Bow River Project
Final Report

Prepared by | The Bow River Project Research Consortium

December 2010

Alberta Water Research Institute
water

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Newell

Rocky View County
Cultivating Communities

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The Bow River Project Research Consortium acknowledges the very large amount of time and expertise contributed by its members in undertaking and completing this project. The multi-stakeholder nature of the project and the willingness of these organizations and individuals to collaborate and consider potential opportunities created a remarkable level of synergy and creativity.

The Consortium deeply appreciates the involvement of staff from four provincial government departments. These individuals generously provided their ideas and shared their technical and scientific knowledge and experience in many diverse areas, which greatly improved the results of our work. The Consortium respects their need to remain neutral with respect to the opportunities identified for the Government of Alberta and other stakeholders to consider. Although they participated in the discussions and provided indispensable input, responsibility for the content of this report rests with the Consortium. All individual participants in the project are listed in Appendix A.

The large amount of data and information provided by many sources was an invaluable contribution to the Bow River Operational Model and is gratefully acknowledged. As well, Alberta Environment provided the supplementary water quality modelling for the selected scenario.

The expertise and professionalism contributed by HydroLogics Inc. cannot be overstated. All members of the HydroLogics team were extremely responsive to the suggestions put forward by participants and worked very hard under challenging timelines to help realize the vision of this project.

Finally, the Consortium is extremely grateful to those agencies and organizations that provided funding for this work. In addition to identifying opportunities to improve water management in southern Alberta, their investment has helped create the Bow River Operational Model, a valuable and timely tool for all of those interested in the way the province's rivers are managed.

BOW RIVER PROJECT RESEARCH CONSORTIUM MEMBER ORGANIZATIONS

Alberta Water Research Institute
Alberta WaterSMART
Bow River Basin Council
Bow River Irrigation District
Calgary Regional Partnership
City of Calgary
County of Newell
Ducks Unlimited Canada
Eastern Irrigation District
HydroLogics Inc.
Rocky View County
Trout Unlimited Canada
Water and Environmental Hub
Western Irrigation District

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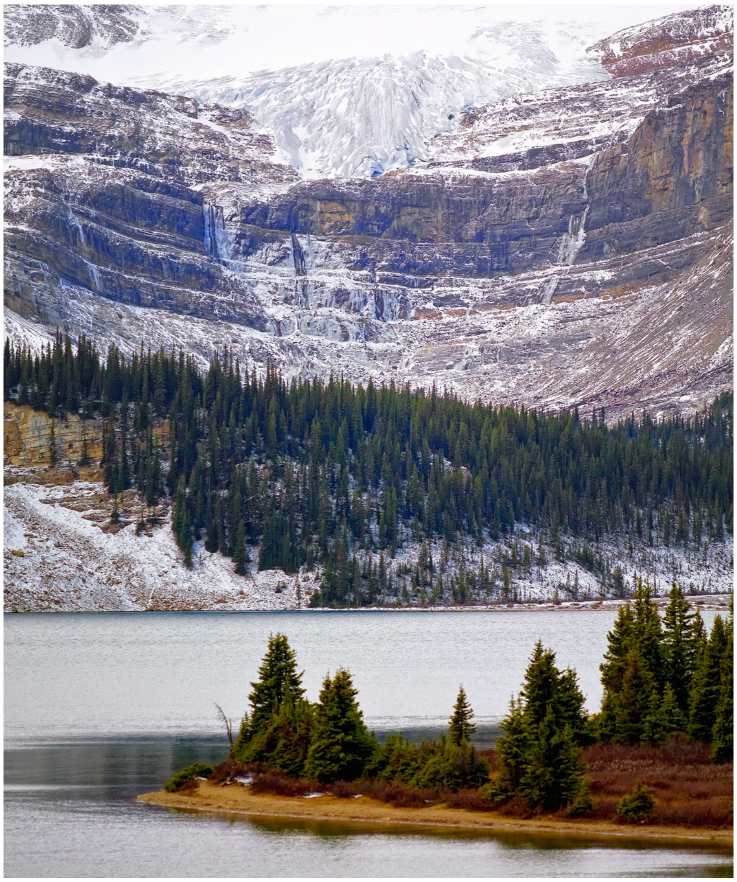
EXECUTIVE SUMMARY

The Bow River is one of Alberta's most historically, economically and environmentally significant waterways. It flows through the most populous river basin in the province where more than one-third of Alberta's residents live. A growing population, a thriving economy and the fact that the Bow River Basin is closed to new licence applications are all placing ever-increasing pressure on water supplies in the region.



Bow Glacier at Bow Lake

For the past 100 years, the flow of the Bow River has been controlled by dams and reservoirs and by the operating rules established by the owners of these facilities. Since 1911, TransAlta has been the main influence on the storage and release of water in the river and its tributaries. The fact that the timing and flow rate of the Bow River are already being managed offers a unique strategic opportunity to change the way decisions are made and make water available to more users when and where it is needed most.

In 2010, the Bow River Project Research Consortium was established to explore options for re-managing the river system from headwaters to confluence. Participants worked with an interactive, hydrologic simulation model to develop plausible and achievable scenarios for protecting the health of the river throughout the basin and meeting the needs of water users. The fully functioning, data-loaded Bow River Operational Model is a very significant output of this project that will be publicly available for further analysis of the Bow River System and can be adapted for other river systems in Alberta.

The key results of this project and the opportunities it identifies support the goals and principles of other major policy documents and approaches, including the *Water for Life* strategy, the Calgary Metropolitan Plan, and the South Saskatchewan Regional Plan being developed under the Land-use Framework. The Consortium's work shows that improvements in managing the Bow River System are realistic and doable with minimal economic impact on power generation revenues.

Five specific opportunities were identified for consideration by the Government of Alberta and others with a stake in the way the Bow River System is used and managed:

1. Manage the Bow River System in an integrated, adaptive, end-to-end manner, considering all users, interests and values
2. Pursue and support discussions between the Government of Alberta and TransAlta
3. Identify and consolidate the functions required to enable integrated, adaptive management of the Bow River System
4. Encourage and enable transparency and open data
5. Continue working toward an improved and integrated Bow River Management System.

The results of this project demonstrate that integrated management of the Bow River from headwaters to confluence could realize the following benefits:

- Releases from upstream storage reservoirs can significantly improve flows downstream without negatively affecting water quality. Water quality below the Bassano Dam can be expected to improve.
- Changes in management of the Kananaskis River have potential to greatly improve aquatic ecology and the existing fishery.
- Stabilizing water levels in Lower Kananaskis Lake will greatly improve the fishery and create new and enhanced recreational and tourism experiences.
- Long-term water demand forecasts for the City of Calgary, the Siksika First Nation, the Calgary Regional Partnership, Rocky View County and other surrounding municipalities can be accommodated.
- Minimum flows through Calgary will continue to be met and may be able to improve dissolved oxygen levels at critical times of the year.
- Modest irrigation expansion is expected to result from improvements in conservation and efficiency with no impact on the river.
- Previous studies have shown that, with sufficient capital investment, the Spray Lakes Reservoir can be restored to its original design capacity. This would restore about 75,200 dam^3 (61,000 acre feet) of storage, significantly enhancing total storage on the system and enabling most of the other benefits to be achieved. More immediately, there is an opportunity to create a water bank, which would utilize all the reservoirs in combination to achieve substantial overall benefits from the Bow System.

Areas for further work to flesh out and refine the proposed opportunities have also been identified.

Integrated management would optimize opportunities for licence holders, the environment and other users along the entire system. The collaborative approach used in this project and the resulting tool—the Bow River Operational Model—exemplify the importance and value of knowledgeable stakeholders working together, with access to agreed-upon data. The Consortium believes that successfully managing the Bow River System in an integrated fashion will require a shared approach involving the key water managers and users of this vital resource.

1. INTRODUCTION

Water has been the lifeblood of southern Alberta since the region was settled. This crucial resource has enabled the establishment of communities and supported a wide range of economic activities, to the benefit of the region and the province as a whole.

Although always recognized as a fundamental human need, water supplies in southern Alberta have become increasingly important in the face of existing and anticipated future pressures. For example, the Calgary region alone is expected to more than double its current population of 1.2 million to around 2.8 million in 60 to 70 years, adding about 800,000 new jobs in the process (Calgary Regional Partnership, 2009).

The challenge will be to accommodate this increase in population and economic activity while retaining the features that enhance the region's quality of life and define its character.

Spray Lakes Reservoir in Spray Valley above Canmore

Alberta's provincial water management strategy—*Water for Life: Alberta's Strategy for Sustainability*—has been the vehicle for managing Alberta's water resources since it was published in 2003. The strategy was renewed by the Province in 2008, reaffirming the commitment of the Government of Alberta "to the *Water for Life* approach for the wise management of Alberta's water quantity and quality for the benefit of Albertans now and in the future" (Government of Alberta, 2008, p.3). Southern Albertans understand the significance of water to the continued economic, environmental and social health of the region, and the challenges associated with sometimes conflicting needs.

These challenges, plus the realities that the Bow River Basin is closed to new licence applications and the percentage of municipal water licence use is increasing, have increased pressure to better manage the river system. The Bow River Project recognizes that water in the Bow River System is fully allocated and does not contemplate or suggest that water licence allocations will be re-opened. Many water users are already working on realistic, practical and innovative approaches to improve water management practices in the South Saskatchewan River Basin (SSRB). The Alberta Water Research Institute has played an important role in leading and supporting the development of new ideas and partnerships that will help solve these significant and growing water challenges.

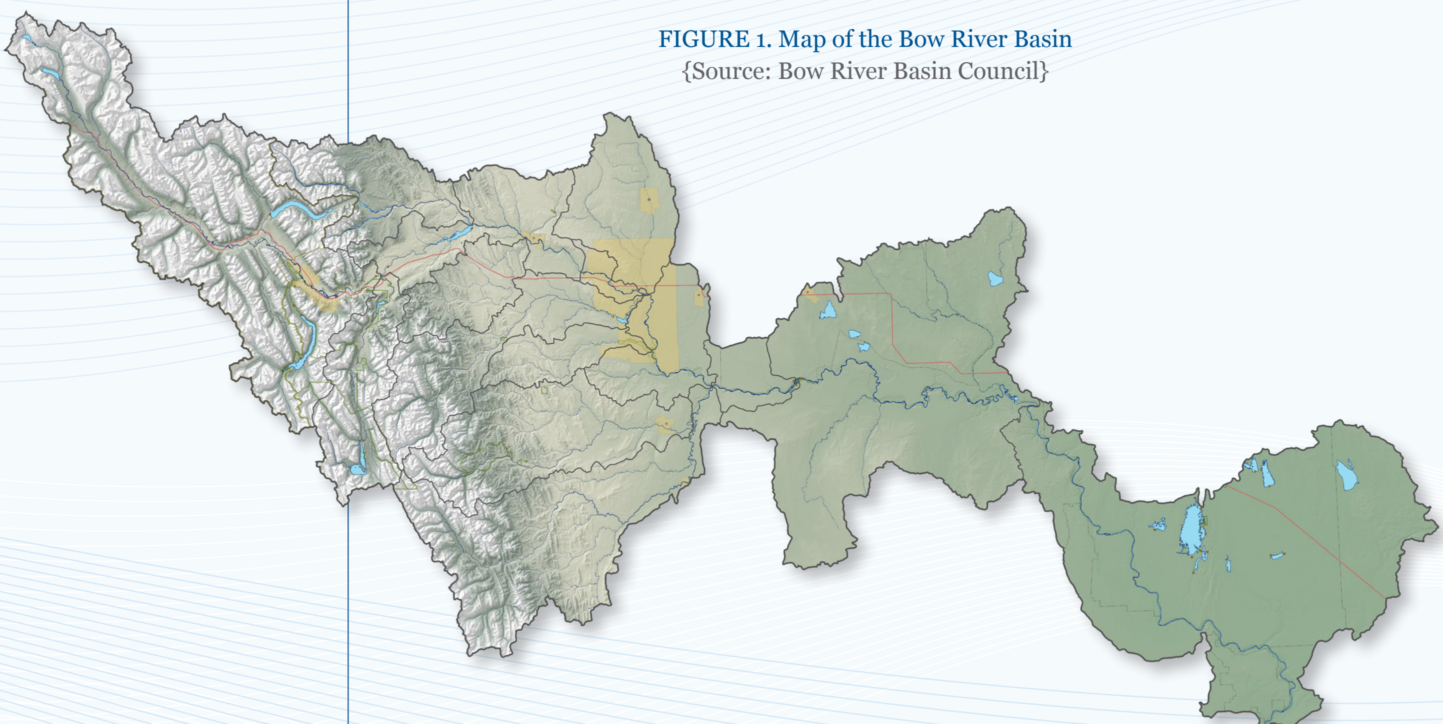
This report looks at new ways to manage water in the SSRB by focusing on improved management of the Bow River System as an integrated watershed. Taking advantage of the opportunities that emerged from this work could significantly improve water management and contribute to the long-term environmental health and economic growth of southern Alberta. All of the opportunities described in this report support the goals and key directions in *Water for Life*.

1.1 THE BOW RIVER SYSTEM AND ITS MANAGEMENT

Like most of Alberta's major river systems, the Bow River (the Bow) originates in the Rocky Mountains. On average, snowmelt from the mountains contributes about 80% of the river's total annual flow. This fact, combined with the high variability of snowfall from year to year, accounts for the extreme variability of annual flows in the river system. Although glacial meltwater contributes relatively little to the river's total annual flow, it plays an essential role in maintaining the health of the aquatic ecosystem in the headwaters during late summer, and in maintaining stream flow in low-flow periods and drought years.

The Bow passes through Calgary and, further downstream, joins the Oldman River to become the South Saskatchewan (see Figure 1). The Bow is approximately 645 km long and drains an area of nearly 25,000 square kilometres. The Bow Basin is home to 22 urban municipalities, including the City of Calgary, 12 rural or regional municipalities and three First Nations, making it the most populous river basin in Alberta (BRBC, 2010).

FIGURE 1. Map of the Bow River Basin
{Source: Bow River Basin Council}



The Bow and its tributaries provide water for drinking, irrigation, waste assimilation, electricity generation and wildlife, as well as for recreational activities including fishing, rafting, kayaking and canoeing. The river system and its shorelines also provide important aquatic habitat for many plant and animal species.

For the past 100 years, the flow in the Bow has been controlled by dams and reservoirs and by the operating rules established by the owners of these facilities. In 1911, TransAlta (then called Calgary Power) constructed the first of 11 hydroelectric stations on the Bow. Since that time, TransAlta has been the main influence on the storage and release of water in the river and its tributaries, and has played a major role in regional economic development. The locations of TransAlta's hydro facilities are shown on the map in Figure 2 and summarized in Table 1.

FIGURE 2. Map of TransAlta Facilities
{Source: TransAlta}

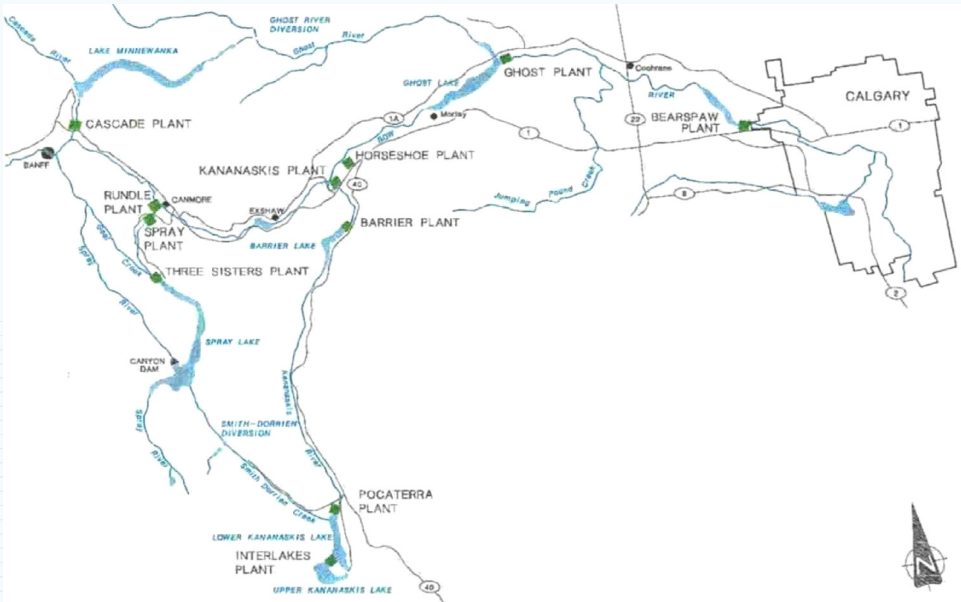


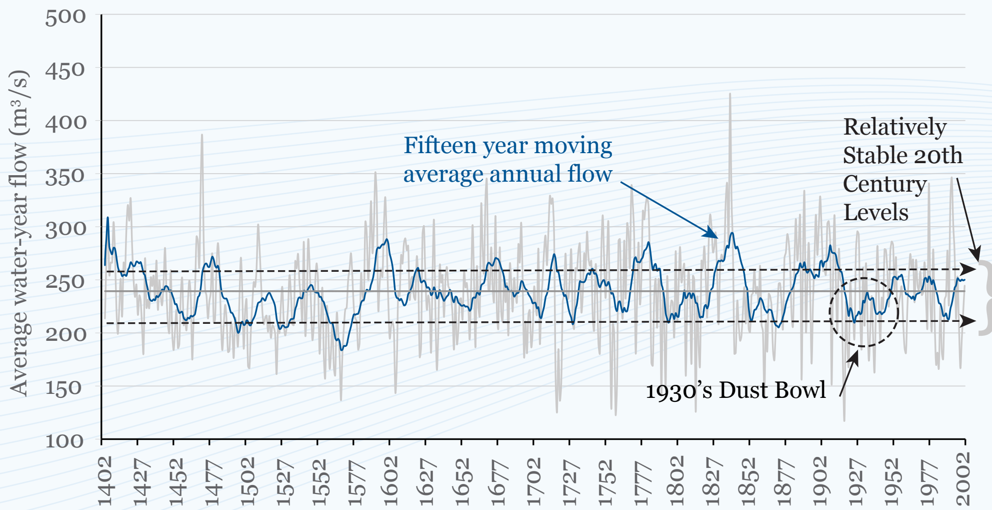
TABLE 1. Summary of TransAlta Hydro Facilities on the Bow River System
{Source: TransAlta}

Plant	Reservoir	Primary Reservoir Supply	Installed Capacity (MW)	Live Reservoir Storage (dam³)
Cascade	Lake Minnewanka	Cascade, N. Ghost	34	221,900
Spray Group (Three Sisters, Spray, Rundle)	Spray Lake	Spray River	155	177,600
Interlakes	Upper Kananaskis Lake	Kananaskis River	5	124,500
Pocaterra	Lower Kananaskis Lake	Kananaskis River	15	63,100
Barrier	Barrier Lake	Kananaskis River	13	24,800
Kananaskis	fore bay	Bow River	19	-
Horseshoe	fore bay	Bow River	16	-
Ghost	Ghost Lake	Bow River	56	92,500
Bearspaw	fore bay	Bow River	17	-
Bow Basin Total			330	704,400

For most of the year in most reaches of the Bow, the average annual flow is almost always adequate to meet environmental requirements and the demands of water licence holders. But there are exceptions during certain times of the year in certain reaches of the river, and in times of major drought.

