South Saskatchewan River Basin Adaptation to Climate Variability Project

Final Report

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South Saskatchewan River Basin (SSRB) Adaptation Project

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Abstract

Water management in southern Alberta will become increasingly critical in the face of existing and future pressures – population growth, economic expansion, competition for finite and shared resources and, not least of all, ongoing climate variability and change. The challenge will be to anticipate and respond to these pressures while retaining the features that enhance the region's quality of life and define its character. The South Saskatchewan River Basin Adaptation to Climate Variability Project brought together those who know the region's water systems best to look for opportunities to further enhance the resiliency of the Bow and Oldman-South Saskatchewan river basins. This initiative built on prior work in the Bow River Basin, and capitalized on the success of that project by bringing together the data, knowledge, information and experience of water resource managers, watershed and community stakeholders, scientists, and environmental advocates to create a robust foundation for improved river management outcomes under a range of climate variability scenarios.

The integrated and collegial process applied to this work enabled participants to work collaboratively and creatively, drawing on each other's expertise and insights to explore practical options for adapting to climate variability and change. Because of this project and the work that preceded it, there is now a much better, and more integrated, understanding of the river systems. Given the collaborative experience of this initiative, engaged and committed stakeholders have created strong momentum and a sense of shared future. They identified practical and implementable solutions to improve resilience and adapt to current and future water management challenges.

Keywords

Adaptation; SSRB; Oldman River; South Saskatchewan River; Bow River; Water Management; Climate Variability; Stakeholder; Collaboration

Acronyms and Abbreviations

ARD	(Alberta) Agriculture and Rural Development
BRBC	Bow River Basin Council
BROM	Bow River Operational Model
BRP	Bow River Project
CAN	Computer-Aided Negotiation
ESRD	(Alberta) Environment and Sustainable Resource Development
GoA	Government of Alberta
IDM	Irrigation Demand Model
IJC	International Joint Commission
LKL	Lower Kananaskis Lake
OSSK	Oldman and South Saskatchewan
PARC	Prairie Adaptation Research Collaborative
SSRB	South Saskatchewan River Basin
WID	Western Irrigation District
WPAC	Watershed Planning and Advisory Council

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Executive Summary

Alberta's social, economic and environmental history and heritage is directly tied to its water resources. Although fuelled by hydrocarbons, Alberta's economy runs on water. Water is nearly always a limiting factor whether for population growth in the South, water quality issues in the Capital Region, or in-stream flow requirements and quality issues in the oil sands region. Water availability constrains and challenges economic and population growth throughout the province. Alberta's continued prosperity depends on the decisions made about how these water resources are managed. In the face of climate variability and change, these decisions are becoming more complex and more critical to the future of the province. Alberta faces significant water challenges, such as an increasing population, accelerating economic growth, and the increasing impact of this growth on the environment as the climate continues to shift.

This project was about harnessing the experience and expertise of people in the region who are working together to create a shared future by building a common understanding of what is possible given the uncertainties of climate variability and change. It presented a broad, multi-stakeholder opportunity to assemble the data, tools, processes and frameworks to create new and expanded capacity to deal with these challenges over the long term.

A number of valuable products were developed during the course of the project to support integrated river management over the long term. These products include a publicly available set of trusted, vetted databases, river models and performance measures for testing and screening adaptation opportunities; a novel methodology for developing streamflow forecasts reflecting plausible climate variability; and a collaborative process and network of resident water experts practiced and invested in working together to identify and implement system-wide opportunities to build the resiliency of river systems in southern Alberta.

Based on an elevated and documented understanding of how the river systems in southern Alberta are managed and how climate variability might affect them, the project participants identified and assessed a range of potential adaptation strategies for the Bow, Oldman and South Saskatchewan basins. Looking toward implementation, the project reports put forward specific next steps to move towards integrated river management and improved watershed resiliency

Expectations are high within the water community and the opportunities for improved decision making and outcomes are real. Alberta continues to benefit from the commitment and involvement of the water community. Now is the time to move from "talk" to "walk" and implement water resource management strategies and solutions that build on what is already being done. This type of collaborative water management opportunity identification, assessment and implementation is fundamental to maintaining and building the resiliency of Alberta's river systems and the communities that rely on them in the face of growing demands and uncertain climate.

