the "robo-river" approach could possibly have shown. The more-difficult-to-implement strategies of steps 3 and 4 are still quite important. The new TransAlta rules and Eyremore Reservoir combine to completely eliminate all days of flow through Calgary below 900 cfs, and nearly eliminate the days of flow through Calgary below 1,250 cfs. This is particularly notable since the only other strategy that showed this much effect was the direct reduction of minimum river flow through Calgary (strategy D3).

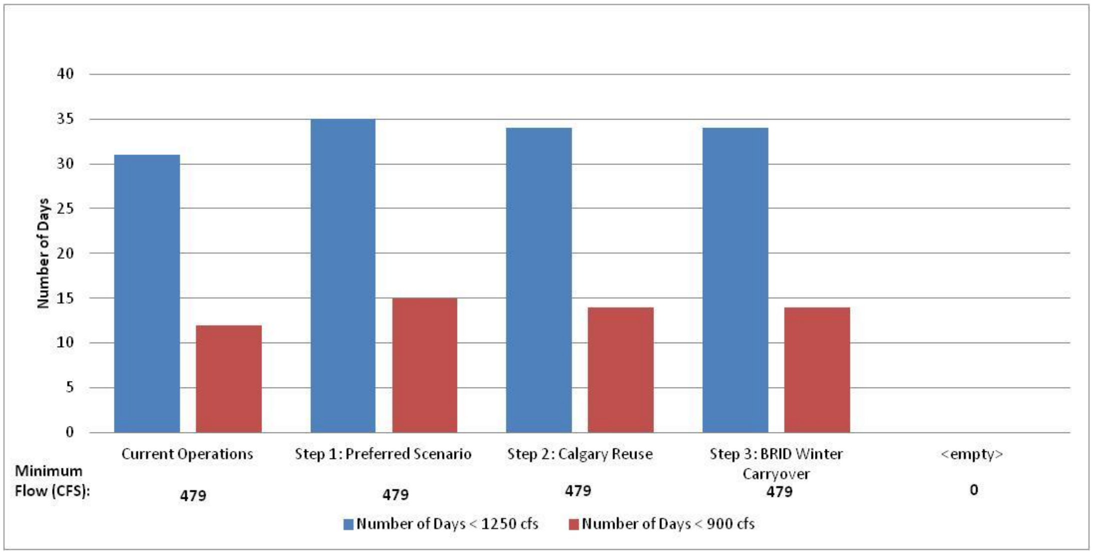

Figure 87: Calgary low flow days, steps 1-3

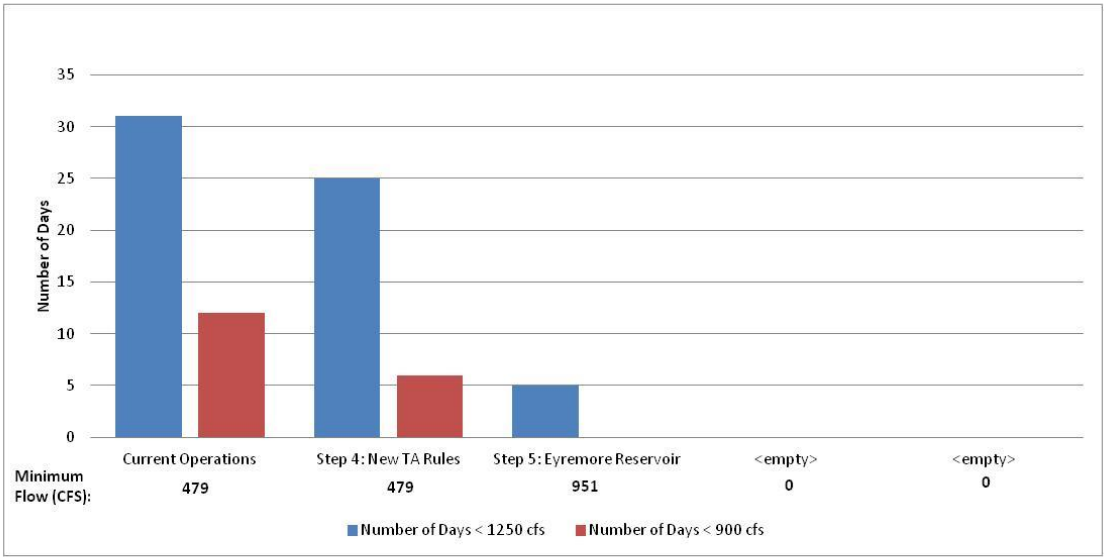

Figure 88: Calgary low flow days, steps 4-5

The benefits to the re-management of the river go beyond the health of the river itself. Steps 1-3 do not show a significant increase in risk of shortages to other water users on the system and, in most cases, even show small decreases (Figures 89 and 90).