Figure 3 shows the historic and prehistoric tree-ring calculated variation in flow associated with droughts and floods. As the chart shows, historic weather events have been more severe than in the more recent record, thus making drought and flood planning a prudent priority for all users of the river.

FIGURE 3. Historic Drought and Flood Record
{Source: David Sauchyn, University of Regina}

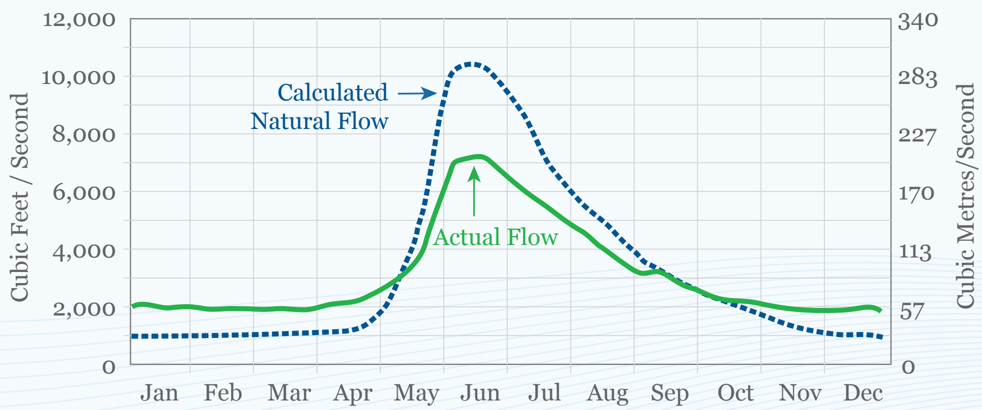


The Bow's hydro operations were designed over the past 100 years to maximize power production and revenue. Although economic circumstances and water usage have changed dramatically, little has changed in the technology or operation of the hydro system. The ability to almost instantly "spin up" its generators and produce electricity on demand allows TransAlta to balance the province's constantly changing electricity loads. This enables TransAlta to provide ancillary services to the provincial electricity grid to help maintain stability in the power system. Hydro facilities are, for the most part, operated to generate power when electricity prices are at their highest, on both a daily and annual basis (known as "peak power" generation).

The fact that the timing and flow rate of the Bow are already being managed, offers a unique strategic opportunity to change management decisions and make water available to more users when and where it is needed most. Responding to the needs of multiple users in a more integrated fashion can be achieved by changing the way the river system is managed. The chart in Figure 4 reflects that the Bow is a managed river, with these managed flows varying considerably from natural flows.

In the fall of 2009, the Alberta Water Research Institute (AWRI) provided seed funding for an initiative to determine interest among key water stakeholders in the Bow River Basin to look at alternatives for managing water and water facilities within the basin. As a result of those discussions, carried out for the AWRI by Alberta WaterSMART, the Terms of Reference for a Bow River Operations Modelling Pilot Project were drafted, and funding for the initiative was obtained in May of 2010 from the AWRI, the Water and Environmental Hub, and from several water stakeholders in the Bow River Basin. The goal of the project was to explore options for improving management of the Bow and to demonstrate the environmental, economic and risk mitigation benefits and costs related to the proposed changes in operating policies and rules, including performance in meeting water conservation objectives within the Bow River Basin.

FIGURE 4. Bow River at Calgary, Natural vs. Managed Flows (1960 - 1997)
{Source: Alberta Environment}



The timing of the project was seen as key. It is generally known that TransAlta is considering re-investments in its hydro infrastructure in the upper Bow Basin. Alberta Environment indicated that background information obtained from this exercise may be beneficial to proposed discussions between the Government of Alberta and TransAlta in 2011. Therefore, the originally-proposed project timeline was shortened considerably to conclude by the end of 2010.

1.2 THE BOW RIVER PROJECT RESEARCH CONSORTIUM

Building on a substantial foundation of work completed by the AWRI, Bow River Basin Council, WaterSMART and others, the Bow River Project Research Consortium was formed in May 2010. The Consortium is a collaborative group of water users and managers whose members control approximately 95% of all water allocations and estimated water use in the Bow River Basin (see Appendix A for a list of project participants).

Ghost Dam

As well as a significant amount of time and expertise, many Consortium members also contributed funding to support the project. TransAlta was invited to join the project but did not feel it was appropriate to participate fully. However, the company was cooperative in providing data and information, but is not responsible for any errors or omissions in this report. This diverse group of individuals brought their experience and a great depth of knowledge to the project as they assessed possible changes to water storage and timing of flows in the Bow system that would enhance environmental, social and economic development opportunities. Over an intense six-month period, they worked with an interactive, hydrologic simulation model to determine plausible and achievable scenarios for meeting the needs of water users and protecting the health of the river throughout the basin.

The Consortium considered other related policies and initiatives in place and underway, notably Alberta's *Water for Life* strategy, the South Saskatchewan Regional Plan now being developed under the province's Land-use Framework, the Bow River Basin Council's State of the Watershed Report, the recent WaterSMART publication on Bow River Opportunities, the Calgary Metropolitan Plan and Alberta Environment's review of TransAlta operations. The Bow River Project's (BRP) desired outcomes and principles, described in section 1.3, and the opportunities noted in section 5 are entirely compatible with the goals and principles of these important policy documents and studies.

The potential to restructure operations on the Bow provides a valuable and timely opportunity to incorporate environmental improvements that will contribute to all three *Water for Life* goals. The opportunities identified in this report explicitly support these goals, which are:

» A safe, secure drinking water supply for Albertans;

» Healthy aquatic ecosystems; and

» Reliable, quality water supplies for a sustainable economy.

Section 5 includes a more detailed description of how the opportunities specifically advance the *Water for Life* goals.

1.3 GOALS, OUTCOMES AND PRINCIPLES

The goals for the BRP, as described in the original terms of reference for the project, were to:

» Develop a common understanding of river flow and the respective timing and uses of water by each large senior licence holder and other key water users, including essential environmental processes. Agree on the available data series to be applied and computer model(s) to be used for purposes of this technical research project.

» Develop water demand and management scenarios to alter on-stream storage, flow rate timing, and water uses to determine an optimal river system management regime to protect the aquatic ecosystem while better accommodating the interests of the various water users along each reach of the Bow's tributaries and main stem.

» Determine, within reasonable ranges, the costs and benefits to existing water users and/or to other users to create the infrastructure, management, and commercial mechanisms necessary to implement the practical agreed-upon scenarios.

» Identify and recommend needed legislative or regulatory changes, or commercial arrangements that would be needed to enable selected scenarios to be accomplished.

» Develop preliminary practical scenarios to alter the storage, release and flow regime of the river system that can: 1) demonstrate economically achievable improvements to reduce risk to downstream users from drought and flood, 2) improve water accessibility for human use and environmental protection, and 3) support policy on long-term economic development and population growth within the basin.

» Communicate these scenarios and operating regimes effectively to government and stakeholders for their purposes.

» Develop a process for: maintaining and updating the model, managing and prioritizing the changes needed to implement the recommended operational changes, and providing for continuing monitoring and management functions.

» Conduct any additional modelling that may be needed and recommend the agreed-upon adaptive management model to government and other stakeholders as the basis for developing the next version of the Watershed Management Plan for the Bow River System.

If the opportunities identified by the project are implemented, the following outcomes and benefits are expected, all of which are viewed as realistic and achievable:

- Reduce risk from drought through targeted on- and off-stream reservoir management.
- Improve protection from moderate flood and drought events over the longer term.
- Improve access to water for human and municipal use.
- Improve recreational opportunities in various reaches and tributaries.
- Improve aquatic ecosystem protection in the Bow River System.
- Ensure long-term integrated management of the river system based on improved data, knowledge and information.

When considering scenarios for how the river could be managed differently to achieve these outcomes, several principles served to underpin the discussions and decisions:

Trout in the Bow River

- All opportunities presented in this report are based on the principle of causing no significant measurable environmental harm compared to current river management practices (that is, the base case scenario). The expectation is that various reaches in the Bow will be improved, as will overall ecosystem health.
- The Bow River Basin will remain closed to any new surface water licences.
- TransAlta's reputation as an environmentally responsible and proactive corporation is respected and protected.
- TransAlta should be compensated for the cost of providing benefits to other parties.
- Alberta's annual apportionment commitments to Saskatchewan must be met.
- Municipalities on the Bow have minimum flow requirements that cannot be compromised.
- Any system changes must support the long-term population growth forecast for the region, as described in the Calgary Metropolitan Plan (CRP, 2009), out to 2076.
- An amount of 43,200 dam^3 (35,000 acre feet) is set aside to meet the forecast long-term needs of the Siksika First Nation. Unused water will remain in the river flow until needed.
- The existing water licence allocations under Alberta's priority system will continue to be respected.

2. PROCESS AND METHODOLOGY

To examine opportunities, costs and benefits of potential operational changes on the Bow, the Consortium worked with a team of experienced professionals to develop and technically evaluate an interactive simulation model—the Bow River Operational Model (BROM). The model quantifies and maps water supply and usage, establishes flow thresholds and maintains a full suite of performance measures. This tool enables users to establish and test plausible scenarios that balance future water needs, environmental objectives, social considerations and economic feasibility.

The BROM is a valuable legacy of the project. It was built on a strong foundation of Alberta work and every attempt has been made to verify the data that was used. The model is directional; although it was built very quickly, it provides a solid base for evaluating water management options and scenarios, and the Consortium believes it accurately represents the Bow River System. The BROM will be publicly available for further analysis of this system and could be adapted for other river systems in the province. There is great potential to continue to refine and improve the model to make it an even more effective tool for those interested in the use and management of Alberta's rivers.

2.1 A COLLABORATIVE APPROACH

The Consortium met monthly to provide direction and support for the project. There were also two, two-day intensive interactive modelling sessions where participants worked with the consultant to explore the impact of proposed changes in river management and see, in real time, the impacts of the changes. An early important task was to create a baseline modelled scenario to show that the model was reacting realistically. The collaborative nature of the project meant that members spent a considerable amount of time in valuable discussions to better understand the perspectives of others and to gain insight into potential alternatives for managing the river.

Winter on the Bow River

The Consortium focused on three technical aspects of the project: modelling and data, environment and economics, drawing in additional experts and resources as needed to provide advice and input.

The Modelling and Data team worked closely with the consultants as the model inputs were tested and refined, ensuring that the outputs reflected their knowledge and historical experience with use and management of the river. The team met weekly by teleconference to review assumptions, data issues, operating logic and any other items related to building the model.

The team tested and validated the work by interacting with the model, raising questions about the data and analysis, and checking the accuracy of the data.

The Environment team focused largely on developing the suite of environmental performance measures. This work enabled them to accumulate a list of environmental issues and concerns that needed to be considered through this project. If a performance measure could not be developed, the issues were noted and, in some cases, targeted for future work. This team also was instrumental in identifying data sources for many of the performance measures.

The economics work considered the financial impact of proposed changes to the river system. This included modelling the estimated power revenue impact for TransAlta, identifying preliminary capital and operating costs associated with infrastructure changes and investigating other potential economic benefits such as recreation and fisheries improvements. An analysis of historical electricity prices was commissioned and integrated into the model to indicate directional impact on total return from power generation under various scenarios and stress tests. Additional work was also commissioned on the valuation of fish habitat.

2.2 HYDROLOGICS AND THE OASIS MODEL

The Consortium chose HydroLogics, Inc. as the consultant to lead the modelling work, using the sophisticated simulation software they developed for modelling water systems throughout the US and internationally. Since 1985, HydroLogics, Inc. has used advanced optimization and simulation techniques to help water users and managers with long-term planning, operations planning, environmental impacts evaluation, water quality management, drought management, and the re-licensing of hydroelectric projects.

Participants working at CAN session.

HydroLogics has also pioneered the use of Computer-Aided Negotiations (CAN) which enables parties with disparate goals to work together to develop operating policies and solutions that mutually satisfy their diverse objectives. The CAN sessions integrate computer modelling techniques with the existing water management structures. HydroLogics has used these techniques in resolving water resources disputes in the Washington D.C. metropolitan area, Las Vegas and the Kansas River basin. HydroLogics was also familiar with southern Alberta, as they had previously done similar work on the South Saskatchewan River Basin through the University of Lethbridge.

HydroLogics' software—called OASIS, for Operational Analysis and Simulation of Integrated Systems—is very flexible, completely data-driven and effectively simulates operators' behaviour. It is also easy to use and is compatible with other models, which means it can send and receive data from other programs while the programs are running, enabling each program to react to information provided by the other.

2.3 DATA ACQUISITION AND QUALITY CONTROL

The Consortium undertook considerable work to assemble and validate data for use in OASIS. Data were gathered from a number of sources, with permission; these sources included TransAlta, Alberta Environment's Water Resources Management Model (WRMM), In-stream Objectives, the Irrigation Demand Model, the Alberta Electricity

System Operator, and Alberta's Water Conservation Objectives. Due to the limitations faced by earlier modelling initiatives, the BROM has data only from 1928 to 1995. HydroLogics devoted a great deal of effort to checking the data, formatting it and ensuring the data sets were comparable.

EDC Associates, a Calgary-based consulting company that is very familiar with Alberta's electricity system and power pricing, was engaged to provide expert guidance, data analysis, forecasting, and extensive background information to assist with modelling the power business. Only publicly available TransAlta financial data were used to build the power revenue component of the model. More details on the economic data provided by EDC appear in the sidebar. EDC also prepared for the project a very helpful overview of the structure, governance and operating rules of the Alberta electricity and ancillary services market (EDC Associates Ltd., 2010).

Power Industry Data and Information

EDC provided the project with projections of hourly price values for electricity and for ancillary services (spinning reserve and load regulation in multiple categories). The values were for every hour of the year for each of the forecast years (2011 - 2026). While the value for any particular hour in the projections is unlikely to be correct, the forecast prices are representative of the general prices to be expected, and the variation among hours in the projections is representative of the variation to be expected. Thus, the prices represent a good basis for evaluating the overall changes in electrical revenues one might expect from changing the operations of the power plants. Impacts on firm energy production have not been considered. Based on conversations with EDC, firm energy impacts are expected to be small.

To simplify the analysis, HydroLogics used the EDC results to create a set of hourly prices for each calendar month. The set was created so that the hourly prices were the same for every day of the calendar month. The EDC output for the first three forecast years (2011-2014) was used in creating the simplified data set. The hourly price for the first hour of every day in a calendar month was computed by averaging the data for the first hour in every day of the calendar month for all of the three years (2011-2014). Only the first three years of the forecast values were used because the Consortium felt that the earlier year forecasts were more likely to be a more appropriate basis for estimating impacts. Price forecasts for the first three years were significantly lower than those for later years.

EDC has since created a new price forecast data set that incorporates historic meteorological conditions. Each series of forecasts in this new EDC data set reflects predicted prices in a year with weather similar to a historical year. In the future, these new forecasts can be used in simulations so that the meteorological data used in forecasting prices corresponds to the weather that produced the historical flows used to drive the simulations. When this is done, the evaluation of impacts on energy and ancillary services revenues will explicitly consider the simultaneous impacts of weather on both flows and energy prices.

2.4 CONSTRUCTION OF THE BOW RIVER OPERATIONAL MODEL

The Bow River Operational Model (BROM) is built on foundations lain by the SSRB model. Constructed for the University of Lethbridge, the SSRB model emulates Alberta Environment's simulation of the SSRB. The BROM diverges from the SSRB model, however, in that it attempts to more accurately model existing and potential future operations beyond the constraints of a strict licensing system.

Data in the BROM were derived largely from the WRMM, but operating rules were changed to reflect current demands. The WRMM models strict licence priority water allocation and is intended as a regulatory assurance model rather than an interactive management model. OASIS attempts to create a model that reflects current operations and allows for greater variation in potential operational changes. To that end, there are a number of significant specific changes in the way the BROM operates. These operational rules are the result of numerous discussions with stakeholders from the irrigation districts and the City of Calgary. A description of the BROM base case appears in Appendix B.

As the model was being developed, Consortium members reviewed the results and the operating rules and provided their input over the course of several meetings on sources of inflow and return flows, protected demands, projected available system storage, performance measures and other aspects as required.

2.5 DEVELOPMENT OF PERFORMANCE MEASURES

Developing performance measures is one of the first steps in the process to help parties scope the issues. Performance measures reflect the objectives and desired outcomes for the project and indicate whether one result is better or worse than an alternative. They define the functional aspects that the model needs to have, and thus they inform and influence how the model is constructed.

Drawing on their knowledge and experience, the Consortium identified a wide range of performance measures to be considered in developing the scenarios. In some instances, data were either not available or could not be sourced within the timelines. Thus some performance measures were not included in the scenarios, but the Consortium felt they were important and deserved a brief qualitative commentary; at least some of these warrant further attention in a future phase of the work. The performance measures for the project are briefly described in section 3.1.