Introduction and Project Overview

This project was designed to harness the energy and creativity of southern Albertans to explore practical options for adapting to climate variability and change. Water is fundamental to community sustainability and growth, and the way water is managed in the South Saskatchewan River Basin (SSRB) will become even more important in the face of increasing demands and changing weather patterns and climate. The project was divided into four coordinated phases.

Foundational Blocks: Initial Assessment

Phase 1 was an initial assessment of the data, tools, capabilities, processes and frameworks that already exist and could form elements of the foundational blocks to support integrated water management by water users, decision makers and other interested parties over the long term. This work identified the core resources for the project and critical gaps to be addressed. It ensured existing knowledge, tools, and experiences were leveraged, while avoiding duplication of work already completed or underway.

Bow River Basin: Adaptation and Live Test Year

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

Oldman River Basin and South Saskatchewan River Modelling

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

Foundational Blocks: Development

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

This project took approximately two years to complete. It significantly advanced understanding of potential climate impacts and adaptation resilience in the SSRB. It left a legacy of data, information, tools and experienced participants in a structured and collaborative process. The project results will inform similar future work throughout the rest of the SSRB. Subsequent support could enable expansion of this work to encourage climate adaptation throughout the entire SSRB.

Project Goals

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

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

Project Final Products

Methodology

Throughout the project, participants worked collaboratively, providing advice and insight based on their extensive knowledge and experience. Before working group sessions began, the project team invested significant time and effort in identifying and meeting with key stakeholders to introduce them to the project, understand their interests and concerns, and engage them in the collaborative process.

Participants actively offered ideas and comments to advance the discussion while respecting the views and opinions of others. This process was not designed to seek or achieve consensus; rather, it was designed to explore viable adaptation strategies based on the best data and knowledge in the basins. The results are presented as a solid foundation for discussion including tools for further analysis by those who use, manage, and make decisions about water in the Bow and OSSK basins as they consider adaptations to climate variability and change.

HydroLogics, Inc., the consultant who was involved with the original BRP, led the modelling for the Bow and OSSK basins, using the sophisticated simulation software – called OASIS –they developed for modelling water systems throughout the US and internationally. HydroLogics has also pioneered the use of Computer-Aided Negotiations (CAN), which enables parties with disparate goals to collaboratively develop operating policies and solutions that mutually satisfy their diverse objectives. The CAN sessions integrate computer modelling techniques and real-world data with the existing water management structures.

Developing performance measures is the first crucial step in the process to help parties scope the issues. This work gave participants the opportunity to share, hear and learn about the wide variety of perspectives at the table and slowly established trust and understanding, both vital to any collaborative process. Performance measures (PMs) reflected the objectives and desired outcomes for the project and indicated whether one result is better or worse than an alternative for each PM. They define the functional aspects that the model needs to have, and thus they inform and influence how the model is constructed. Participants identified and developed specific performance measures based on their individual and collective water outcome needs, while continuing to draw on those that were used in the earlier BRP.

Once performance measures are in place, the model can be run and the results tested and vetted to determine if the outcomes are reasonable and realistic, based on the deep knowledge and experience of participants. Exploring and modelling alternative operations is what most often results in model improvements and updates and strengthens model results. When the model is refined and ready to be tested, participants then work collaboratively in small groups to identify and test opportunities and potential scenarios or strategies. Based on these outcomes and the results of the performance measures, collaborators can then work to reach agreement on the alternatives that are most beneficial to the basin and that meet as many user needs as possible.