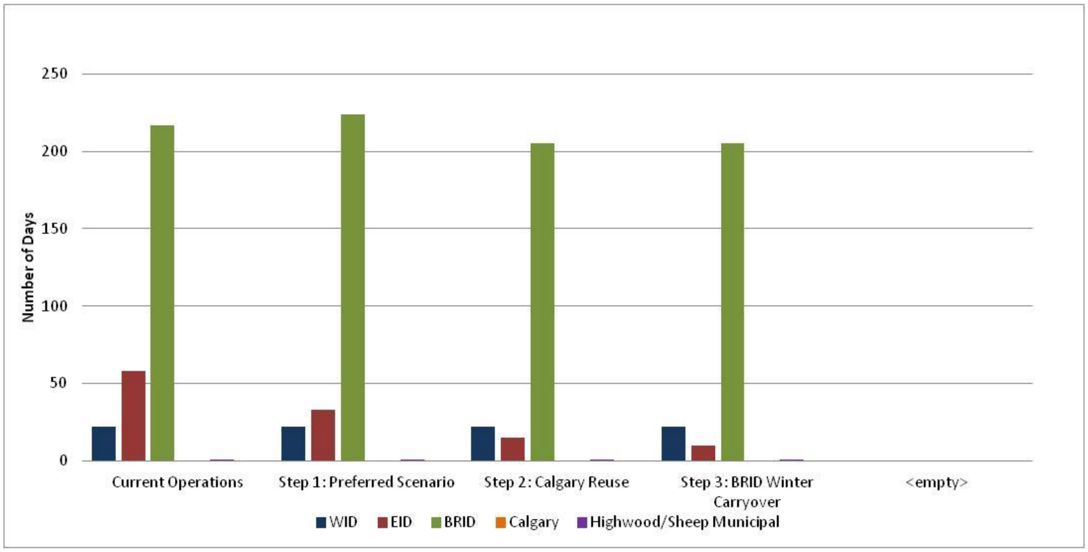

Figure 89: Number of shortage days, steps 1-3

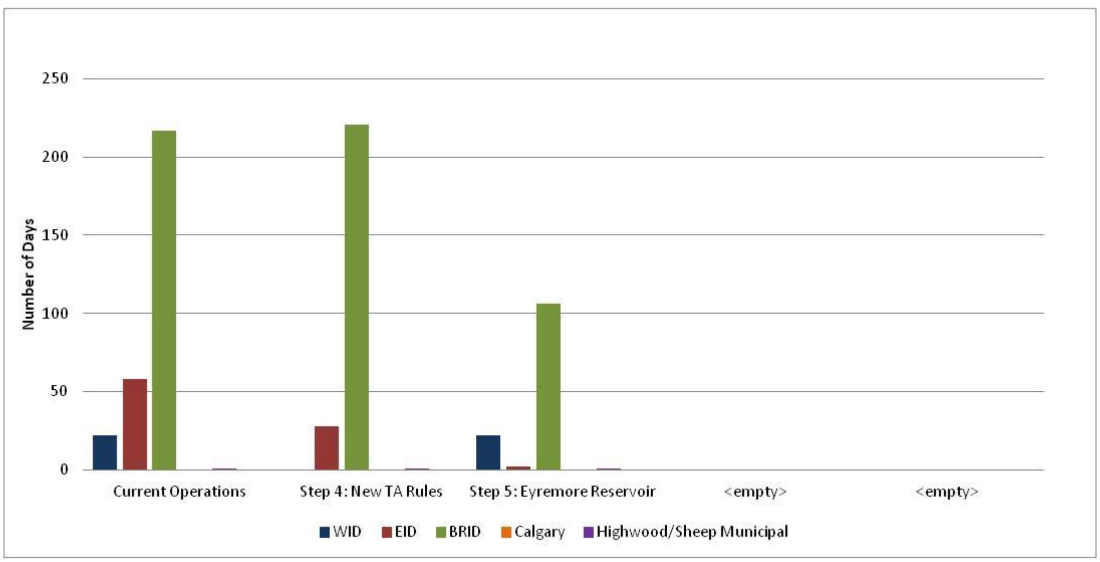

Figure 90: Number of shortage days, steps 4-5

Steps 1-3 very modestly reduce shortage volumes (Figures 91 and 92), but adding Eyremore Reservoir (step 5) dramatically decreases the number and volume of shortages as it eases the burden of flow maintenance from the irrigation districts, while retaining a higher and more consistent flow downstream.