2.6 SCENARIO DEVELOPMENT

The model base case reflects the way the Bow system is currently being managed and the Consortium worked closely with the consultant to ensure that it was as accurate and complete as possible. This was the starting point for developing alternate scenarios.

Applying a systematic approach and building on experience with the base model, the next step was for the Consortium to agree on the alternatives that would be evaluated so the consultant could design the appropriate analytical tools and develop the alternate scenarios.

Consortium participants spent two, two-day sessions working with the model to see how it responded to particular demands and what the impact was on performance measures. Operational changes included: increasing storage at various reservoirs, timing of reservoir filling, meeting water conservation objectives (WCOs) first, stabilizing the Kananaskis system, increasing Calgary demand and others. Additional performance measures were developed as needed and specific details and operating logic of the model were adjusted in response to new data and comments from the group.

At each session, participants discussed and refined potential alternatives in response to what the model runs revealed. Between sessions, substantial additional work was done on the base model and scenarios, in consultation with the Modelling and Data Team. The Modelling and Data Team stressed that the river needs to be considered as an integrated system. Although many downstream benefits were observed by increasing storage, all objectives needed to be considered and modelled and the links between them maintained to ensure the impacts of any one component on others were addressed. The intent was to meet the needs of as many users as possible without increasing risks for others, while ensuring environmental requirements were maintained or enhanced.

The Consortium also recognized the potential for innovatively combining opportunities to get synergistic effects, and this approach is reflected in the scenario results. By adjusting model parameters and considering a wide range of possibilities and ramifications, the Consortium was able to identify management changes that it believes will improve environmental conditions and better accord with the interests of water users throughout the Bow River Basin.

Although several scenarios in addition to the base case were developed, as noted in section 3, four were considered in more depth and are described in detail in Appendix C.

The purpose of this project was not to determine detailed costs for any scenarios. Where costs were publicly available or could be accurately estimated, they are noted later in the report, along with ideas for possibly offsetting some of the costs. The Consortium recognizes the increased importance of confidentiality and competitiveness issues in the wake of deregulation of the electricity sector, and acknowledges that additional capital and operating costs will undoubtedly need to be considered as part of any efforts to manage the Bow River System in a more integrated manner.

3. PROJECT RESULTS

3.1 PERFORMANCE MEASURES

Table 2 lists all the performance measures (PMs) that were pursued for this project. Most were developed and implemented and the process was sufficiently flexible that some could be combined or rolled up as the work proceeded. Those are noted in the right column. Several PMs were viewed as important but could not be included in this version of the model for various reasons; these are noted as "deferred" and are described briefly below the table, including the reasons for deferral. PMs 22, 33-39 and 44-49 were set aside early in the process for various reasons and, for ease of record keeping, those numbers were retired. Plots of the PMs that were incorporated into the model are shown in Appendix D.

TABLE 2. BROM Performance Measures

#	Performance Measure	Model Output/Description
1.	Flow in Kananaskis River	Flow stabilization in the Kananaskis River between Lower Kananaskis Lake and Barrier Lake to benefit the aquatic environment.
2.	Flows in various reaches	Flow in the Bow River at selected reaches during critical periods.
3.	Flow frequency curve over time by reach	Frequencies of various flow rates in the Bow River.
4.	Flow frequency curve over time, comparing different reaches	Group agreed to capture this in PM 3.
5.	Master Agreement on Apportionment	Minimum daily flows and annual volume is maintained. Daily contributions for the Bow, Oldman, and the Red Deer towards the total flow into Saskatchewan.
6.	Flood events in Calgary	Number of flood flow events across the simulation period according to flood flow classifications provided by the City of Calgary.
7.	Diversion difficulty days	Number of flow events in each year which, according to criteria specified by BRID, describe flows that cause diversion difficulty.
8.	Low-flow diversion restriction shortages	This PM has been rolled into PM 7.
9.	Stage frequency curves for various reservoirs	Frequencies of stages on reservoirs by sorting the stages largest to smallest and assigning an exceedance probability to each data value.
10a.	Stage probability plot	Time series output of a given reservoir's stage across the simulation period in two-week increments.
10b.	Storage probability plot	This PM is generated in a similar fashion to PM 10a.
11a/b.	Stage/Storage Probability Plots (grouped by wet, dry, normal years)	Deferred; see paragraphs below table.

12a.	Shortages	Daily shortage and maximum diversion for each of the irrigation districts and Calgary.
12b.	Shortages (as a percent of the request)	Shortages as a percent of the total request for each of the irrigation districts and Calgary.
12c.	Shortage frequency curves	Frequencies of shortages in EID by sorting the shortages largest to smallest and assigning an exceedance probability to each data value.
13.	Number of days of shortages	Number of days where there is some shortage (>0.01 dam^3) in EID, WID, BRID, Calgary, and the total system.
14.	Consecutive-day shortages	Number of consecutive-day shortage events for each of the irrigation districts.
15.	Irrigation return flows	Deferred; see paragraphs below table.
16.	Riparian habitat regeneration	Deferred; see paragraphs below table.
17.	Acres of riparian habitat flooded	Deferred; see paragraphs below table.
18.	Stages for walleye spawning	Walleye spawning is assessed by counting the number of good years where the reservoir stage on June 1 has not fallen below the reservoir stage on April 1. This PM is implemented for Crawling Valley, Newell, McGregor, and Travers reservoirs.[1]
19.	Consecutive days of fish spawning	Deferred; partially covered by PM 18 (see paragraphs below table).
20.	Frequency curve of the percentage of the WCO met	Frequencies of the WCO percentage-met by sorting values largest to smallest and assigning an exceedance probability to each data value.
21.	Frequency curve of the percentage of the IFN met	Frequency of years the IFN (or percentage of IFN) is met for each week of the year.
23.	Flow at the mouth of the Bow	Flow in the Bow River where it joins the Oldman River.
24.	Flow frequency curve for the mouth of the Bow	Frequencies of flows in the Bow River where it joins the Oldman River by sorting the flows largest to smallest and assigning an exceedance probability to each data value.
25.	Percent of natural flow at the mouth of the Bow River	Rolled into PM 24.
26.	Water Restrictions	Deferred; see paragraphs below table.
27.	Homeowner Impact	Deferred; see paragraphs below table.
28.	Police/Fire boat ramp impact	Not included because infrastructure was designed to withstand flows far outside of normal operating conditions.

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[1]*Walleye, lake whitefish, pike, brown trout, rainbow trout, brook trout, mountain whitefish and lake trout are all found in the Bow system. This measure was dropped for all species except walleye. Lakes are typically stable during lake whitefish spawning season (fall) so staging would not be an issue. Pike and walleye spawn in the spring, so if the model shows that walleye are not at risk, it was thought that pike should not be either. Lake trout do spawn in the Ghost, Spray and Minnewanka reservoirs, but there is insufficient information to incorporate into the model. Most of the remaining sport fish spawning in the Bow system occurs in rivers and tributaries, not in lakes or reservoirs. This measure was retained for the purpose of considering impact on walleye eggs in some prairie reservoirs.*

29.	Irrigation boat ramp impact	Not included because infrastructure was designed to withstand flows far outside of normal operating conditions.
30.	Power revenue	Average annual power generation revenue and average annual ancillary services revenue for the TransAlta system in the upper Bow Basin.
31, 32.	Total power revenue and power generation Box and Whisker Plots	The PM is created for four variables: power generation revenue, ancillary services revenue, total power revenue, and power generation. For each day, the model calculates revenue for generation, revenue for ancillary services, and power generation.
40.	Flood events	Days where the flows are considered flood flows. The PM is generated for two reaches: (1) the WID diversion to Highwood confluence, and (2) Carseland to Bassano.
41.	Dissolved Oxygen	Deferred; see paragraphs below table.
42.	Dissolved Oxygen frequencies	Deferred; see paragraphs below table.
43.	Birds	Deferred; see paragraphs below table.
50.	Glenmore recreation season	Each recreation-season day on Glenmore reservoir is counted and classified in relation to the reservoir stage. Percentages are then based on the total number of recreation-season days in the simulation.
51, 52, 53.	Travers, McGregor, and Little Bow Recreation	Each recreation-season day is counted and classified in relation to the reservoir stage. Percentages are then based on the total number of recreation-season days in the simulation. For each year and for all three reservoirs, recreation season runs from May 15 to September 10.
54, 55.	Travers and McGregor pump intake problems	Number of days where reservoir stage is too low for some irrigators' pumps to reach the water. Percentage of days with pumping problems is then calculated.
56a.	Rafting hours (daily and annual)	Rafting hours for each kayaking/rafting-season day and annual sum of rafting hours in each year on the Kananaskis River below Barrier. Rafting season runs from May 15 to September 15.
56b.	Rafting days	The number of kayaking/rafting hours is counted to determine the number of rafting days, and the logic for counting rafting hours is the same as that used in PM 56a. The PM is generated for the Kananaskis River below Barrier.
57.	Annual stage variation (aggregated across record)	Minimum and maximum annual stage variation on Lower Kananaskis Lake relative to the target stage.
58.	Annual stage variation (by year)	Annual minimum and maximum stage on Lower Kananaskis Lake relative to the target stage.

59.	Hydropeaking	The difference between maximum and minimum intra-day flows through turbines in the TransAlta system; implemented for flows out of the Lower Kananaskis Lake and the Barrier Lake generation plants.
60.	Siksika demands	Annual volume of water of the required Master Apportionment, the actual Siksika diversion, and the actual flow out of the basin.
61.	IFN flow duration curves	Frequencies of flows in the reaches with IFNs.
62.	Bassano flow classifications	Number of flow events at Bassano across the simulation period where the flow is less than 34 cms (1200 cfs), in three categories.
63.	Calgary Regional Partnership (CRP) shortages	Impacts of demand for forecast population growth to 2076 evaluated in stress test (described below).
64.	Percent of natural flow before the Bow-Oldman confluence	Percent of natural flow.

The following performance measures were not included in this version of the model for various reasons. In some cases, there was not enough time to identify and assemble data, and for those PMs, research is needed to find data for use in a future version of the model.

PMs 11a/b related to stage and storage probability, grouped by wet, dry and normal years

Due to time constraints and lack of specific definitions for "wet", "dry" and "normal" years, these PMs were deferred. For example, a dry year in the mountains with below average snowpack may be offset by rainfall during summer on the prairie reaches of the Bow. The consequences of results need to be further considered and resolved before continuing with these PMs.

PM 15: Irrigation return flows

In this modelling exercise, the irrigation return flows were derived from the Irrigation Demand Model and thus could not be affected by operational changes. The ability to set a firm number for return flows (e.g., 15 or 20%) was deferred, although the BROM could proportionally scale the current return flows. Irrigation return flows at 10% were evaluated in one stress test (see section 3.4).

PM 16: Riparian habitat regeneration, and PM 17: Acres of riparian habitat flooded

The biology of riparian systems is dynamic and complex. The upstream and downstream riparian systems on the Bow differ considerably, with a transition at the Bassano Dam. Riparian health is depressed through Calgary and this is unlikely to change because flow stabilization and bank armoring will not allow riparian development. The riparian system is functional from the Highwood River downstream to Bassano reservoir, with flood inflows promoting balsam poplar regeneration. Downstream of Bassano Dam to the Oldman confluence, the river does not meander and naturally has fewer woodlands. Discussions among BRP participants indicated that, in this area, willows rather than poplars grow relatively easily at lower elevations and require lower flow events.

Pulsed flows may be sufficient to support riparian systems. Optimal pulse size and duration would need to be determined, and impacts on water quality and aquatic ecosystems would also need to be assessed. Riparian systems are important to aquatic and ecosystem health, and research is underway at the University of Lethbridge on this topic. Further work will be done on these performance measures for use in future iterations of the model.

PM 19: Consecutive days of fish spawning

This measure was initially viewed as valuable in determining the amount of time available for fish spawning in the system. However, it was agreed to defer this measure due to a lack of data and the need for further investigation in parameters for the PM. This PM is partially addressed by PM 18.

PM 26: Water restrictions

This PM will be implemented pending collection of the necessary parameters and data and development of clearer definitions. By not having these restrictions in the model, less flow may be shown by the model than actually would be in the river during low-flow periods, thus providing a positive margin of error. Decisions related to water restrictions are complex and consider infrastructure parameters, system operations, forecast demands and available water supply. Project participants did not want to oversimplify these decisions by linking them only to river flow or stage.

PM 27: Homeowner impact

This PM will be implemented pending collection of the necessary PM parameters and data. The definition of "homeowner impact" needs to be clarified and refined, as this is a complex social issue that considers many aesthetic and usage elements.

PMs 41 and 42 related to Dissolved Oxygen

Dissolved oxygen (DO) enters water from the atmosphere and as a product of photosynthesis by aquatic plants. Healthy aquatic ecosystems contain enough DO to support the organisms that live in them. The amount of DO that organisms need varies with the species, the water temperature and other factors. DO levels in a waterbody become a concern when they fall too low and result in the death of fish and other species. This generally occurs for three main reasons: increased temperatures, which affect water chemistry and reduce oxygen levels; high levels of aquatic vegetation, which consume oxygen at night during the respiration phase; and high levels of decomposing organic material that consume oxygen.

Canoeing on the Bow River

DO in the Bow is particularly critical through Calgary and downstream of the city, typically during the hot summer months of July and August, but this has been an issue as early as May. Minimum flows need to be maintained to ensure adequate dilution of Calgary's treated wastewater. DO data are complex due to hourly and daily fluctuations and are therefore more challenging to incorporate into the model. For the next phase of this work, the aim is to obtain hourly data (rather than daily data, as at present), which will enable the temperature and flow relationship to be reflected in the model. The next version of the model is expected to demonstrate a big improvement in the ability to understand DO, and hence understand the impacts of management decisions on this very important biological factor.

PM 43: Birds

Data specific to bird habitat and breeding patterns in the Bow system were not available for modelling. It is expected that changing the stability of water levels in the Kananaskis area of the Bow would affect mainly food production, with some positive impacts on habitat. Specifically, stabilization would benefit invertebrates, which would be expected to increase the available food supply for birds as well as fish. Similarly, shoreline stabilization can provide better access to food and nesting sites for some bird species. Loons, osprey, other raptors and shore birds would likely increase throughout the area as a result of stabilization.

Pelicans on Irrigation Reservoir

PM 63: Calgary Regional Partnership (CRP) shortages

This PM was an attempt to look at annual shortages for each CRP grouping or location. The CRP includes nearly 20 municipalities, which vary significantly in size. For a large municipality such as Calgary, it is easy to identify the withdrawal locations and model them. However, for the many smaller municipalities, not all of which are in the CRP and some of which obtain their water from the Highwood and Sheep River systems (which are not modelled in the same detail as the Bow), it is much more challenging to isolate the nodes and monitor their response as the model changes.

Further work to more clearly distinguish the specific off-take and return flow locations can be built into the model for future use. These locations were treated in aggregate in the stress tests of alternate scenarios for forecast CRP and Calgary water use for the next 65 years. The stress test went beyond the CRP forecast of 1.6 times current municipal water use, and modelled the full use of the Calgary licence at 2.4 times current municipal water use. The stress test was positive in that this significant forecast population increase had very little impact on overall water flow or on other performance measures; see sections 3.4 and 3.6.1 for more details.

3.2 THE SCENARIOS

The "base case" scenario was the starting point for all subsequent work; it reflects the way the Bow River System is operated at the present time and is described in Appendix B.

3.2.1 INITIAL SCENARIOS

Participants focused on various aspects of the system and recommended further modelling of several specific scenarios to, among other things:

- Stabilize Lower Kananaskis Lake and reduce flow fluctuations in the Kananaskis River, providing a wide range of benefits to fisheries and recreational users.
- Ensure minimum flows through Calgary and sustain environmental flows below Calgary.
- Meet the WCO at Bassano during low-flow periods, which cannot currently be done without affecting the water supply to major users, including irrigators. The BRP did

not examine WCOs for the entire Bow River System. However, participants agreed to use the WCO at Bassano as a proxy for meeting WCOs along the river.

Figures 5 and 6 show the sections of the Bow River System where impacts of the scenarios would be most apparent.