River Models

The Bow River Operational Model

The Bow River Operational Model (BROM) is a mass balance, river system model that reflects the stream flows and operations of the Bow River system. It was developed as part of the 2010 BRP, which used the University of Lethbridge's SSRB model as the starting point. The BROM diverges from the SSRB model and from Alberta Environment and Sustainable Resource Development's (ESRD) Water Resources Management Model (WRMM) in that it attempts to model existing, real-world management and potential future operations beyond the constraints of a strict licensing system and includes the entire Bow system from headwaters to the confluence with the Oldman. As it is now configured, the BROM is intended to provide as many environmental benefits and meet as many needs as possible. It focuses primarily on what water users actually do in practice rather than strictly replicating theoretical water use mandated by the current regulatory scheme in Alberta. That said, the operations within BROM do comply with the limitations established under the *Water Act.*

The BROM does not directly take into account groundwater or water quality aspects although both are indirectly and partially encompassed. Groundwater inflows and outflows occur in each reach, between monitoring and measuring stations, and the resulting effect on streamflow is measured and reflected in the BROM. What cannot yet be done due to a lack of the highly detailed groundwater data that would be needed is a parsing out of the precise amounts of water flowing through the ground versus the surface water flows, less evapotranspiration and the other natural functions within each reach. Many point sources containing dozens of potential parameters affect water quality along with the non-point source overland flows and erosion. Although these are not measured in the BROM, maintaining higher flows during low flow periods is a key variable in improving water quality and addressing issues such as lack of dissolved oxygen, nutrient concentrations and so forth.

The schematic diagram in Figure 1 illustrates the breadth and complexity of the area modelled in the BROM, including the Highwood and Sheep river systems which were individually modelled and added for this project. All BROM assumptions and input data are described and documented in the publicly available electronic BROM files accessible through the University of Lethbridge servers, at http://www.uleth.ca/research/node/432/.