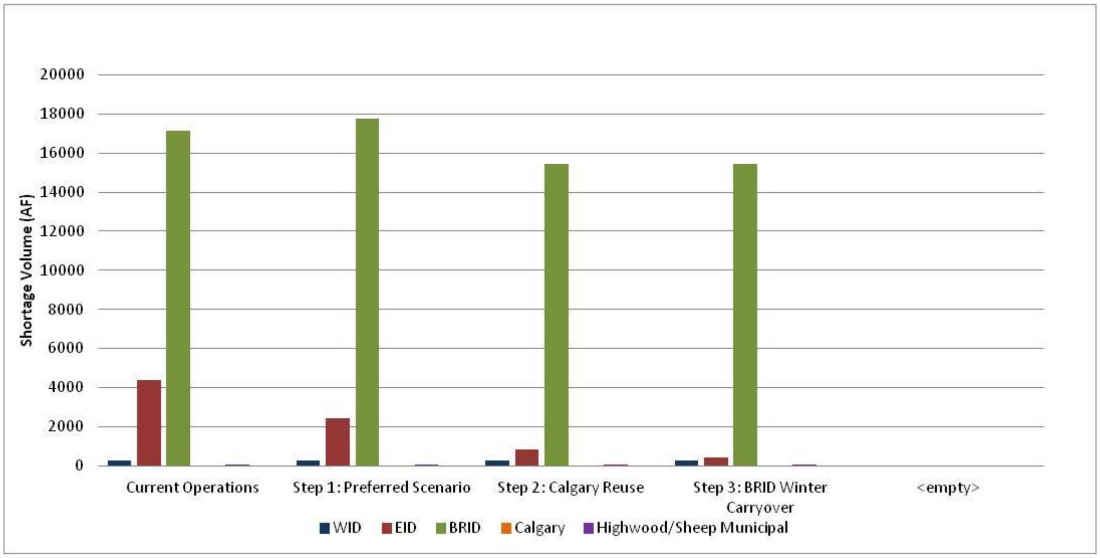

Figure 91: Volume of shortages, steps 1-3

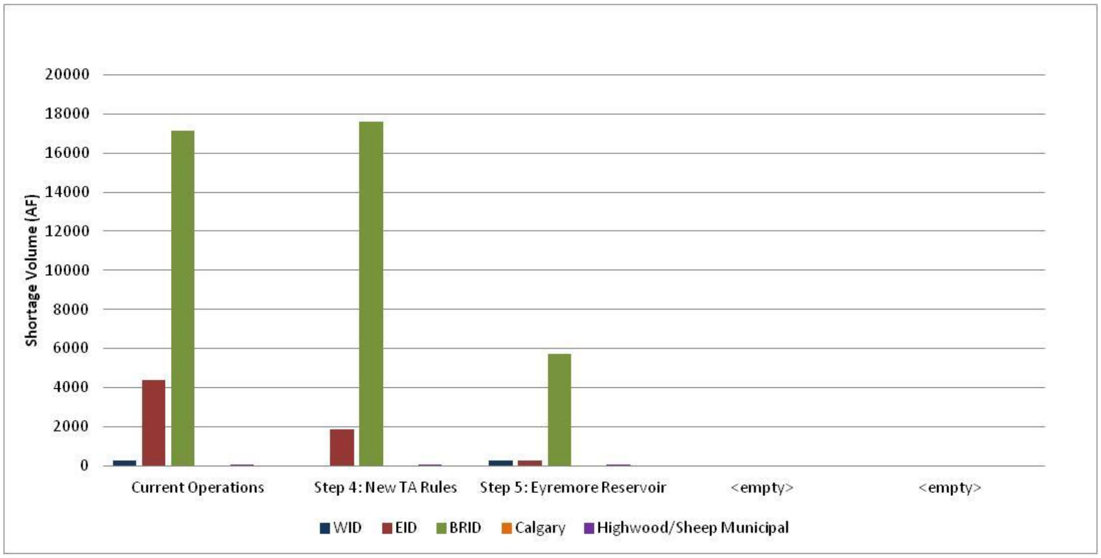

Figure 92: Volume of shortages, steps 4-5

This does not suggest that there are no downsides to the implementation of the operations proposed for this combination of strategies, merely that the chosen performance measures do not capture all impacts of implementation. Additional data and more specific information regarding costs, other environmental implications, and governance of the various infrastructure and altered reservoir operations can be linked into the model and examined if more detailed consideration is warranted in the future.

5 Conclusions

An important focus of the SSRB Adaptation Project was to build robust adaptation options for the Bow Basin in response to climate variability and change, including periods of prolonged and extreme drought. The fifteen individual and six combination strategies described in this report were suggested and explored by a diverse group of water users and managers, and the strategies reflect actions that could be taken by all major water users in the Bow Basin.

Some strategies could benefit the watershed and improve river management if they were implemented now, while others become important during times of severe drought. The strategies were based on various approaches, from reducing demand and changing management practices to building new infrastructure. Performance measures focused on impacts to the river and aquatic ecosystem health as well as to water users, and benefits are commonly seen for many of the strategies. Several strategies could also create opportunities for new economic development in the basin. It is recognized, however, that some strategies could have offsetting impacts on the environment, land and property owners, and further analysis would be needed to examine tradeoffs as well as specific environmental, economic and social costs and benefits.