FIGURE 5. The Kananaskis Section of the Bow River System
{SOURCE: Bow River Basin Council}

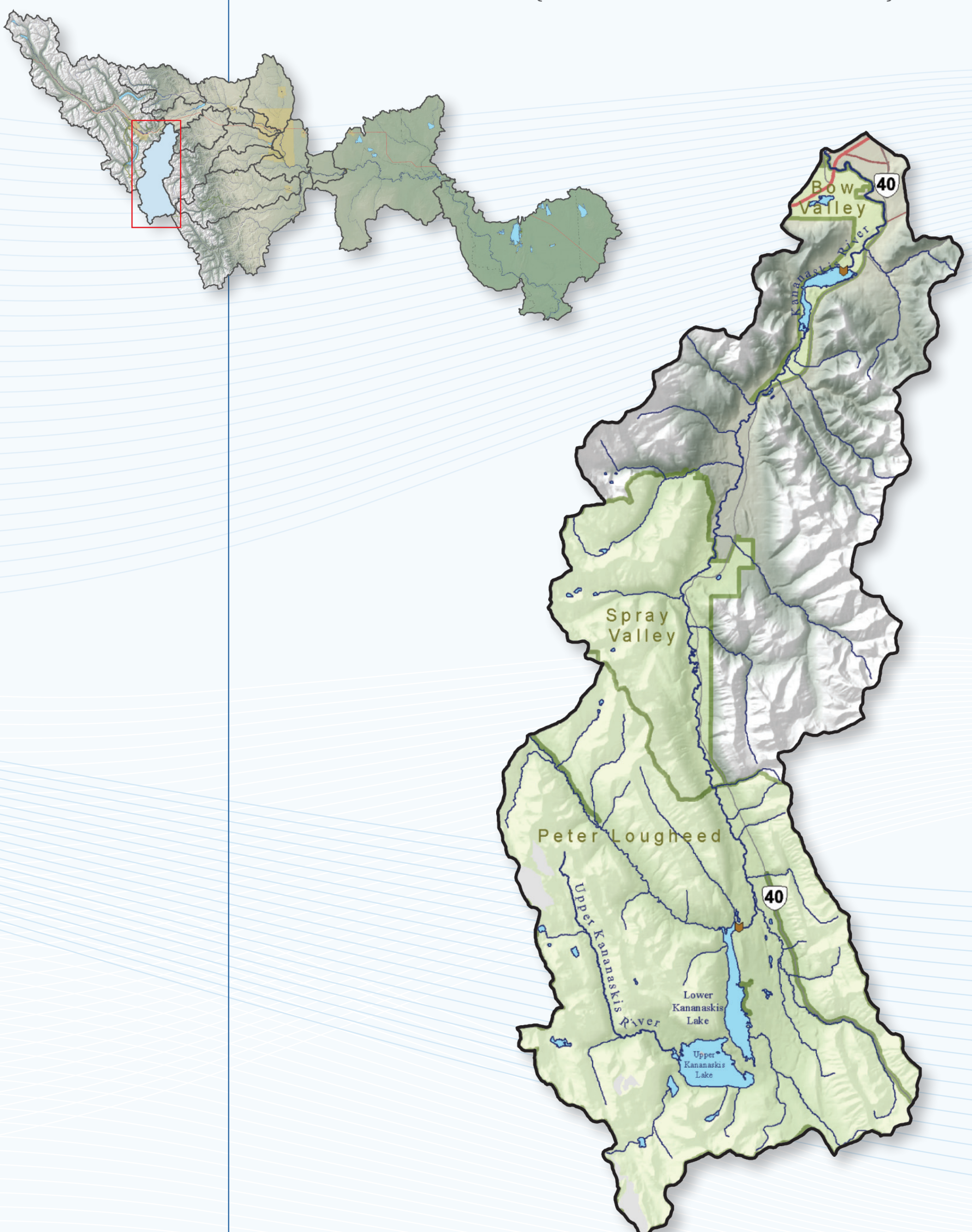
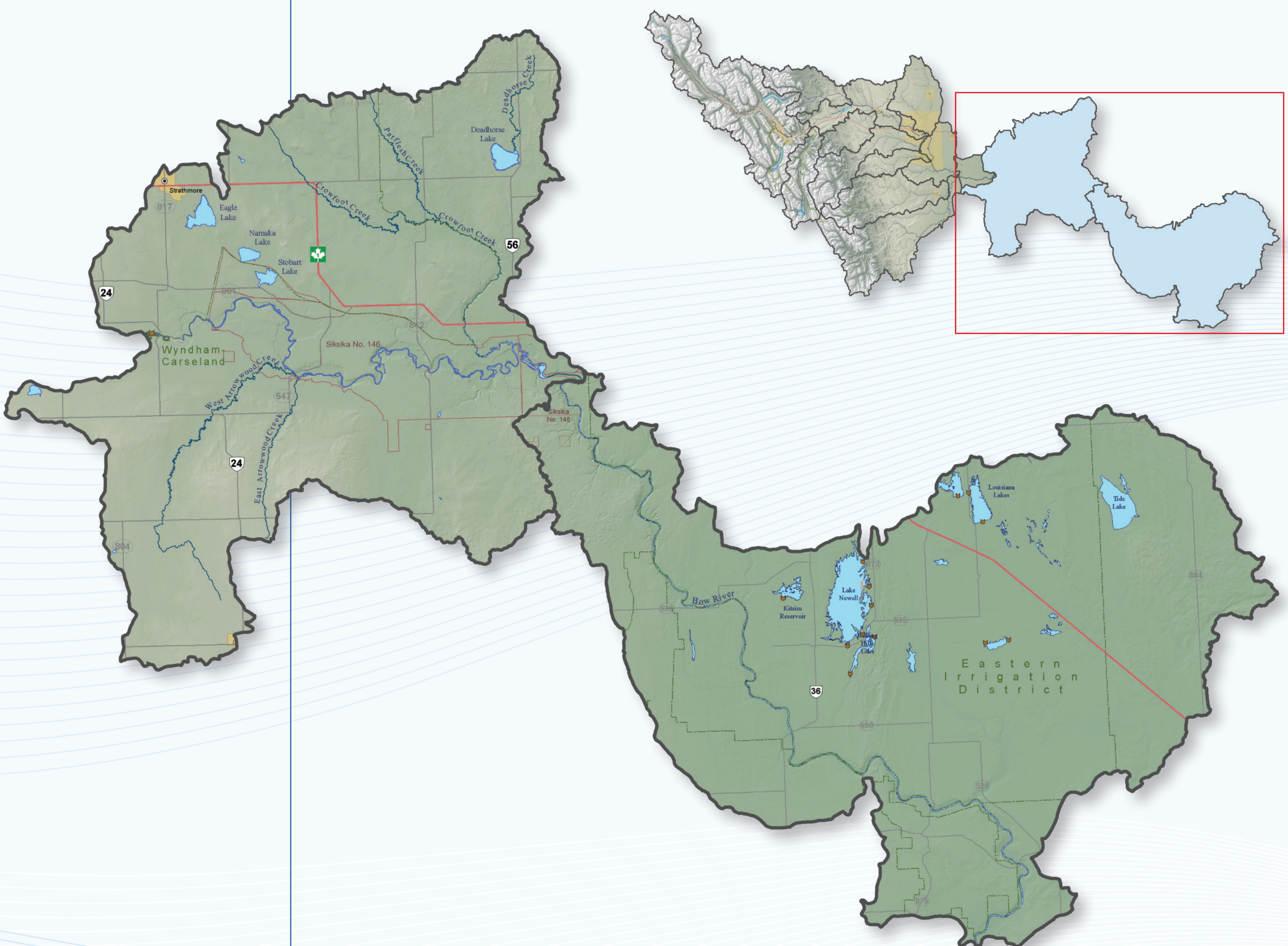


FIGURE 6. The Bow River from Carseland to its confluence with the Oldman River
{SOURCE: Bow River Basin Council}



Based on the results of this work, four additional scenarios were considered:

A: Kananaskis Stabilization

This scenario was developed to examine the effects of stabilizing Lower Kananaskis Lake as well as steadying flows into the Kananaskis River from the Pocaterra power plant.

B: Restored Spray Lakes Reservoir

This scenario was developed to model the effect of restoring the capacity of Spray Lakes Reservoir (Spray) to its original design specifications, thus increasing storage by 75,200 dam^3 (61,000 acre feet). In the initial run, this extra storage was used to maintain some measure of Calgary flow in the summer and to assist in meeting Bassano WCOs.

C: Barrier Lake

This scenario was developed to use Barrier Lake to serve the same purpose as the Restored Spray scenario, but with less storage. Barrier Lake would fill and empty with the objective of meeting the extra flow required at Bassano and is not allowed to refill from August 1 to October 15. This option could provide about 30,800 dam^3 (25,000 acre feet) of water but would result in extended draw-down at Barrier. It includes stabilization of Lower Kananaskis Lake and Kananaskis River, and the water would contribute to meeting the WCO at Bassano. This scenario would minimize infrastructure changes compared to the restored Spray scenario.

D: Water Bank

This scenario includes stabilization of Lower Kananaskis Lake and Kananaskis River, but instead of using Spray or Barrier for additional storage, it involves taking up to 49,300 dam^3 (40,000 acre feet) of water proportionately from every TransAlta reservoir above Ghost Dam. This water would also contribute to meeting the WCO at Bassano. This volume would minimize infrastructure changes compared to the restored Spray scenario..

3.2.2 FINAL SCENARIOS

As results of each model run were reviewed and examined, the Consortium fine-tuned the parameters it considered most important in meeting the overall goals of the project, and the model runs were adjusted accordingly. Four scenarios, in addition to the base case, then emerged and are described in more detail in Appendix C.

All scenarios except for the base case include a doubling of storage in the WID's Langdon reservoir, from 8,340 to 16,700 dam^3 (6,750 to 13,500 acre feet), which significantly reduces WID shortages in the BROM. This expansion has financing in place and is in the final design stage so it was regarded as a certain development that should be included in the model. As well, in all scenarios except the base case, Lower Kananaskis Lake and Kananaskis River are stabilized.

Scenario 1: Stabilized Lower Kananaskis Lake and Kananaskis River

- » In this scenario, Lower Kananaskis Lake is stabilized at 1663.5 metres—3.5 metres below the current 1667-metre full supply level (FSL)—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 the FSL of 1667 metres. Stabilizing Lower Kananaskis Lake was modelled based on the operating parameters proposed by FREWG (2001).
- » 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, and minimum day-to-day instantaneous flows vary by no more than a factor of 0.5.
- » Langdon reservoir capacity is doubled.

Scenario 2: Stabilized Lower Kananaskis Lake and Kananaskis River + Water Bank of 49,339 dam^3 (40,000 acre feet)

- » This scenario includes all the conditions described in #1, plus access to 49,300 dam^3 (40,000 acre feet) using the "water bank" approach.

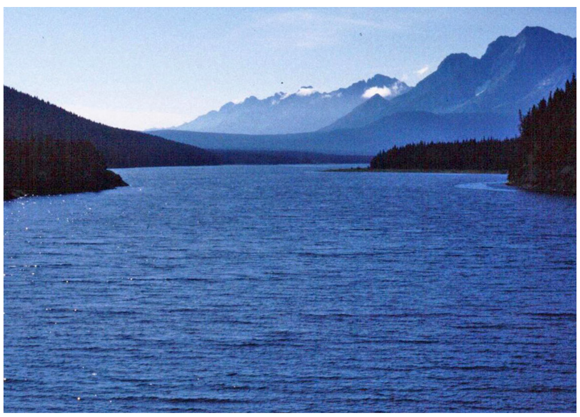
Scenario 3: Stabilized Lower Kananaskis Lake and Kananaskis River + Water Bank of 74,000 dam^3 (60,000 acre feet)

- » This scenario includes all the conditions described in #1, plus access to 74,000 dam^3 (60,000 acre feet) using the "water bank" approach.

Scenario 4: Stabilized Lower Kananaskis Lake and Kananaskis River + Water Bank of 74,000 dam^3 (60,000 acre feet) + Restored Spray at 75,200 dam^3 (61,000 acre feet) (the Integrated Scenario)

- This scenario includes all the conditions described in #1, plus access to 74,000 dam^3 (60,000 acre feet) using the "water bank" approach.
- It also includes restoring the capacity of Spray to its original design specifications, thus increasing storage by 75,200 dam^3 (61,000 acre feet).

In the water bank scenarios, downstream needs are met by taking water from each of the upstream reservoirs in approximate proportion to their water storage capacity or their current (given time of travel) storage levels. This tends to lower several reservoirs proportionately rather than draining a single reservoir. The integrated scenario with a restored Spray reservoir (scenario 4) also includes a water bank. The additional storage in Spray is drained down to generate additional power and is used in combination with the other reservoirs. This results in higher water levels in the other reservoirs for a longer period, likely creating environmental, recreational, aesthetic and other benefits. More refined analysis is needed to understand all the implications of the water bank approach.



Note the difference in water levels in these two photos of Lower Kananaskis Lake taken four months apart {l: Lower Kananaskis Lake in September (full); r: Lower Kananaskis Lake in May (empty).} This extreme annual fluctuation, caused by hydro power generation, reduces productivity and the invertebrates that fish feed on.

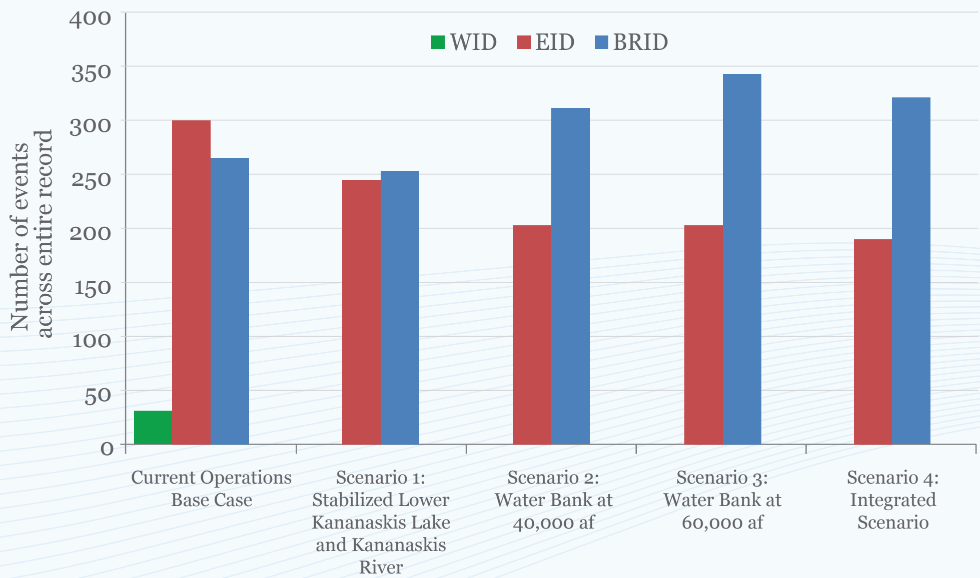
3.3 COMPARISON OF SCENARIOS WITH THE BASE CASE

All four alternate scenarios were run in the BROM; the impacts on performance measures are shown in Appendix D.

Figure 7 compares days with shortages (PM 13); a shortage is defined as one day in the historical record when the user could not divert the full amount of water required. The BROM modelled 68 years (1928 to 1995, inclusively), which means that the entire historical record reflected in the chart covers 24,820 days.

Figure 7 shows that all the alternate scenarios reduce the number of days of shortages for WID and EID. Calgary demands are always met.

FIGURE 7. Comparison of Shortages (PM 13) under the Base Case and the Alternate Scenarios



In the water bank scenarios, the BRID experiences some additional shortages; as an example, in scenario 2, this increase amounts to about 50 days over the 68 years of the record. Because the water bank scenarios intend to supplement low Bassano flows, they change the timing of water in the river from the current base scenario. In some years, this changes the ability of the irrigation districts to capture water. In dry years, this equates to additional draw-down in McGregor reservoir. Since demand 341 in the BROM (BRID Irrigation block, McGregor reservoir) is unable to draw water when McGregor reservoir drops below 871.74 metres, this causes a small increase in the number of days with some shortage for BRID. Further refinement of the release rules for the water bank storage could likely ameliorate many of these new shortages.

FIGURE 8. Comparison of Average Annual Power Revenue (PM 30) under the Base Case and the Alternate Scenarios

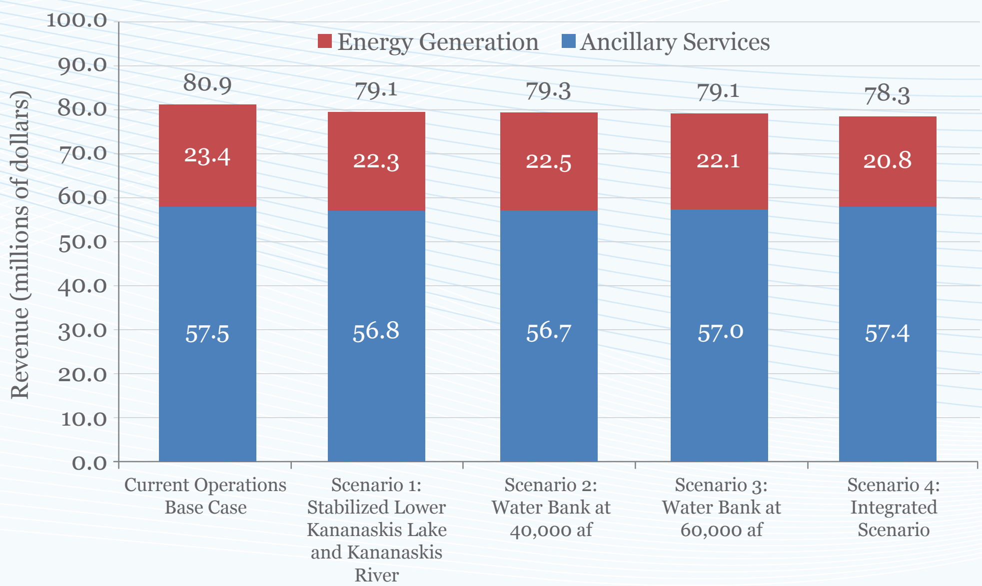
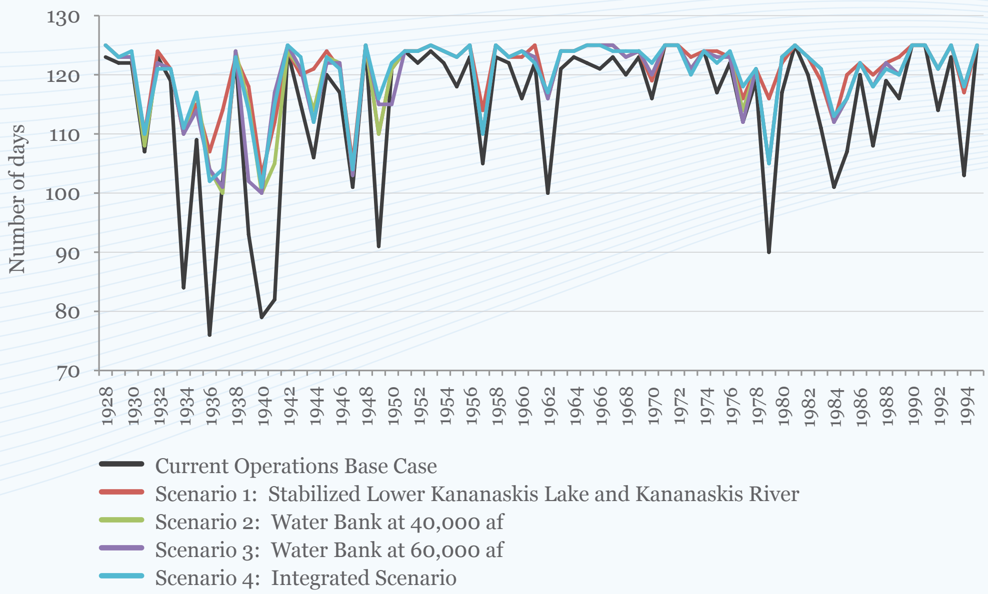
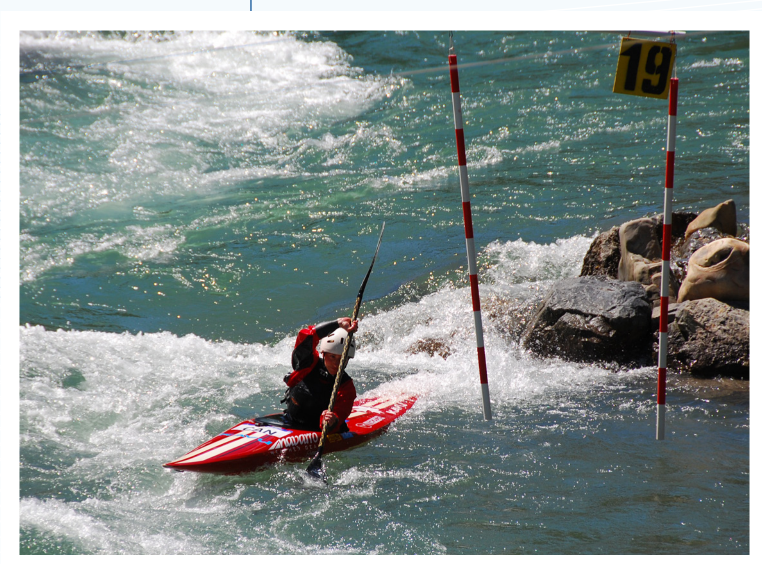


Figure 8 illustrates the relatively small impact on average annual power generation revenue (PM 30); most of the lost revenue is related to ancillary services. Revenue is reduced under Scenario 1 but some is recovered when a water bank is implemented. The difference from highest to lowest revenue is about $2.6-million, or about 3% of the base case revenue. Without restoring Spray capacity, the revenue difference between the base case and water bank scenario 3 is less than $2-million.