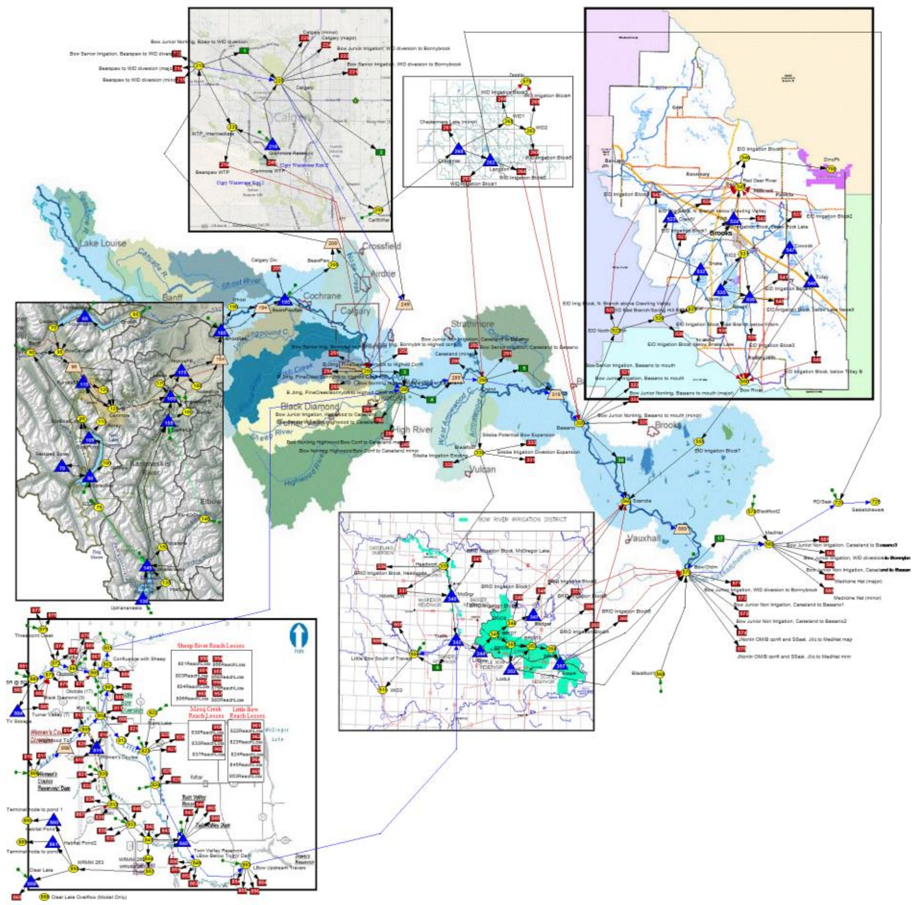

Figure 1: Schematic showing the area modelled in the BROM

The Oldman and South Saskatchewan River Basin Model

Like the BROM, the OSSK model is a daily mass balance model that reflects the streamflows and operations of the river systems involved (Figure 2). The OSSK model is a single, unified model that includes the full Oldman and South Saskatchewan basins with all their major tributaries (including the Southern Tributaries). This allows users to understand today's integrated demands and operations through the entire system, simulate the balancing of the reservoirs throughout the system for optimal operations, and track the impacts and benefits all through the system that could accrue from changes in operational or storage strategies.

The primary inputs to the OSSK model are naturalized flows, lake evaporation, precipitation, consumptive uses, return flows, and physical data. For all canals and reservoirs in the OSSK basin, whether operated by ESRD (i.e., Oldman, Waterton, St. Mary, and Ridge) or managed by an irrigation district (Chin, Stafford, Horsefly, Yellow, Sauder, and others), physical data were provided by ESRD, Alberta Agriculture and Rural Development (ARD) and individual irrigation districts as needed. The OSSK model does not explicitly calculate and account for groundwater or include water quality aspects, but groundwater contribution to streamflow is inherently part of the naturalized flow data, which are used as inflows to the model. Implications for water quality as it relates to flows at points in the river can be assessed using the OSSK model when relationships between water quality and quantity at a particular point in the system are known.