Of the fifteen individual strategies examined, several were regarded as having the most promise. Five were viewed as having the most promising benefits to the watershed under the "normal" conditions that occurred over most years of the 30-year period for the chosen climate scenario. They could be considered or implemented now and would also be valuable in building resilience and helping the basin adapt to more severe climate conditions should these conditions arise:

N1: Implement preferred scenario
N2: Adjust fill times for three largest TransAlta reservoirs (Minnewanka, Spray and Upper Kananaskis)
N5: Move municipal licences from Highwood/Sheep system to Bow River
N6: Increase winter carryover in Travers Reservoir
N3, N4, N7: Conservation and demand reduction

Three strategies were suggested as having the most promise for adapting to the most severe drought conditions that occurred over three years of the 30-year period for the chosen climate scenario. Two involved new infrastructure to expand storage capacity, one off-stream and one on-stream. These "drought" options, once in place, would also be expected to benefit the region if and when conditions returned to normal:

D3: Reduce minimum river flow through Calgary
D4: Increase off-stream storage in the WID (Bruce Lake)
D7: Increase on-stream storage downstream of Bassano (Eyremore Reservoir)

These strategies are not being recommended or advocated; rather they are presented as a starting point for discussion and further consideration by those who use, manage and make decisions about water in the Bow Basin.