FIGURE 9. Comparison of Annual Rafting Days (PM 56b) Below Barrier Lake under the Base Case and the Alternate Scenarios

(days with a minimum of three consecutive hours with flow >= 30 cms)





Kayaking at Canoe Meadows on the Kananaskis River below Barrier Dam

Figure 9 illustrates the impact on a major recreation activity on the Kananaskis River—kayaking and rafting (PM 56b). Compared to current operations, all of the alternate scenarios produce substantial improvements in the annual number of rafting days below Barrier Lake. “Rafting days” is just one example of how recreation in the Kananaskis region would be improved. Improvements in fishing, day use of facilities, camping and other tourism and recreation activities would also be expected.

Figure 10 shows the significant improvement in stability of Lower Kananaskis Lake (PM 57) that occurs with all of the alternate scenarios.

The green bars reflect the positive desired outcome of stabilization; that is, for essentially 100% of the time, Lower Kananaskis Lake is within 0.5 metres of the target elevation with the alternate scenarios; for 60% of the time, it is 0 to 0.5 metres above the target elevation, and for about 40% of the time, it is 0 to 0.5 metres below the target elevation.

FIGURE 10. Comparison of Lower Kananaskis Lake Levels (PM 57) under the Base Case and the Alternate Scenarios

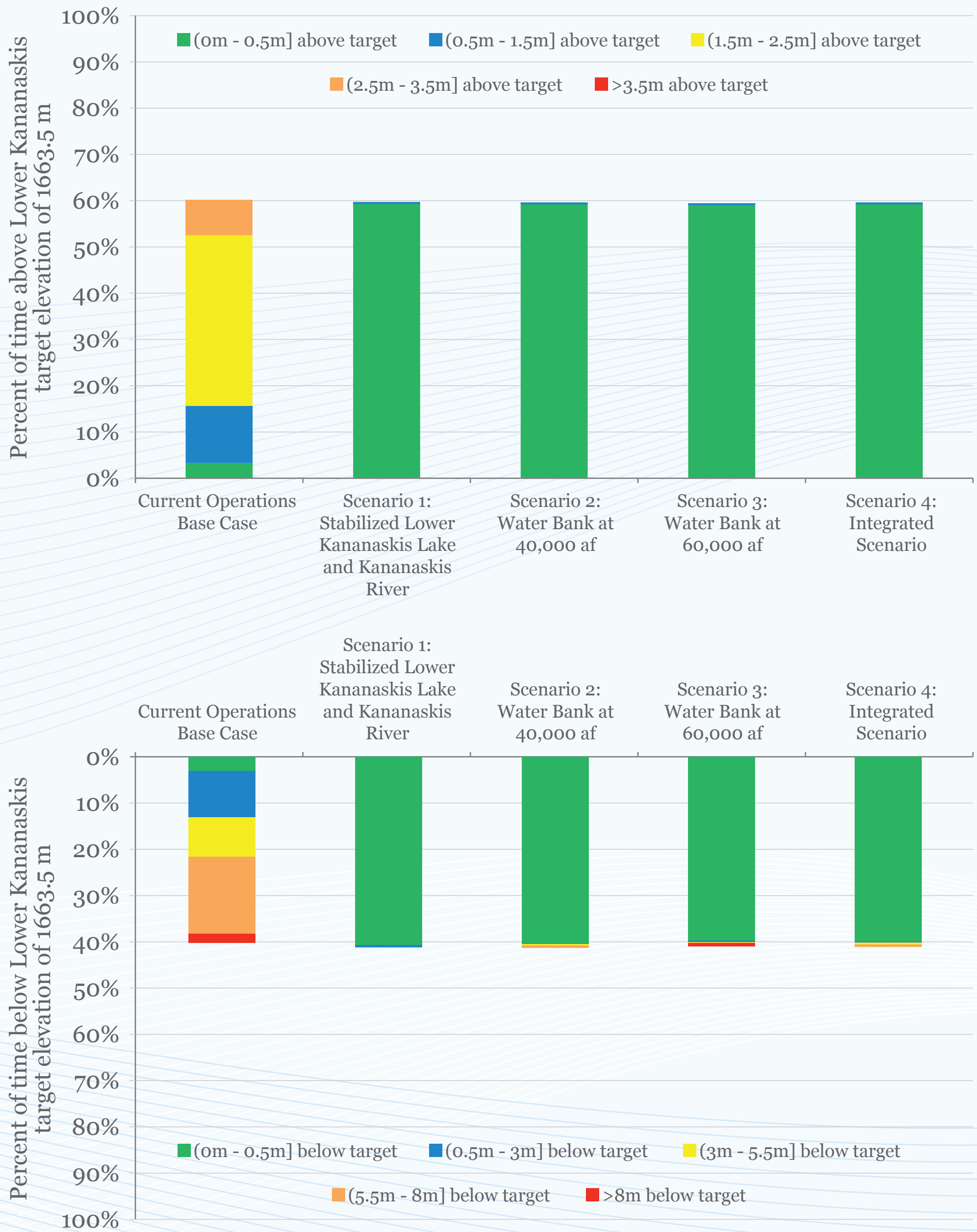


Figure 11 shows the annual stage range on Lower Kananaskis Lake (PM 58). For scenario 2, the lake level is nearly always within 0.5 metres of the target elevation (1663.5 metres), although in two years out of the 68 on record, it drops to meet Bassano flows. With the integrated scenario, the added water from Spray counteracts even that dip.

Figure 12 shows the impact on Bassano flows of the alternate scenarios over the 24,820 days in the 68-year simulation. The goal was to reduce the number of lower-flow days below Bassano; i.e., reduce the number of days in the 400-800 cfs column (orange and increase the number of days in the 800-1200 cfs column (green) or above 1200 cfs (purple).

FIGURE 11. Comparison of Lower Kananaskis Lake Annual Stage Range (PM 58) under the Base Case and the Alternate Scenarios

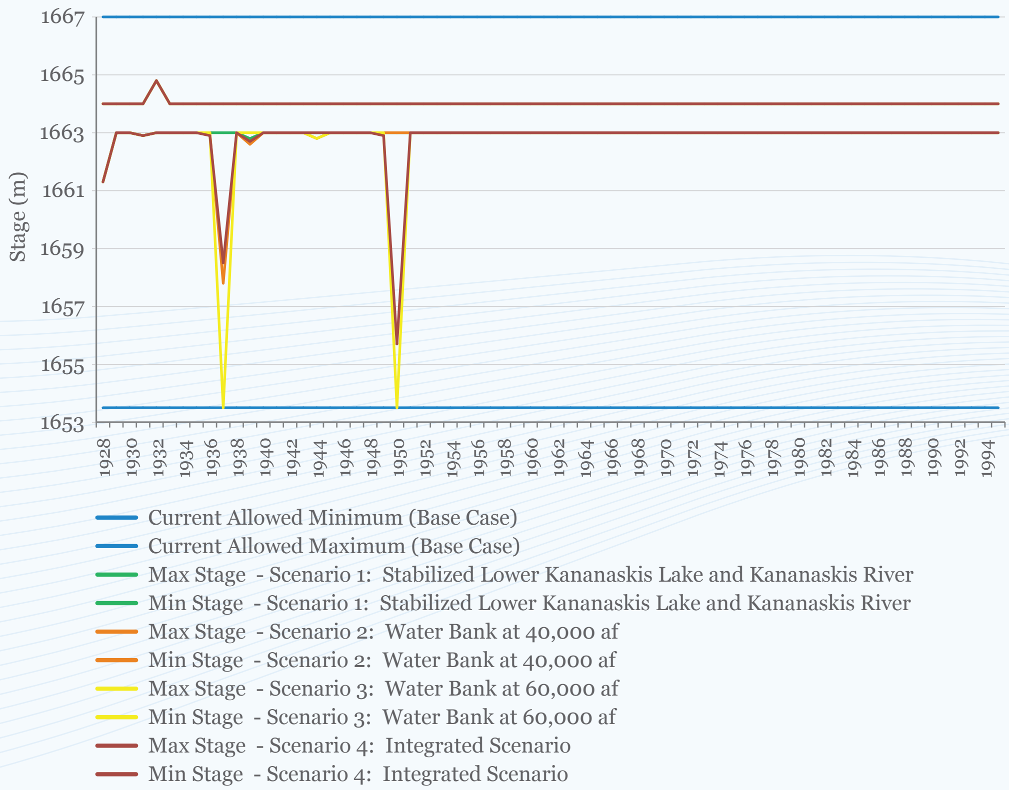
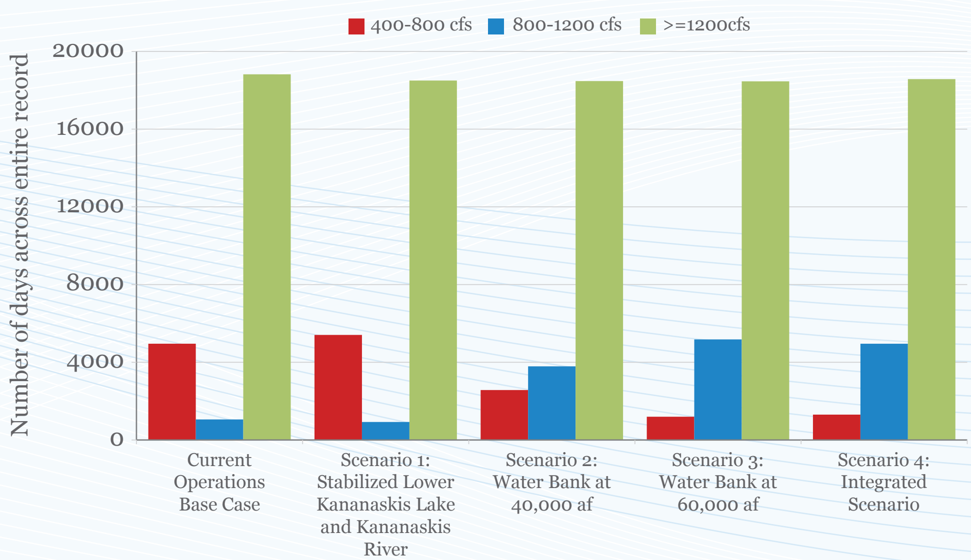


FIGURE 12. Comparison of Bassano Flows (PM 62) under the Base Case and the Alternate Scenarios



Although scenario 1 alone increases the number of lower-flow days (11.3-22.6 cms, or 400-800 cfs), the three scenarios that include a water bank dramatically reduce the number of these days. When the water bank is at 74,000 dam³ (60,000 acre feet), as it is for scenarios 3 and 4, the number of low-flow days is 20-25% of the number for the base case and scenario 1. Thus, it is clear that some water bank water is needed to offset any possible negative impacts of stabilizing Lower Kananaskis Lake and Kananaskis River. In addition to affecting Bassano flows, there could be negative effects in Calgary in some years with just this stabilization and no water bank.

Several other key performance measures, including PM 6 (flood events in Calgary), PM 18 (walleye spawning), and PMs 50-53 (reservoir recreation seasons), were essentially unchanged by any of the scenarios from the base case. Significantly, this was also the situation with PM 5 (apportionment) and PM 64 (percent of natural flow before the Bow/Oldman confluence). In other words, none of the alternate scenarios showed any significant impact on the natural flow that is passed on to Saskatchewan. The full set of performance measures is included in Appendix D.

The alternate scenarios are expected to have a substantial benefit for the aquatic ecosystem of the Kananaskis River above Barrier Dam. For the most part, improvement on the Kananaskis River does not come at a cost to the Bow River and alternate scenarios even show some benefit to the Bow at various times of the year. However, under the alternate scenarios, there may be lower flows in April in the Bow to enable storage of water to offset other environmental effects later in the year. Further work is needed to better understand any possible effects on instream flow needs.

3.4 SCENARIO STRESS TESTS

To assess how well select scenarios might respond to future challenges and stresses, five stress tests were performed on the base case and all of the alternate scenarios. The full results of all the stress tests can be viewed in the BROM and its attached charts.

Stress test 1: Calgary region demands increased by a factor of 2.4

This was identified as an important stress test to validate that the proposed alternate scenarios would address future population demands and support *Water for Life* goals. The stress test went beyond the forecast in the Calgary Metropolitan Plan of 1.6 times current municipal water use, and modelled the full use of the Calgary licence at 2.4 times current municipal water use. This increase in water use by municipalities of 2.4 times current use had little impact on overall water flow or on any of the performance measures, as seen in Figure 13.

In particular, this increase in municipal demand does not substantially increase shortages for the irrigation districts, as Figure 13 indicates. Although more water is being taken, the municipal return flow remains at about 85% and total water used is still small relative to irrigation diversions.

Irrigation Canal

Stress test 2: Irrigation District return flows at 10% of total diversion

This stress test was designed to assess the impact if the irrigation districts were to provide 10% return flow back to the river. Some increased shortages were apparent for EID and BRID over the historical record with the two alternate scenarios, as Figure 14 shows. Most return flows come in below Bassano or into the Red Deer or Oldman Rivers, which were not part of the BROM.

FIGURE 13. Effect of Stress Test 1 (Increased Calgary Region Demands) on Days with Shortage (PM 13) under the Base Case and Scenario 3: Water Bank at 60,000 acre feet

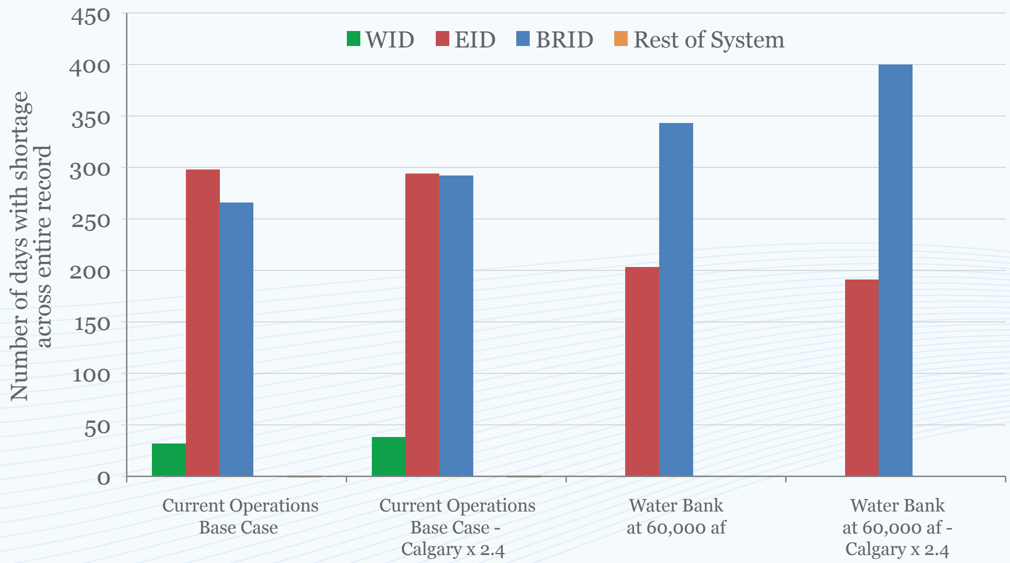
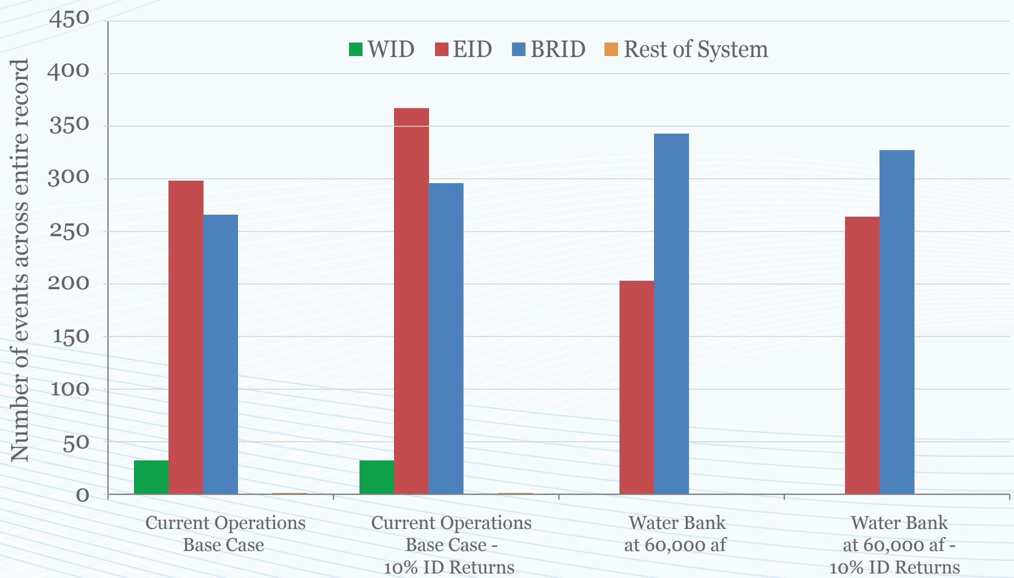


FIGURE 14. Effect of Stress Test 2 (Reduced Irrigation Return Flows) on Days with Shortage (PM 13) under the Base Case and Scenario 3: Water Bank at 60,000 acre feet



Stress test 3: Three consecutive wet years

This test looked at the impact on performance measures of three consecutive wet years; the years chosen were 1965-1967. In general, the results demonstrated that there was little impact from the alternate scenarios compared to the base case and the alternate scenarios outperformed the base case.