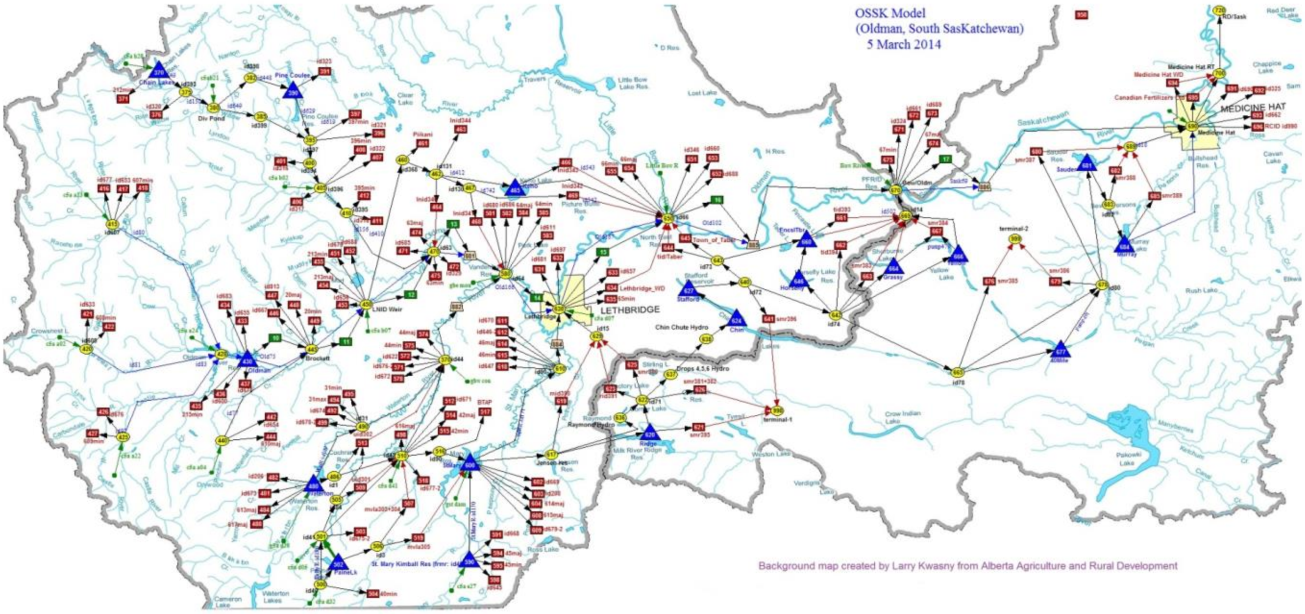

Figure 2: Schematic showing the area represented by the OSSK model

The base case applies how the river is currently operated, within the context of licensed priorities and water management plans, to historical flows (1928-2009). It is also important to note that there has been a progression of reservoir development in the Oldman River Basin. For example, the St. Mary, Waterton, and Oldman reservoirs were completed in 1951, 1964, and 1991, respectively. The OSSK model does not account for this progression, but rather implies that all existing infrastructure was present in the basin from 1928 to 2009 in order to use historic flows as a proxy for potential future flows with current infrastructure in place. In the model, trans-boundary entitlement flows (as set by the International Joint Commission, or IJC) are part of the base case. The OSSK model was validated against historical records, generally matching outflows and reservoir levels for the post-Oldman Dam period. Some deviation from the historical record is to be expected, and while there is a modest overestimation of optimum crop water requirements in the ARD Irrigation Demand Model (IDM) these deviations are not seen as being out-of-scope for the modelling activities that have taken place. Additionally, 2011 crop mix, on-farm efficiency and district infrastructure are used in the IDM to calculate irrigation demands based on historical weather records (i.e., 1995 hydrology would utilize 2011 irrigation acreage in the model rather than the historical 1995 acreage that led to the historical flows and elevations). Other assumptions and key aspects of the model including inflows and time of travel, water allocations and priorities, St. Mary (trans-boundary) flows, and reservoir balancing are described in the April 2014 report, *South Saskatchewan River Basin Adaptation to Climate Variability Project: Phase III: Oldman and South Saskatchewan (OSSK) River Basins Summary Report.*

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

Climate Variability Modelling Methodology

One goal of the SSRB Adaptation Project was to propose an adaptive and robust water management framework that takes into account the regional impacts of climate variability and change. This required the development of a scientifically valid set of possible future streamflow conditions that would enable water users and managers to test water management alternatives under a range of potential future climate and hydrological scenarios. Thus, developing climate scenarios that could be used in the BROM and OSSK models was the first step in contemplating potential climate adaptation strategies.

The innovative approach to developing the climate scenarios is described in detail in the June 2013 report, South Saskatchewan River Basin Adaptation to Climate Variability Project: Climate Variability and Change in the Bow River Basin. This aspect of the Phase II and Phase III work was led by the Prairie Adaptation Research Collaborative (PARC), which has been developing provincial climate scenarios for ESRD for some time.

The climate variability data sets for the Bow and OSSK basins are available to the public through the University of Lethbridge servers, at http://www.uleth.ca/research/node/432/.

Project Results

Phase 1 Initial Assessment

The objective for Phase I was to ensure that the best fit-for-purpose model was used for this project. The model needed to align with project timelines and budget and meet project goals and objectives for collaborative stakeholder assessment of adaptation strategies. It was decided to continue with OASIS as the modelling software of choice for several reasons: stakeholders were familiar with the software, support resources were already identified and engaged, OASIS can accept a variety of data and linkages to other models, and it had been used to build the BROM so this model was ready to support adaptation discussions. OASIS also has the component capacity for the Bow, Highwood, Oldman, South Saskatchewan and Southern Tributaries, enabling the development of one integrated model. Each individual model serves a valid purpose for water management in the SSRB and should be developed in a way that complements the other basin models. Based on the initial assessment, the project team recommended that WRMM and OASIS be developed in parallel as complementary tools, offering distinct benefits but with a common data foundation, for long-term use in the SSRB.

