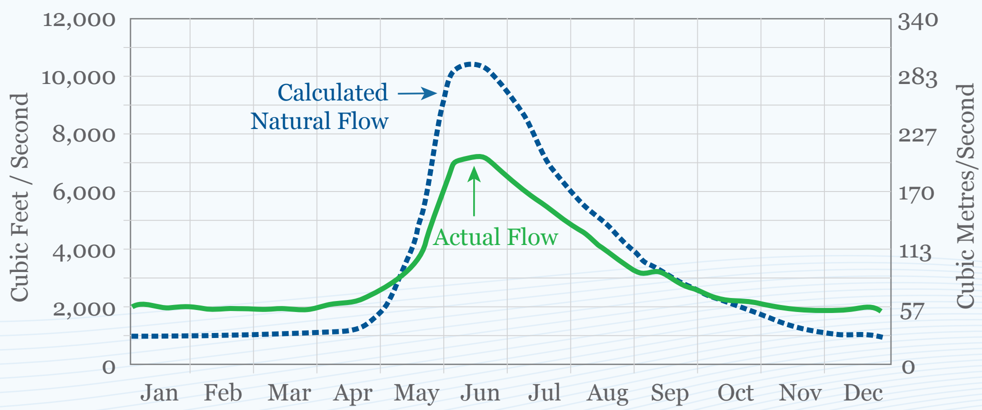
FIGURE 4. Bow River at Calgary, Natural vs. Managed Flows (1960 - 1997)
{Source: Alberta Environment}



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.

[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