Appendix A: SSRB Adaptation Project Introduction Memo

South Saskatchewan River Basin Adaptation to Climate Variability Project
May 2012

A new project being launched this spring will harness the energy and creativity of southern Albertans to explore practical options for adapting to climate variability and change. Water is fundamental to community sustainability and growth, and the way water is managed in the South Saskatchewan River Basin (SSRB) will become even more important in the face of changing weather patterns and climate.

In January 2012, the Climate Change Emissions Management Corporation awarded funding for the *SSRB Adaptation to Climate Variability Project*. The funds were provided to Alberta Innovates-Energy Environment Solutions and WaterSMART Solutions Ltd. to support the first stage of this adaptation work.

This initiative will build on and integrate existing data, tools, capacity and knowledge of water users and decision makers to improve understanding and explore how to manage for the range of potential impacts of climate variability throughout the SSRB's river systems. This understanding will support collaborative testing and development of practical and implementable adaptive responses to climate variability, from the local community scale to the provincial scale. Using existing analytical and decision-support tools, the project will engage many people and groups to build:

- a common understanding of feasible and practical mechanisms for adapting to climate variability and change, and
- increased capacity for an informed, collaborative and adaptive approach to water resource management throughout the SSRB. This will enable organizations, communities and individuals to assess their risks in near real-time and determine their most suitable responses to climate variability within the physical realities of SSRB river flows, requirements and infrastructure.

The first stage of the project is divided into four coordinated phase:

Foundational Blocks: Initial Assessment

The first phase of the work is an initial assessment of the data, tools, capabilities, processes and frameworks that already exist and could form elements of the foundational blocks to support integrated water management by water users, decision makers and other interested parties over the long term. This work will identify the core resources for the project, identify critical gaps to be addressed, and ensure existing knowledge, tools, and experiences are leveraged, while avoiding duplication of work already completed or underway.

Bow River Basin: Adaptation and Live Test Year

The second phase will re-engage Bow River Project participants and engage new participants with an interest in the Bow River Basin to: advance climate adaptation decision making related to water resources, explore climate variability scenarios, identify impacts and risks to the river system and its users, and identify adaptation options. Participants will also document the net benefits of re-managing flows in the Bow River and identify infrastructure options that could assist with adaptation strategies. All of this work will provide support for a 'virtual' river test year, or perhaps an actual test year of modified flow, to better match the three Water for Life goals

Oldman River Basin and South Saskatchewan River Modelling

In the third phase, participants will model the Oldman River Basin (Oldman River and Southern Tributaries, including the Belly, St. Mary and Waterton Rivers), and the South Saskatchewan River to the Alberta border. Users, decision makers and others in the Oldman and South Saskatchewan River (OSSK) Basins will form a river consortium and set principles to guide and inform the model-based work, incorporating an environmental and climate adaptation focus. A comprehensive river system model for the OSSK Basins will be developed. Inputs to the SSRB from the Milk River will be part of this data, but the Milk will not be explicitly modelled. Throughout the model building, participants will discuss work that has been or is being done, and possible next steps in building the capability and capacity for adaptation around river management in the SSRB.

Foundational Blocks: Development

The final phase will see development of new adaptation foundational blocks. This work will be based on the gaps identified in the initial assessment, which may include acquiring, updating, or purchasing useful data and tools for future work to develop adaptation options for integrated river management.

This project will take approximately two years to complete. It should significantly advance climate adaptation resilience in the SSRB, leave a legacy of data, information and tools, and inform similar future work throughout the rest of the SSRB. We hope, with subsequent support, to then expand the work to encourage climate adaptation throughout the entire SSRB.