Through both formal and informal discussions, participants provided comments and observations about limitations and opportunities related to river management in the SSRB. This led to the identification of two categories of gaps in the SSRB's integrated water management foundational blocks: those that were addressed through the work of this project, and gaps that will remain at the conclusion of the initiative. Both types of gaps are briefly described below.

Gaps Completely or Partially Addressed Through this Project or Related Activity:

Gap 1: Synthetic daily time series of climate variability-affected streamflow along with other basin-scale analytical tools that can be used in BROM to identify potential climate variability impacts on streamflow in the basin to facilitate exploration of potential adaptation strategies by stakeholders.

Gap 2: Synthetic daily time series of climate variability-affected streamflow along with other basin-scale analytical tools that can be used in the OSSK model to identify potential climate variability impacts on streamflow in the basin to facilitate exploration of potential adaptation strategies by stakeholders.

Gap 3: A complete data set of withdrawals (volumes, locations and timing) reported by all licence holders throughout the SSRB. Ideally this data would be real time, or at least relatively current. If possible, irrigation withdrawal data would be matched with current year crop data by geography. The irrigation districts, with the assistance of ARD keep detailed diversion records on an annual basis. These records are not just point-of-diversion, but include diversions through internal works to individual farms. The data are generally available at the end of each season and ARD publishes an annual summary that is publicly available.

Gap 4: Basin-wide SSRB physical model(s) enabling collaborative exploration of the relationships and opportunities between land use or land cover and streamflow.

Gap 5: The following comment is extracted from the 2010 BRP Final Report and still appears to be valid: "Encourage and enable transparency and open data. Collaborative and transparent processes can successfully address complex, multi-faceted issues, yielding cost-effective and innovative approaches. The right information is a fundamental element for success, but 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."

Gap 6: Sufficient mass balance modelling capability resident in Alberta to use the BROM and OSSK models for stakeholder needs and to train others. There is an opportunity to have ongoing and collaborative discussions about tools and models to share what has been learned, improve understanding of the unique needs of SSRB river management work, and continue to build the spirit of collaboration. There appears to be a need for appropriate tools to support collaborative "what if" discussions about river management and operations.

Gap 7: Although significant research and piloting have occurred to develop the tools, relationships and processes for basin-scale adaptive management, at present, many parties manage the SSRB system on a reach-by-reach basis for independent purposes, including power generation, irrigation and meeting municipal needs. Social and environmental considerations such as fisheries, aquatic and riparian habitat, and recreation are not always factored into management decisions, although they can have important economic spin-offs too.

Gap 8: It is a challenge to manage longer term interests within the context of short term demands and current river flows. There is some concern that longer term river planning is done on an *ad hoc* basis and only when short-term management needs are met.

Gaps Not Directly Addressed Through this Project

Gap 9: Synthetic daily time series of climate variability-affected streamflow along with other basin-scale analytical tools that can be used in Red Deer models to identify potential climate variability impacts on streamflow in the basin to facilitate exploration of potential adaptation strategies by stakeholders.

Gap 10: A tool and the necessary data to forecast demand needs for all licence holders for various times of the year, based on the historic record. The Irrigation Demand Model (IDM) performs this function within the irrigation districts and possibly could be adapted to represent private irrigation outside of the irrigation districts. Non-irrigation demand data might be available directly from some of the water users within the basin; e.g., cities may have access to daily diversion requirements based on population and infrastructure. It will be important to build the relationships and connections to ensure the access to such information in the future.

Gap 11: A tool and the necessary data correlating historic weather forecasts with requested demands and actual withdrawals. While actual weather data set for all of Alberta on a 10 km x 10 km grid are available and are being used, there are limitations in the historical statistical information used to assist in predicting weather and in the historic record of weather forecasts. A further issue is the representation of future climate conditions that could be modelled to develop adaptation responses.