Stress test 4: Three consecutive dry years

This stress test looked at the impact on performance measures of three consecutive dry years; the years chosen were 1983-1985. In general, the results demonstrated that there was little impact from the alternate scenarios compared to the base case and the alternate scenarios outperformed the base case.

Stress test 5: BRID infrastructure at 300 cfs from 500 cfs

As described in the box below and referenced in other parts of this report, the BRID canal infrastructure requires a minimum flow of 14.1 cms (500 cfs) to enable off-take at the Carseland diversion. The stress test was designed to test the effect of reducing this minimum requirement from 14.1 cms to 8.5 cms (500 cfs to 300 cfs). Figure 15 illustrates that reducing the minimum flow required for BRID increases the number of days with substantially higher flows at Bassano. This chart likely understates the full benefits, as it does not show flow improvements within the bars; for example, moving flows from 450 cfs to 750 cfs. This infrastructure change would produce a substantial net benefit, particularly on the most critical low-flow days in late summer.

FIGURE 15. Effect of Stress Test 5 (BRID Infrastructure Change) on Bassano Flows (PM 62) under the Base Case and Scenario 3: Water Bank at 60,000 acre feet

3.5 WATER QUALITY IMPACTS OF THE INTEGRATED SCENARIO

Alberta Environment agreed to run the OASIS output through its Bow River Water Quality Model (BRWQM), which covers the reaches of the Bow from Bearspaw Dam to Bassano Dam. The BRWQM is an integrated system of selected surface water quality and quantity models that is used to assess and compare the water quality impacts of different scenarios and has been used as part of a number of computer model exercises to support the South Saskatchewan Regional Plan (Government of Alberta, 2010)

At the point in the project when the Consortium worked with Alberta Environment to run the BRWQM, it was decided to test the integrated scenario. At that time, the integrated scenario included stabilized Lower Kananaskis Lake and Kananaskis River, and restored Spray; a water bank and increased storage at Langdon reservoir were not part of the integrated scenario when the BRWQM was run.

Alberta Environment took output from the OASIS model for both the base case and the integrated scenario and ran it through the BRWQM. This analysis was done to represent three hydrologically different years, selected by the Consortium: 1988, 1990 and 1993. The assessment nodes, reflecting the three reaches of the river in the model (Bearspaw to Highwood, Highwood to Carseland, and Carseland to Bassano), were Stiers Ranch, Carseland and Bassano, and the parameters were water temperature, dissolved oxygen, and phosphorus. Due to the time constraints of the project, this model run was done using a semi-final version of the data. As the Bow River Operational Model is refined over time, there will be future opportunities to again run it through the BRWQM.

Bearspaw Water Treatment Plant, Calgary

The water quality simulation results for the base case and the integrated scenario show essentially no differences in water quality for any of the three parameters at any of the three sites, as noted in Table 3 and Figure 16.

TABLE 3. Summary of Bow River Water Quality Modelling Results

1. WATER TEMPERATURE

	Evaluation Criteria	Averaging Period	Assessment Node	Water Temperature Exceedance (days)					
				Base Case			Integrated Scenario		
				1988	1990	1993	1988	1990	1993
Central Bow River	<=24° C	instantaneous	Stiers Ranch	0	0	0	0	0	0
			Carseland	0	0	0	0	0	0
Lower Bow River	<=29° C anytime	instantaneous	Bassano	0	0	0	0	0	0

2. DISSOLVED OXYGEN - ACUTE

	Evaluation Criteria	Averaging Period	Assessment Node	Dissolved Oxygen Exceedance - acute (days)					
				Base Case			Integrated Scenario		
				1988	1990	1993	1988	1990	1993
Central Bow River	>=5.0 mg/L	instantaneous	Stiers Ranch	0	0	0	0	0	0
			Carseland	0	0	0	0	0	0
Lower Bow River			Bassano	0	0	0	0	0	0

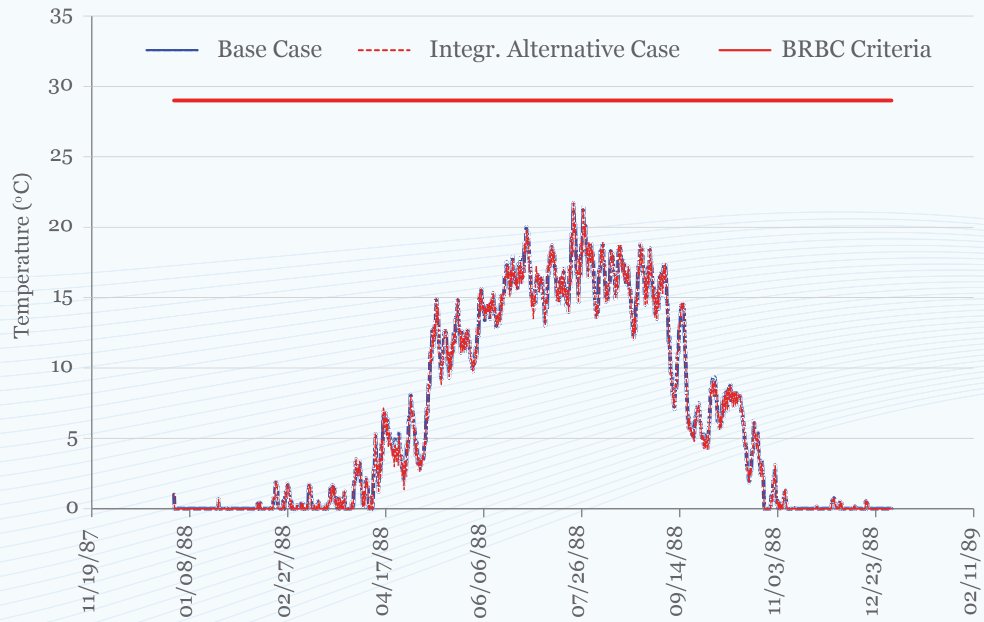
3. DISSOLVED OXYGEN - CHRONIC

	Evaluation Criteria	Averaging Period	Assessment Node	Dissolved Oxygen Exceedance - chronic (days)					
				Base Case			Integrated Scenario		
				1988	1990	1993	1988	1990	1993
Central Bow River	>=6.5 mg/L	7 day mean	Stiers Ranch	0	0	0	0	0	0
			Carseland	0	0	0	0	0	0
Lower Bow River			Bassano	0	0	0	0	0	0

4. TOTAL DISSOLVED PHOSPHORUS

	Evaluation Criteria	Averaging Period	Assessment Node	Total Dissolved Phosphorus Exceedance					
				Base Case			Integrated Scenario		
				1988	1990	1993	1988	1990	1993
Central Bow River	<=0.015 mg/L	daily mean	Stiers Ranch	169	118	164	167	119	166
			Carseland	131	0	167	131	79	165
Lower Bow River			Bassano	62	63	133	58	65	134

FIGURE 16. BRWQM Predicted Temperature (Degrees C) at Bassano for Three Consecutive Drought Event Scenarios
{Source: Alberta Environment}



3.6 POTENTIAL BENEFITS FROM THE PREFERRED SCENARIO

The Consortium reviewed the modelling results and concluded that a water bank approach to managing the Bow River System was very desirable, producing a wide range of economic, environmental and social benefits. For the purpose of this section of the report, the focus is on the water bank scenario with 74,000 dam³ (60,000 acre feet) of available water (scenario 3 in the modelling outputs). This is referred to as the Preferred Scenario from this point forward. To recap, the Preferred Scenario features the following major changes from current operations:

- The capacity of Langdon reservoir is doubled from 8,340 dam³ to 16,700 dam³ (6,750 acre feet to 13,500 acre feet).
- Lower Kananaskis Lake is stabilized at 1663.5 metres—3.5 metres below the current 1667-metre full supply level (FSL)—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. Stabilizing Lower Kananaskis Lake was modelled based on the operating parameters proposed by FREWG (2001).
- 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.
- Access is provided to 74,000 dam³ (60,000 acre feet) using the “water bank” approach.

The Preferred Scenario could be enhanced to provide additional potential benefits by considering the option of restoring Spray, thus providing storage and managed access to another 75,200 dam³ (61,000 acre feet) of water. The Preferred Scenario with this option included was modelled as the integrated scenario (scenario 4).

Further work is required to assess how the integrated scenario might be implemented and the extent of additional benefits that would accrue. Although there was not time to reliably quantify all of the value that could be obtained through the Preferred Scenario, a number of benefits clearly emerge if this scenario were to be implemented. These benefits are described in the following sections. None of the proposed changes are expected to affect deliveries under Alberta's existing priority water allocation system.

3.6.1 MEETING THE NEEDS OF A GROWING POPULATION

A key desired outcome of the BRP is mitigating future risk for a growing population that will need access to water. There are limited opportunities for new reservoirs in or around Calgary and the only current option may be off-stream storage. Costs to construct an off-stream storage reservoir with capacity of 67,800 dam^3 (55,000 acre feet)—considered sufficient to serve 70,000 people outside the Calgary Regional Partnership—has been estimated at $115-million (WID, 2009). Thus the next best sources of available water are likely to be costlier for municipalities, compared to using existing and expanded upstream storage. There are some advantages to having off-stream storage near the licensed use, especially if the use is critical to the user, as this storage can offset periods when water cannot be taken directly from the river. Examples include municipal use, an industry that requires water continuously for its processes, and fire protection.

The Preferred Scenario may also improve opportunities to manage waste assimilation from higher base flow during certain times of year if total loading increases from population growth and municipal expansion. The focus of the BROM on water supply complements the work being done by municipalities to improve water conservation, efficient use and water treatment technologies.

Calgary Region Water Needs

The Calgary Regional Partnership has forecasted municipal use of water to 2076; their most likely scenario projects municipal water use to increase by approximately 1.6 times current use given technological changes and other conservation measures. To add in a 50% margin for error to the forecast, the BRP increased this forecast future use of water for municipalities to encompass the entire amount of all the City of Calgary water licences, which amounted to 2.4 times the amount of water presently used. This amount of water for municipal use was the basis for the stress test for each scenario.

Given the uncertainties related to where water diversions may be located and the timing of these diversions and return flows over the next 65 years, the BROM simply took this amount of water at Calgary and forecast return flows of 85% downstream of Calgary. This increase in water use by municipalities of 2.4 times current use had little impact on overall water flow or on any of the performance measures because return flows are high and the total water used is still small relative to irrigation diversions. Since the flow rate did not change significantly, and the assumption is that wastewater treatment technology over the next 65 years will at least match the small reduction in flow, water quality should not be affected. If water quality is affected, additional flow may be available under the larger water bank and the integrated scenarios. To further refine the analysis, future testing of the model should include specific parameters for water effluent from the system based on forecast water use, return flow and forecast technologies for wastewater treatment.

3.6.2 ENHANCED AND EXPANDED RECREATION OPPORTUNITIES

Information and data to determine recreation and tourism benefits across the entire basin are lacking. However, substantial positive impacts are expected to emerge from managing the Bow River in a different way, and the need for such opportunities has been noted in the terms of reference for the South Saskatchewan Regional Plan.

This project and the associated performance measures indicate that the Kananaskis area, which is already a globally recognized recreation destination, would benefit from the proposed changes in river management. A re-managed Bow system, including the Kananaskis, would enhance opportunities and expand the shoulder season for rafters, kayakers, canoeists and anglers as well as those who support the recreation and tourism industry (hotels, restaurants, retailers, fishing guides, travel operators and the nearby casino/hotel). For example, in 2001, it was noted that stabilizing Lower Kananaskis Lake could increase annual visitor-days by 35% through expansion of lakeshore recreation and some new facilities, dramatically improve productivity of the littoral zone, increase fish production by three times or more, improve wildlife habitat in the re-vegetated shoreline area and improve the aesthetics of the lake (FREWG, 2001). The river from Barrier Lake power plant down to the confluence with the Bow could also be managed during certain portions of the year to enhance the recreational and commercial use of the significant white-water run.

3.6.3 FLOOD MITIGATION

Integrated management of the Bow system could reduce the peak of moderate flood events, but would require an improved forecasting capability; e.g., if a flood or heavy rain in the headwaters was forecast, one or more reservoirs could be drawn down in advance. This could be a very important factor for population centres. For example, Ghost reservoir upstream of Calgary could be adjusted within the Preferred Scenario to increase the full supply level by three metres, but reserved for flood emergency purposes only. This would have enabled Ghost reservoir to have absorbed one full day of the ten days of flooding in 2005 in Calgary.

Bow Bridge, Calgary

Depending on the operating decisions, this amount of emergency storage may have been used to reduce the peak flow for a few hours on several of those days. Other potential flood mitigation opportunities are available, but only for helping to mitigate moderate flooding events. A more detailed assessment is needed to determine costs and benefits of potential flood mitigation than could be done by this project. Given the potentially catastrophic consequences of recorded historic (and indicated prehistoric) floods, it is only prudent to more carefully assess the potential for flood mitigation.

It is recognized that considering Ghost reservoir for potential emergency flood mitigation could affect local residences, so this possibility needs further assessment and analysis.

3.6.4 DROUGHT MITIGATION

There are opportunities for drought mitigation if management decisions were made for water storage to be carried over for emergency human supply under certain drought conditions. There are risks involved in carry-over storage in the event of an unexpected flood event. Improvements would be needed in snowpack monitoring, short- and longer-term weather forecasting, and modelling, but over the long term, significant opportunities could be available from coordinated management of the reservoirs. Part of the Preferred Scenario involves a stabilized Lower Kananaskis Lake to improve the aquatic ecosystem and fisheries. This reservoir could act as a water supply of last resort for human use in the event of an Australian-like drought emergency.

Stabilizing this reservoir for environmental protection and fish productivity may provide this important secondary purpose and would certainly be less damaging to the system than what currently happens with an annual draw down of up to 13.5 metres. Drought mitigation planning by all the users of the Bow System could also be valuable to irrigation districts by such methods as refilling off-stream reservoirs to their full supply level in the fall, thus providing carry-over water for municipal and agricultural purposes.

3.6.5 IRRIGATION

Value-added and yield contributions from irrigated agriculture is estimated at 2.66 times those of dryland farming (Anderson and Associates Ltd., 2002) and some particularly high-value crops can only be grown in southern Alberta under irrigation (e.g., peas, sweet corn, sugar beets, carrots, dry beans). Irrigation expansion has been driven primarily by improved efficiency and many irrigators believe they can live within their existing water allocations.

Irrigation pivot

Continued conservation efforts through water controls and on-farm technologies will create an opportunity to increase irrigated acreage and agricultural production with the same Bow River water diversions. The BROM can assist in setting the acreage limits that demonstrate that river sources are not negatively affected.

3.6.6 FISH HABITAT

Fish habitat is defined as “spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes” (Fisheries Act, sec. 34(l)). Any aspect of river management that improves the aquatic environment and riparian health is likely to also improve the fisheries in those reaches. A study done during the 1990s (FREWG, 2001) found that altering the operating criteria of the Pocaterra power plant could at least triple biological productivity, including fish productivity, in Lower Kananaskis Lake. The BRP modelled the hydrologic feasibility of this considerable improvement to the aquatic ecosystem in the Bow headwaters and found it to be doable without having a large impact on capital costs for hydro operations.

Another benefit is the potential value associated with fish habitat units. Canada's Fisheries Act requires that the Harmful Alteration, Disruption or Destruction of fish habitat (HADD) be offset in a 2:1 ratio; that is, two fish habitat units are required to offset each unit lost to a HADD. The BRP commissioned a literature review of the cost to develop an approved fish habitat unit that could be used as an offset (see sidebar for details). The number of potential offsets created by altering the operating conditions of the Pocaterra power plant (i.e., stabilizing Lower Kananaskis Lake and the Kananaskis River) is enormous. Provincially, there may be significant cost savings, fewer negative environmental impacts, reduced land impacts, and much higher success rates in increasing fish populations simply by creating a fish habitat "bank" of HADD offsets in Kananaskis Country. This would require removing any known regulatory interpretation barriers that may stand in the way of the "offset bank" concept.

Fisherman on the Bow River

Economic Aspects of Improving Fish Habitat

The FREWG study (2001) concluded that the cost to TransAlta in terms of power generation and capital costs to alter the operating criteria at Pocaterra would be under $1-million per year, at that time. The BRP's modelling work showed these changes would have little effect on power production revenues. Capital costs may be different since the capital equipment has been partially rebuilt. The original wood-stave penstock is currently being replaced. As well, the turbine and generator equipment (15 megawatt capacity with about 30,000 MWhrs annual production) have been in place since 1955 and may be due for replacement. Whether replacement or overhauled equipment is optimized for original operating rules of peak price production or for stabilized flow to enhance biological and fish productivity may not have a large impact on capital cost.