Project updates and reports can be accessed through the Alberta WaterPortal at: www.albertawater.com

If you have any specific questions regarding this work, please contact AI-EES or WaterSMART Solutions Ltd.

Appendix B: Project Participants

Organization	Representative(s)
Alberta Agriculture and Rural Development	Andrea Gonzalez Bob Riewe
Alberta Environment and Sustainable Resource Development	Allan Locke Andrew Paul Andy Ridge Anil Gupta Dave McGee Derek Lovlin Jim Stelfox Michael Seneka Satvinder Mangat Zahidul Islam
Alberta Innovates – Energy and Environment Solutions	David Hill Jon Sweetman
Alberta Tourism, Parks and Recreation	Joey Young
Bow River Basin Council	Mark Bennett Mike Murray
Bow River Irrigation District	Richard Phillips
Calgary Regional Partnership	Bob Miller Darrell Burgess
City of Calgary	Edith Phillips John Jagorinec Margaret Beeston
Eastern Irrigation District	Earl Wilson
Highwood Management Plan – Public Advisory Committee	Shirley Pickering
Kananaskis Improvement District	Arnold Hoffman
Municipal District of Bighorn	Erik Butters
Rocky View County	Jorie McKenzie
SEAWA – South East Alberta Watershed Alliance	Bob Phillips
TransAlta	Lora Brenan Roger Drury
Trout Unlimited Canada	Brian Meagher
Western Irrigation District	Erwin Braun
Alberta WaterSMART	Megan Van Ham Mike Kelly Mike Nemeth
HydroLogics Inc.	Dan Sheer A. Mike Sheer
Prairie Adaptation Research Collaborative	Dave Sauchyn Jeannine St. Jacques

Appendix C: Refinements Made to the BROM

As with most models, refinements and updates are continually made to reflect new information and operations. Several refinements, listed below, were made to the BROM for this project.

- Meeting current and future Siksika demands

  The BROM has been updated to model meeting Siksika demands based on current agreements. This does not imply that the modelled approach is accepted or supported by the BRID. The BROM now shows both the current Siksika allocation (7,500 AF) and the potential future allocation (35,000 AF) coming off the Carseland headworks. To deliver this volume, when the Siksika First Nation has demands, the model will protect a 300 cfs pass-through requirement to ensure delivery of the Siksika allocation. With this change, it will now appear in the model as if BRID shortages are reduced at the expense of the EID, but this is not the case. In this project we will continue to look at shortages for the three IDs as a whole and focus less on individual ID shortages.

- Monthly Calgary return flows

  Recent Calgary return flow data was provided to replace the base 83% that had previously served to generate Calgary's returns in BROM. Historical monthly wastewater returns from 2010-2012 were averaged to provide "typical" returns and then compared to existing demand pattern data to provide average percentage returns from Calgary. This monthly average percent return is now used to generate Calgary returns in BROM.

- Demand 807 in the Highwood River System

  Demand 807 was determined to be an artifact remaining from the combination of the individual Highwood and Sheep WRMM models. It represented Highwood demand in the Sheep model, and has been removed since that aggregate demand is now represented individually within the Highwood component of the model.

- New demand and return flow data from Okotoks

  For the Sheep River, Okotoks' demand and returns had originally been assumed to be constant year-round. Following discussion with local stakeholders, the Okotoks demand was adjusted to follow seasonal variation as seen in 2011 and 2012. Returns were also adjusted to seasonal percentages of demand averaged from historical 2011 and 2012 demand and return data.

- Correction to Lower Kananaskis Lake stabilization, and adjusted weighting on Lower Kananaskis Lake

  It was observed that Lower Kananaskis Lake was drawing down too easily under drought scenarios in BROM; this was corrected so that Lower Kananaskis Lake is now withdrawn later.