Gap 12: Publicly available water quality models for the Oldman, South Saskatchewan and Red Deer rivers. A water quality model for a portion of the Bow (from Bearspaw to Bassano) is updated and available through ESRD with the permission of the City of Calgary. A Red Deer River model, which requires updating, is also available through ESRD. The project team is not aware of commitments by ESRD, ARD, or Watershed Planning and Advisory Councils (WPACs) to develop water quality models for any of the other basins.

Gap 13: There are storage issues and opportunities in the OSSK basins that need to be reviewed collaboratively and openly.

Gap 14: While the WPACs play an important role in their basins, they have limited resources, mechanisms and authority to direct change. Armed with the appropriate tools and potential solutions it should be possible to identify, pilot and refine new institutional arrangements that will support improved outcomes and ongoing adaptive management.

Gap 15: Engagement processes related to river management are fragmented and information flow can be limited. There appears to be a heavy reliance on informal communications between parties. There is an opportunity to build collaboration between stakeholders to enhance the ability of organizations and the basin to adapt to change.

Bow Business Case

This Business Case demonstrated the type and magnitude of benefits associated with the Preferred Scenario, based on reasonable and transparent assumptions. This Business Case did not assess the impact(s) of potential climate change on the Base Case or on the benefits attributed to the Preferred Scenario. In summary, the benefits of implementing the Preferred Scenario include:

- The estimated annual incremental economic benefits of stabilizing Lower Kananaskis Lake are significant at $2 million - $3 million with an estimated net present value range of $30 million - $40 million. Furthermore, these estimates are considered to be a low range of the possible benefits to be derived from stabilizing Lower Kananaskis Lake and did not include additional non-angling benefits such as re-establishment and protection of a world class fishery in Lower Kananaskis Lake, improved wildlife habitat, improved opportunities for camping and other accommodations, or potential enhanced commercial and recreational kayaking and rafting below Barrier Lake.
- The estimated cost of securing a comparative amount of water equivalent to that managed by the Water Bank has a net present value range of $41 million - $313 million. Although it is difficult to place a cost on water without considering many factors (e.g., application, the water user, timing of valuation), this estimate is considered to be a reasonable approximation of that comparative cost. This analysis is not meant to imply that the Preferred Scenario creates additional water or new water allocations, but rather that it enables these allocations to be used more effectively without environmental harm.
- The estimated avoided cost of building water storage equivalent to that managed by the Water Bank is $51 million - $148 million. The Water Bank approach of achieving integrated water

management for the Bow River system provides for the management of 60,000 acre-feet of water without this cost.

- An intuitively obvious benefit of the Preferred Scenario is the overall improvement to the environment. The Preferred Scenario offers an increase in the environment's future value and, by improving environmental conditions now, increases the likelihood that future generations will be able to enjoy the lakes and rivers that the scenario serves.
- The Preferred Scenario supports the *Water for Life* goal of providing a reliable, quality water supply for a sustainable economy. This includes assurance of minimum flows (1,250 cfs) through Calgary under the maximum forecast future water demands by municipalities for the next 35 years. These assured minimum flows will improve security of water quality standards, fisheries protection, and enhanced flows between Calgary and the Bassano Dam and in other reaches.
- The Preferred Scenario using the Water Bank approach to integrated water management will help mitigate risks associated with possible inaccuracies in estimates or assumptions about water requirements and availability, such as not being able to meet future water demands for short periods and environmental impacts attributable to population and economic growth. The Preferred Scenario's Water Bank approach to integrated water management also has the potential to ensure the year-round availability of water to meet the needs of junior licensees in the basin.

Costs associated with implementing the Preferred Scenario and obtaining certain of the benefits noted above would include the costs of operating the Water Bank. These costs have not yet been determined.

Climate Variability Analysis

An important focus of the SSRB Adaptation Project was to build robust adaptation options in response to a range of future climate scenarios that would test the Bow River system under periods of prolonged and extreme drought. The work described in Climate Variability Analysis report lays the foundation for developing adaptation options by projecting the impacts of changes in climate in the SSRB.