With respect to the value of fish habitat units, a Canadian study has found that the cost of creating them varies from $0.24 to $1,074.00 per square metre (mean=$85.00, SE=$56.00) (Harper and Quigley, 2005). Based on these calculations, any new fish habitat in the Kananaskis River system could have an estimated value of about $85 per m^2. Establishing a market for offsetting at least some of the 2:1 ratio HADD requirement could, over the medium to long term, easily pay for all of the opportunity, capital, and maintenance costs needed to restore the fishery and biological productivity of this high-profile portion of Kananaskis Country.

The current and hypothetical stabilized flows for the Pocaterra facility are illustrated in Figure 17. The hypothetical stabilized flows are estimated flows that are not yet built into the model as more detailed analysis is needed to narrow the proposed operating rules.

FIGURE 17. Current and Hypothetical Stabilized Flows for TransAlta's Pocaterra Facility

{Source: 1988 data from TransAlta; Hypothetical stabilized flows are BRP estimates)

The water level in Lower Kananaskis Lake could be stabilized at the desired level without changing the turbine system in the Pocaterra power facility. As changes are anticipated to this facility anyway, decisions could be made within the next two years to design, engineer and replace the Pocaterra turbine with an efficient mid-range turbine and generator, which would enable flows to be stabilized in the Kananaskis River. Revenue from a stabilized operation will be lower than with the current peak power operation, but this could be partially offset by certifying this facility as generating "green power." This should be acceptable since its new purpose would be dedicated to improving environmental conditions in the Kananaskis River.

3.6.7 WATER QUALITY AND CONSERVATION

The changes proposed in the Preferred Scenario mean that:

- Water Conservation Objective would be met more often downstream of Bassano during low flow in the spring and fall periods.
- Water flow levels would be maintained through Calgary at a minimum of 35.4 cms (1250 cfs) year-round to ensure water quality standards continue to be met on an ongoing basis.
- Water flow through Calgary and downstream would be maintained at a winter level intended to retain or improve the sport fishery between Calgary and the Carseland Dam.
- Dissolved oxygen levels, temperature and flow rate would be monitored through Calgary to determine if water flow rates could be used to improve dissolved oxygen levels during critical periods.
- Pending further investigation, overnight flow rates though Cochrane could be maintained or improved to maintain fisheries productivity and improve environmental amenities.

3.6.8 OTHER BENEFITS

Further work is needed, but other potential benefits could also result from implementing the Preferred Scenario, including:

- Winter water flow through Calgary would be managed to minimize and mitigate ice dam formation.
- Water flows through Cochrane would continue to be managed to prevent ice dams that create flood conditions.

3.7 POTENTIAL IMPLEMENTATION CONSIDERATIONS

The Consortium acknowledged that there are likely to be some economic impacts related to implementing the Preferred Scenario, which includes several components as noted above. Some of the costs are identified in section 4 but because there are gradients of implementation and each has its own potential costs and benefits, detailed analysis was not possible within the timeframe of this project.

These potential costs vary with the components and need to be refined further, as and when decisions are made to proceed toward implementation. For example, depending on TransAlta's schedule for major maintenance or replacement of equipment, replacing the turbine runner (essentially the water wheel that is powered by flowing water) and possibly the generator at Pocaterra may be an added cost to stabilize flow in the Kananaskis River. (Note: This is not needed to stabilize Lower Kananaskis Lake.) However, if replacement work is already planned for the next few years, the only added capital expense may be the difference between replacing a "peak power" turbine runner with a more "constant flow" turbine. There is likely little difference in cost, and the amount of total power generated should be nearly identical; the difference is whether the water is turned on and off as in current operations, or more regular hourly flows are permitted, similar to the flow from Bearspaw. Additional studies will be needed to ensure the spillway is adequate for the changed operations and other potential local impacts. Depending on the existing maintenance schedule, the actual operating and capital cost for stabilizing Lower Kananaskis Lake and Kananaskis River all the way to Barrier Lake may mostly comprise the lower intra-day power prices realized by a more stable operating rule curve and the different annual flow required by a relatively stable lake level.

Assuming the benefits outweigh the costs, and cost allocation agreements can be reached, a hypothetical sequence of events might be to stabilize Lower Kananaskis Lake in year one, while testing the water bank operating scenario and completing the rehabilitation of the BRID headworks so they can effectively take lower diversion rates during low-flow periods. Lost opportunity costs for TransAlta would include lost peak-power generation (but not total generation) from the small Pocaterra facility and a certain amount of lost peak-power prices for other generating stations on the Bow caused by using the water bank for environmental or other uses at different times than peak power prices are in place. TransAlta may still be able to capture a portion of the peak power prices due to time-of-travel planning when releasing water for downstream purposes.

Capital costs associated with the water bank involve improvements to the diversion canal at Carseland to allow 8.5 cms (300 cfs) diversions rather than the current minimum 14.1 cms (500 cfs), which are thought to be in the $1-million range. This change would allow for more flow downstream of Carseland and Bassano during critical low-flow periods while allowing upstream reservoirs to save the equivalent flow in storage for other purposes. Other costs could include such things as additional risk for testing different operating rules, additional maintenance if any, achieving an adequate rate of return for TransAlta, additional collaboration time for determining required flow rates for different reaches throughout the year, and others.

Implementing the water bank component may postpone the full stabilization of the Kananaskis River until the Pocaterra turbine replacement was scheduled or until the full suite of benefits was determined to be clearly positive. Other improvements could be evaluated and sequentially implemented, or not, as circumstances and careful analysis show significant added value. Further refinement and use of the BROM may uncover options not considered in the short timeframe of the BRP. Additional relatively small studies of potential threats such as flood and drought risk and potential costs, or possible climate change scenarios may either enhance the urgency for certain actions, or provide some assurance that things are being managed adequately and water managers have assessed and addressed the key risks.

3.8 USING THE BROM TO ASSESS ECONOMIC DEVELOPMENT

The BROM offers a flexible, data-driven analytical tool to model and understand the impact of potential new industrial, commercial and real estate developments in the Bow River Basin. Access to water continues to be a critical and costly consideration for population growth and many economic developments in southern Alberta. The ability to understand the true impact of such ventures is a valuable asset for decision makers tasked with planning or approving economic development in a responsible manner.

One example of such use of the model might be to assess the potential flow rate impact of significant water licence transfers. Moving a large diversion upstream or for a different purpose could be modelled for its effects on other users and the environment in the event of future dry years such as represented by the extreme low flows during the 1930s. This type of analysis can be done nearly in real time, saving the director or proponents valuable time and expense.

Perhaps more important, government and other stakeholders and water users can hypothesize various wet and dry years or decades, insert changes in the model to address longer-term climate or shorter-term changing weather patterns, and test whether human water use is protected. They can similarly test under what conditions risks to the water supply become unacceptable, whether for economic, environmental or human usage. Equally important, they can then test what changes to current conditions of conservation, technology, storage and release might be needed to reduce the risk to acceptable levels. Finally, if adequate costs and pricing are known, these can be built into the model to support decisions on least-cost or highest-return alternatives.

4. CONCLUSIONS

The results of this project clearly show that the Bow River System can and should be managed differently. The results of the Bow River Operational Model confirm that proposed changes to improve water management are realistic and doable. They will improve fish and riparian habitat and water flows downstream, enhance recreation opportunities, and potentially improve water quality through many parts of the river. And they can be implemented cost-effectively and in a way that does not significantly diminish economic returns from power generation.

The foundation for these proposed changes is a move to integrated adaptive management of the Bow River System from headwaters to confluence—an approach that considers all users as well as economic, environmental and social impacts. This opportunity represents a significant shift in thinking and action and reflects the approach that is emerging through Alberta's Land-use Framework to place-based management.

The BRP Research Consortium is convinced that if the Bow River and its controlled tributaries were managed as an integrated system, the benefits described in this report would be secured. In support of this conclusion, the Consortium has identified five opportunities for consideration by the Government of Alberta and others with a stake in the way the Bow River System is used and managed.

The key components of the Base Case and the Preferred Scenario are illustrated in Figures 18 and 19.

FIGURE 18. BRP Base Case Summary (Current Situation)

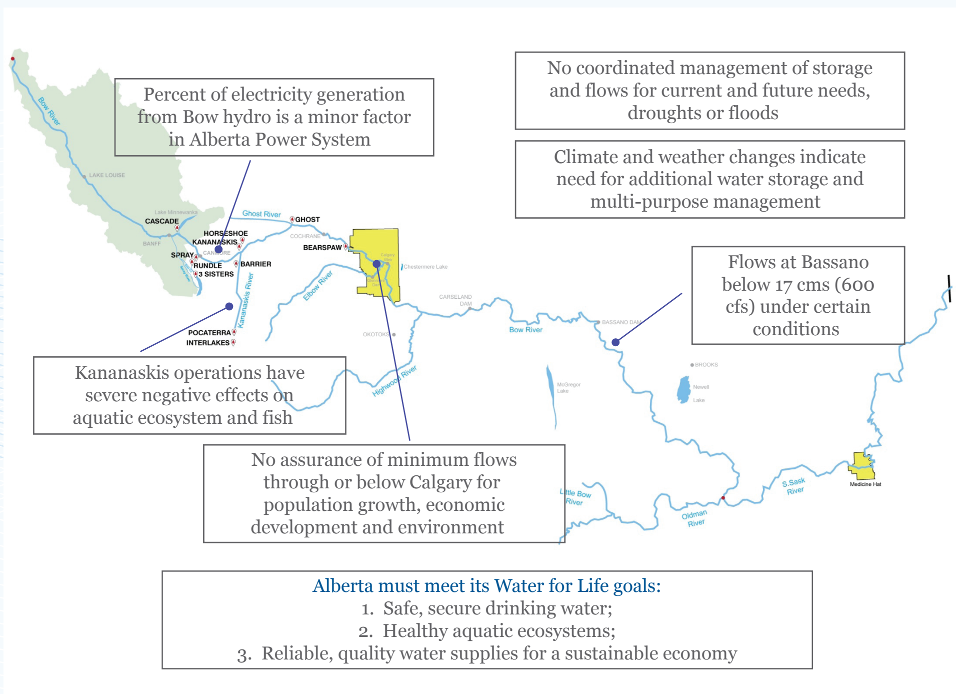
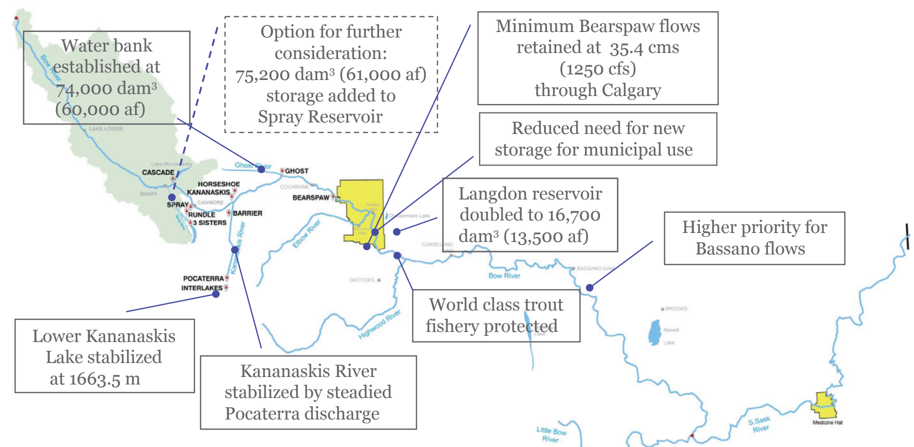


FIGURE 19. BRP Preferred Scenario Summary



Design principles met:

- Net benefit to environment
- Population, economic needs met
- Apportionment met
- Minimum flows met
- Known First Nations requirements met
- Priority water allocations respected
- TransAlta costs covered

Significant benefits for all users:

- Enhanced flows below Bassano & other reaches during low-flow periods
- Protected Calgary flow levels ensuring water quality standards, fisheries protection and reduced ice jams
- Aquatic health, fisheries and recreation improvements in Lower Kananaskis Lake & Kananaskis River
- Greater opportunities to support growing population demands
- Offers flood & drought mitigation options
- Improved alignment of irrigation needs, environmental values and upstream users

Associated costs:

- Compensation for lost TransAlta revenue
- Additional recreation facilities
- Possible capital for Pocaterra turbine
- Possible capital for Spray restoration

Spray Lakes Reservoir in Spray Valley above Canmore

Table 4 summarizes the benefits and costs of the Preferred Scenario compared with the Base Case.

TABLE 4. Benefits and Costs Comparison for the Preferred Scenario

BENEFITS of Preferred Scenario over Base Case	COSTS of Preferred Scenario over Base Case
DIRECT BENEFITS: » Greater achievement of WCOs below Bassano and along Bow River » Protected Calgary flow levels ensure water quality standards and protect fisheries » Aquatic health and fisheries improvements in Lower Kananaskis Lake and Kananaskis River » Opportunity to monetize significant fish habitat offsets in Kananaskis » Enhanced recreation and tourism, specifically in the Kananaskis region but also throughout the Bow Basin » Adequate, quality raw water supply for growing population demands in Calgary and region » Improved alignment of irrigation needs, environmental values and upstream users » Potential to explore and implement further flood and drought mitigation options AVOIDED COSTS: » Reduced infrastructure damage from ice dams in parks and municipalities » Reduced damage from flood events » Reduced damage from drought events » Reduced need for high cost new reservoirs	CAPITAL COSTS: » Replacement of Pocaterra turbine to accommodate steadied flows into Kananaskis River: preliminary estimate of $5-6-million based on 1998 estimate for Ghost Unit #1 replacement (FREWG) » Option for consideration: Restoration of Spray Lakes Reservoir to original FSL, adding 74,200 dam^3 (61,000 acre feet); preliminary estimates range from $20-100-million » Other costs may be identified OPERATING COSTS: » Compensation for lost TA revenue: preliminary estimate from BROM suggests lost revenue from power generation would be $2-2.5-million » Other costs may be identified

In summary, the Consortium believes there is potential for substantial economic, environmental and social benefits for relatively modest cost.

5. OPPORTUNITIES FOR INTEGRATED MANAGEMENT OF THE BOW RIVER SYSTEM

OPPORTUNITY 1: Manage the Bow River System in an integrated, adaptive, end-to-end manner, considering all users, interests and values

River systems are complex and present many challenges to those charged with their management. The Bow River System is particularly complex as it includes TransAlta's 11 on-stream hydro facilities, the Glenmore reservoir in the City of Calgary, numerous off-stream reservoirs throughout three large irrigation districts, and thousands of water diversion licences.

At present, many parties are involved in managing the Bow River System on a reach-by-reach basis for independent purposes. Upstream of Calgary, TransAlta has managed the system for nearly 100 years for the primary purpose of generating electricity. Downstream reservoirs are managed with a focus on meeting the needs of the large irrigation districts. Other parts of the river are managed to meet municipal needs such as drinking water and dilution of wastewater. Social and environmental considerations such as fisheries, aquatic and riparian habitat, and recreation are not always factored into these management decisions, although they can have important economic spin-offs too. Integrated management would optimize opportunities for licence holders, the environment and other users along the entire system.

OPPORTUNITY 2: Pursue and support discussions between the Government of Alberta and TransAlta

Although TransAlta's primary interest is managing the Bow River System to maximize power generation revenues, the company continues to work collaboratively with other water users. TransAlta is now facing significant capital upgrades to its operating system, which creates a rare window of opportunity to influence near- and long-term infrastructure investment choices and introduce a new management approach. The BRP Research Consortium sees a unique and timely opportunity for the Government of Alberta and TransAlta to discuss and negotiate the benefits, costs and opportunities related to integrated management of the Bow River System, specifically with regard to the storage reservoirs upstream of Calgary.

OPPORTUNITY 3: Identify and consolidate the functions required to enable integrated, adaptive management of the Bow River System

The opportunity to take a new direction, as proposed in this report, would mean re-managing the Bow River as an integrated system from source to confluence, with a new long-term management function. The Government of Alberta could continue to be ultimately accountable for administration of water and watershed management activities, but the success of these efforts in the Bow Basin depends on a shared approach to management involving the key water managers and users of the resource. The collaborative approach used in this project and the resulting tool—the Bow River Operational Model—exemplify the importance and value of knowledgeable stakeholders working together, with access to agreed-upon data.

A multi-stakeholder group comprising at least some of the members of the Bow River Project Research Consortium should be convened to design the potential roles, processes and authorities of a shared management function and should draw on the many successful examples from other jurisdictions.

OPPORTUNITY 4: Encourage and enable transparency and open data

Collaborative and transparent processes can successfully address complex, multi-faceted issues, yielding cost-effective, innovative approaches that would likely never have emerged without all the affected stakeholders at the table. The right information is a fundamental element for success and the Consortium worked hard with its partners to secure access to timely and reliable data on which to base its analysis. Often this valuable data and other information are held by the provincial government and it is not always easy to determine what is available and how to access it. The Consortium greatly appreciated the wealth of data provided to it, and encourages the Government of Alberta and stakeholders to explore ways and means of making these excellent resources more easily accessible to researchers and others engaged in similar initiatives. Ongoing open public access to the Bow River Basin data, the BROM, and the body of knowledge being built about river management is particularly desirable.

Pike fishing in the Bow River Basin

OPPORTUNITY 5: Continue working toward an improved and integrated Bow River Management System

The results reflected in this report have yielded important insights into opportunities for better managing the Bow River System. However, additional work is needed to:

a) ensure that all the goals identified for the project are met without unintended consequences, and

b) identify and assemble data to further enhance the Bow River Operational Model and contribute to efforts that may emerge from this project to model other river systems in Alberta.

Moving ahead with this work in 2011 would build on the momentum from this phase of the project and would provide timely support for discussions between the Government of Alberta and TransAlta. As well, other stakeholders may be in a position to take action in some of the six areas identified below where more work is needed.

ECONOMIC ANALYSIS

» Refine the estimated financial impact of potential alternative scenarios on TransAlta's power and ancillary businesses. While this project provided estimates of the financial impact, a more thorough and comprehensive assessment is needed to strengthen the precision of the economic analysis.

» Determine the capital and operating costs of needed infrastructure changes, such as changes to the Spray Lakes Reservoir and Pocaterra turbine, to support the integrated re-management of the Bow River System; for example, a geotechnical study on the Three Sisters Dam should be done to narrow the range of estimated cost.

» Assess new infrastructure-related requirements to support an enhanced recreation and tourism industry.

ECOLOGICAL AND ENVIRONMENTAL CONSIDERATIONS

» Assess the impacts on the Bow River System of a new WID reservoir for residential and irrigation purposes.

» Improving the canal from the Carseland diversion to McGregor reservoir to enable lower rates of off-take is another opportunity for enhancing environmental flow in the lower Bow River during the critical low-flow period in late summer. This would enable the associated large reservoirs to fill during high flows and later be able to divert much lower flow rates (8.5 vs. 14.1 cms, or 300 vs. 500 cfs) during low-flow periods later in the summer. Cost to alter the diversion and associated infrastructure is minimal and can provide measurable environmental benefits downstream of Carseland.

» Confirm the value, potential market and regulatory applicability of potential fish habitat offsets in the Kananaskis system. Removal of regulatory interpretation barriers to using this resource could essentially pay for all or most of the opportunities described in this report.

» Investigate opportunities to enhance riparian health downstream of Carseland and Bassano. Controlled, limited floods at appropriate times, perhaps to coincide with low-level natural flood periods, offer a substantial benefit. Pulsed flows, rather than continual high flows, have also demonstrated beneficial impacts. Research conducted on the Oldman and Red Deer rivers have indicated that riparian health can be improved significantly without a prolonged period of inundation and could thus be planned and managed for some critical areas as part of an overall adaptive management system.

MODELLING

» Further integrate water quality metrics into the Bow River Operational Model; some monitoring and assessment may require hourly data. Leverage the metrics, standards and tools already available for the Bow River System; examples include those developed and used by the Bow River Basin Council.

» Leverage existing climate change models to incorporate into BROM the potential impacts of climate change and adaptation to the extent that global circulation models show potential results even more extreme than the historic and pre-historic record. Precipitation falling as rain rather than snow in the early fall and spring at higher elevations could create conditions of severe flood followed by drought in the same year. Further modelling could enable a prudent consideration of risks, options, costs and benefits of alternative mitigation scenarios under such conditions. Future efforts using existing models can provide water managers with greater ability to respond to the potential effects of climate change on the river system.

» Further explore and refine the balancing of reservoir releases under the water bank philosophy to optimize the use of storage capacity, natural fill periods and offsetting flow patterns. In addition, consider using the available flow releases to meet the other downstream needs beyond the flows below Bassano (as currently modelled).

» Develop a suite of comprehensive environmental performance measures to reduce the uncertainty in projecting environmental outcomes.

INSTITUTIONAL ARRANGEMENTS

» Design a possible stored-water insurance arrangement between TransAlta, municipalities, environmental flow and other users. The feasibility of this action has been modelled in the water bank scenarios (Scenarios 2, 3 and 4 in section 3.2.2).

It is understood that TransAlta prefers a single entity with which to negotiate this or any alternative arrangement to change the operational flow of the Bow River and its tributaries upstream of Calgary. The Consortium encourages the Government of Alberta to be that entity to sort out the specifics of any additional commercial arrangements that may be needed at a later date.

DROUGHT AND FLOOD MITIGATION

» Conduct a preliminary assessment of potential storage expansion of upstream reservoirs for long-term additions to storage, in the event that flood mitigation and/or precipitation capture is shown to be needed as adaptation mechanisms to a changing climate or long-term weather patterns. Likely candidates would be Minnewanka, Upper Kananaskis Lake and Ghost reservoir, although Barrier may also have some small capacity for additional storage if needed.

» Explore flood mitigation opportunities such as improved forecasting of snowpack, weather systems and precipitation. Although heavy rainfall during already high runoff periods is the usual cause of severe flooding, some climate change models forecast rain in place of snow, including possibly late fall or spring rain instead of snow. Both of these conditions may cause more frequent flood flows at different times of the year than has been the usual historic pattern. Coordinated reservoir draw-downs and fills, emergency-only Ghost reservoir storage, and emergency-only increases in Ghost diversion to Lake Minnewanka may be beneficial but have not been analyzed.

» Explore drought mitigation opportunities using integrated reservoir and flow management (e.g., reliable forecasts to support spring draw-down decisions, feasibility of storing water across seasons, Lower Kananaskis Lake storage as "last resort" emergency supply, continued fall filling of irrigation district reservoirs).

GREEN POWER

» Assess the option of green power certification for certain re-managed Bow River hydro facilities. Current criteria for green power hydro have numerous requirements that work for certain other situations in Canada but don't apply well to some Alberta facilities (e.g., requirements for fish passage). In the Bow watershed, providing fish passage may lead to further upstream intrusion of non-native species that could be harmful to natural ecosystems. Furthermore, upstream fish passage may not have occurred prior to dam construction (e.g., there were falls just below Lower Kananaskis Lake).

If TransAlta is planning to rebuild some of its facilities, the criterion that facilities need to be relatively new will fit the Bow situation. Green power premiums would not be enough to cover expected costs to TransAlta for a re-managed system, but would represent another source of revenue that could act as an incentive for environmental improvements.

Climate Change Forecasts

The BRP modelled the flow in the Bow River System for each year from 1928 to 1995—a period that included many extreme weather events as well as the prolonged drought known as the “dirty thirties.” However, some believe that global climate factors may be changing such that even more extreme weather events or more subtle but highly significant changes could occur in the future. The time constraints of this project meant it was not possible to integrate Global Circulation Models of climate change forecasts into the base case or the modelled scenarios and stress tests. The Consortium did model extremely wet and dry periods but climate change-related weather changes could result in different precipitation patterns rather than simply more or less precipitation. Although climate change scenarios may only add to the urgency of making some of the changes described in this report, prudence indicates that further work is needed to test certain climate change weather patterns and their implications.

Most worrisome is not that the region receives more or less precipitation, but that the timing and nature of the precipitation changes. If weather patterns change such that precipitation occurs earlier in the winter and as rain rather than snow, there could be implications for water storage reservoirs. Snowpack provides approximately 80% of the total annual flow in the Bow River. Snowpack acts as, by far, the largest reservoir, storing vast amounts of water-equivalent during winter. In the spring, snowmelt is used to refill reservoirs all along the Bow. Gradually melting snowpack increases river flow in early spring, and creates high flow periods from May to July each year. If winter precipitation comes as rain, whether early or late in the winter, current reservoir capacity may be inadequate to continue managing the flow the same as in the past and in the manner modelled in the BRP.

Another rarely considered possibility is that the climate might change such that the glaciers on the east side of the Continental Divide begin growing rather than receding as they have done since at least the late 1800s. Although glacial melt contributes a relatively small amount to the total annual flow, during mid-summer its contribution is quite substantial in the upper Bow. Environmental consequences could be significant, especially for the pure strain west-slope cutthroat trout, the tourism attractiveness of the region and even the water supply in Banff. The BROM can model these and many alternative scenarios related to changed weather patterns throughout the basin, but particularly for the headwaters region, which affects the environmental, social, and economic bases of the entire watershed.

5.1 ADVANCING THE GOALS OF WATER FOR LIFE

The vision of the BRP is to improve environmental conditions in the Bow River System by more efficiently and productively using the available water for purposes in addition to power generation. This project, like all projects sponsored wholly or in part by the AWRI, takes the *Water for Life* goals as a starting point and as criteria for achievement; as described below, the BRP encompasses all three *Water for Life* goals in innovative and significant ways.

WATER FOR LIFE GOAL 1: Safe, secure drinking water supply for Albertans

The BRP opportunities can secure sufficient water storage and significantly improve headwaters protection, creating the conditions for a long-term safe and secure drinking water supply for the approximately 1.3 million Albertans now living in the Bow River Basin. Stress tests were done on the modelled scenarios to ensure an adequate water supply would be available for the population forecast in the Calgary Metropolitan Plan for the next 65 years. Under all but the most extreme circumstances, different management practices will make available adequate water storage and supply upstream of Calgary without creating any new reservoirs. The proposed stabilization of Lower Kananaskis Lake and the Kananaskis River downstream to Barrier Lake to improve aquatic ecosystem health, fisheries productivity, and recreational opportunities also would provide an emergency-only drinking water supply for the downstream population in the event of a prolonged drought beyond those seen in the historic record. The Spray reservoir could similarly be used in extreme circumstances for municipal water supply upstream of the Kananaskis confluence with the Bow.

Wedge Pond in Kananaskis

WATER FOR LIFE GOAL 2: Healthy aquatic ecosystems

One principle of the BRP was to evaluate each reach of the Bow and its managed tributaries to ensure no measurable environmental harm would occur in any reach while substantially improving aquatic ecosystems in other reaches. The vastly improved knowledge base created by the BROM and the initial scenarios provide the foundation for long-term protection of river ecology without impeding population growth and economic development that are forecast for the next 65 years. Two examples of improvements in every scenario are the dramatic improvement to the Kananaskis Lake and Kananaskis River ecosystems, and the considerable improvement to flow rates downstream of the Bassano Dam (see Figures 10-12). The Bow River Water Quality Model work described earlier confirms the positive ecological benefits offered by an integrated scenario. Managing the entire Bow River System as an integrated system rather than as a reach-by-reach series of unconnected flowing water bodies, can ensure adequate flow to support essential ecological processes for the very long term. This includes additional work to explore pulsed flows downstream of Bassano to improve riparian habitat, examine flow requirements to support the world-class trout fishery downstream of Calgary, and provide additional flow rates to reduce the risk of low dissolved oxygen levels through Calgary. Many other improvements may be uncovered through further collaborative work with the model.

WATER FOR LIFE GOAL 3: Reliable, quality water supplies for a sustainable economy

The three primary economic pillars in the Bow River Basin are the urban administrative and services businesses (including financial services) and the energy sectors, agriculture and its related businesses, and tourism and recreation. All depend on an adequate and reliable water supply. All the BRP scenarios provide for additional water for recreational and aesthetic purposes in the headwaters and throughout the Bow River System. Water for municipalities using or wanting to use the Bow as their source was built into the scenarios by providing for the use of all the water in the Calgary licence, whether by the City, its regional water utility, or other municipalities. The irrigated agriculture sector is the major water user in the Bow Basin. The three Irrigation Districts that use the Bow actively participated in developing scenarios to improve water use efficiency throughout the basin, including in their operations. One of the innovative outcomes of the BRP partnership was modelling the potential use of off-stream storage reservoirs in the BRID to enhance the flow below Bassano during low-flow periods. By maintaining McGregor and Travers reservoirs at high levels during high-flow periods, there would be less need for BRID diversions during low-flow periods in late summer. This would allow more water to flow downstream to support aquatic ecosystem health. The BROM is also a valuable tool to model and increase understanding of the impacts of potential new development in the basin.

> The results, conclusions and opportunities in this report describe many significant benefits to integrated management of the Bow River System. All of these benefits could accrue to southern Alberta and the province as a whole through a thoughtful, well-planned and timely response to the opening that is expected to occur in the next year with respect to managing this river system. The Bow River Project Research Consortium is optimistic that these opportunities will be acted on and is pleased to have contributed to the discussion.

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PHOTO CREDITS

7. GLOSSARY AND ACRONYMS

Unless otherwise noted, the definitions in this glossary were taken or adapted from Alberta Environment's Approved Water Management Plan for the South Saskatchewan River Basin (Alberta), 2006.

AF ~ acre-foot; the volume of water required to cover one acre to the depth of one foot. One AF = 1.23348 dam^3.

Ancillary Services ~ Ancillary services, such as "spinning reserve" and automatic generation control, maintain the electrical system within narrow tolerances as load rises and falls. It also helps ensure that power is delivered at stable voltages. (Alberta Energy)

Aquatic Environment ~ (As defined in Alberta's Water Act) The components of the earth related to, living in or located in or on water or the beds or shores of a water body, including but not limited to all organic and inorganic matter, and living organisms and their habitat, including fish habitat, and their interacting natural systems.

AWRI ~ Alberta Water Research Institute

BRBC ~ Bow River Basin Council

BRID ~ Bow River Irrigation District

BROM ~ Bow River Operational Model

BRP ~ Bow River Project

cfs ~ cubic feet per second; one cfs = 0.02832 cms.

cms ~ cubic metres per second; one cms = 35.314 cfs

CRP ~ Calgary Regional Partnership

dam^3 ~ one cubic decametre (1,233.48 cubic metres)

Dissolved Oxygen (DO) ~ Amount of available oxygen contained in the water, but not including the oxygen that is part of the water molecule (H2O). Expressed as milligrams per litre.

EID ~ Eastern Irrigation District

FITFIR ~ "First-in-time, first-in-right" refers to the priority system for allocating water based on the seniority of the licence (that is, older licences have higher priority). FITFIR has been a key principle of granting and administering water allocations in Alberta since 1894 and continues to be the system of water allocation under the Water Act. It is active only when there is insufficient water to meet the needs of all licence holders. (Alberta Water Council, 2009; and Legislative History of Water Management in Alberta, http://www.environment.alberta.ca/02265.html)

FSL ~ Full supply level

HADD ~ harmful alteration, disruption or destruction (of fish habitat)

Hydropeaking ~ The difference between maximum and minimum intra-day flows through turbines in the TransAlta system (BRP Research Consortium)

Instream Flow ~ The rate of flow in a river, without reference to its purpose.

Instream Needs / Instream Flow Needs (IFN) ~ This is the scientifically determined amount of water, flow rate, water level, or water quality that is required in a river or other body of water to sustain a healthy aquatic environment or to meet human needs such as recreation, navigation, waste assimilation, or aesthetics.

Instream Objectives ~ Regulated flows that should remain in the river via dam operations or as a restriction on licences. Below dams, Instream Objectives are in place in throughout the SSRB, although some offer only limited protection of the aquatic environment. Instream Objectives have usually been set in response to fish habitat instream needs (the Fish Rule Curve) and/or water quality.

Irrigation District ~ An organization that owns and manages a water delivery system for irrigation for a given region. In Alberta, there are 13 irrigation districts. Some districts convey water for other purposes, such as municipal use and stockwatering.

Master Agreement on Apportionment ~ Schedule A of the 1969 Master Agreement on Apportionment for the South Saskatchewan River between Alberta and Saskatchewan allows Alberta to "divert, store or consume" from the river system each year, a volume of water equal to one-half of the apportionable flow of the South Saskatchewan River at the Alberta-Saskatchewan boundary. The remaining volume of flow must be allowed to pass downstream into Saskatchewan. The exception to this general rule is that Alberta is entitled to divert, store or consume a minimum of 2.1 million-acre feet in any year. The effect of this exception is that during years when the volume of natural flow is less than 4.2 million-acre feet (a rare occurrence), Alberta may pass less than one-half of the apportionable flow to Saskatchewan. If at any time during a year Alberta wants to divert, store or consume more than half the apportionable flow, a flow rate of 1,500 cubic feet per second (cfs) must be maintained at the Saskatchewan border, unless the natural flow is less than 3,000 cfs, in which case half the natural flow must be passed. (There is no policy in Alberta as to the amount of water each sub-basin of the SSRB must contribute to the Saskatchewan apportionment.)

Natural Flow / Natural Rate of Flow ~ Natural flow is the flow in rivers that would have occurred in the absence of any man-made effects on, or regulation of, flow. For purposes of water management, natural flow is a calculated value based on the recorded flows of contributing rivers; a number of factors concerning the river reaches (e.g. evaporation, channel losses, etc.); and water diversions. This is also known as "re-constructed flow" and "naturalized flow".

OASIS ~ Operational Analysis and Simulation of Integrated Systems

Return Flow ~ Water that is included in an allocation and is expected to be returned to a water body after use and may be available for reuse, although the water quality characteristics may have changed during use. (Canadian Association of Petroleum Producers, Draft Water CEP Plan)

Riparian Area ~ The area along streams, lakes, and wetlands where water and land interact. These areas support plants and animals, and protect aquatic environments by filtering out sediments and nutrients originating from upland areas.

Riparian Vegetation ~ The vegetation that exists in riparian areas and is supported by the interaction of the water and land.

River Basin ~ An area of land drained by a river and its associated streams or tributaries.

SSRB ~ South Saskatchewan River Basin. The South Saskatchewan River Basin includes the sub-basins of the Red Deer River, Bow River, and Oldman River (including the South Saskatchewan).

Surface Water ~ Water bodies such as lakes, ponds, wetlands, rivers, and streams. It may also refer to sub-surface water or groundwater with a direct and immediate hydrological connection to surface water (for example, water in a well beside a river).

Water Allocation ~ The amount of water that can be diverted for use, as set out in water licences and registrations issued in accordance with the Water Act. (Canadian Association of Petroleum Producers, Draft Water CEP Plan)

Water Conservation Objective (WCO) ~ As defined in Alberta's Water Act, a Water Conservation Objective is the amount and quality of water necessary for the protection of a natural water body or its aquatic environment. It may also include water necessary to maintain a rate of flow or water level requirements.

From the *Water Act:* "Water Conservation Objective" means the amount and quality of water established by the Director under Part 2, based on information available to the Director, to be necessary for the:

(i) protection of a natural water body or its aquatic environment, or any part of it;

(ii) protection of tourism, recreational, transportation or waste assimilation uses of water; or

(iii) management of fish or wildlife, and may include water necessary for the rate of flow of water or water level requirements.

A licence may be issued by the Director to the Government of Alberta for the purpose of implementing a Water Conservation Objective.

Water Diversion (or withdrawal) ~ Describes the amount of water being removed from a surface or groundwater source, either permanently or temporarily. (Canadian Association of Petroleum Producers, Draft Water CEP Plan)

Water Licence ~ A water licence provides the authority for diverting and using surface water or groundwater allocation. The licence identifies the water source, the location of the diversion site, an amount of water to be diverted and used from that source, the priority of the "water right" established by the licence, and the condition under which the diversion and use must take place.

Watershed ~ An area of land that catches precipitation and drains into a body of water, such as a marsh, stream, river or lake.

WID ~ Western Irrigation District

WRMM ~ Water Resources Management Model