The aim of the projections was to come up with a representative picture of what the year 2040 might look like; thus the 2025-2054 period was chosen to provide an outlook far enough from present that potential impacts are not immediate while giving a longer range outlook that is not too far into the future. The methodology to develop the scenarios was outlined in the *South Saskatchewan River Basin Adaptation to Climate Variability Project: Climate Variability and Change in the Bow River Basin* (June 2013 report) and the *SSRB Adaptation Project: OSSK River Basins Summary Report* (April 2014 report). This component of the project provided a range of plausible future flows and offered credible scenarios to be used in modelling sessions to look at impacts to the river and adaptation options for managing the river under possible future climates.

The five climate scenarios used for the Bow Basin modelling sessions were selected from the full set of 50 scenarios to provide a range of plausible future flows and allow stakeholders to explore and test adaptation options. Much of the range in hydrology from the climate scenarios covers flow conditions that were seen throughout the historical record and are well within the range of variability seen in recent history in terms of magnitude and duration. Figure 3 compares, at a weekly time step, the 30-year average flow produced from each of the five chosen climate scenarios, with the 67-year average flow from the historical record in the model (1928-1995), and the two-year average flow from 2000-2001 (a recent low flow period). The plotted historical time series provides context for the hydrology produced by the climate scenarios. The average flow conditions and range of hydrology shown in Figure 3 generally reflect what are considered "normal" or average conditions.

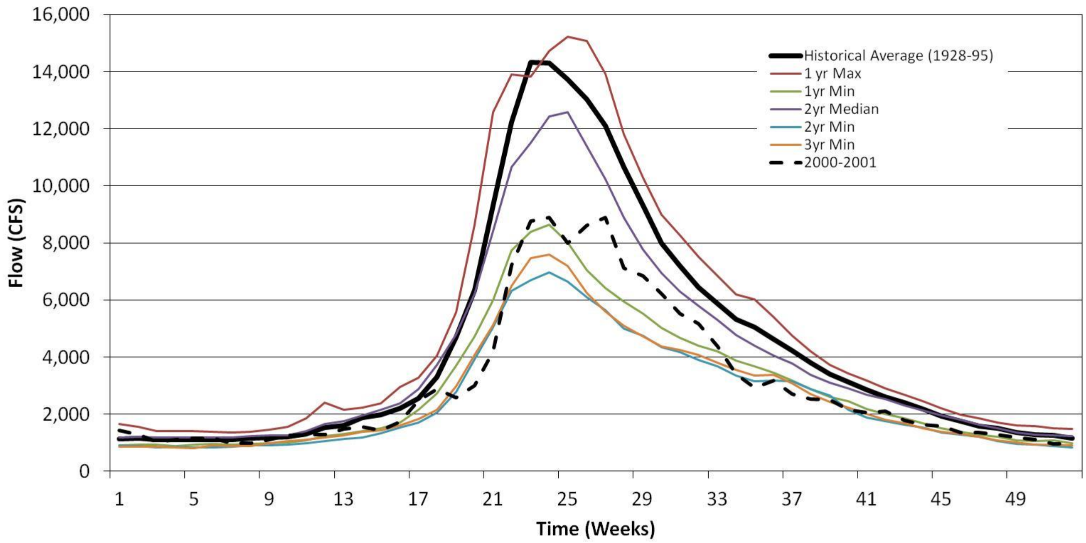

Figure 3: The 30-year average flow for 2025-2054 from each of the five chosen climate scenarios, with the 67-year average flow from the historical record in the model (1928-1995), and the 2-year average flow from 2000-2001

The scenarios highlight the impacts of droughts of higher magnitude and duration than those seen in the historical streamflow record. These scenarios were selected to focus on lower flows and droughts for two main reasons. First, the methodology used to develop the scenarios shows the severe and extended droughts and in some years shows an earlier shift in the hydrograph. However, the methodology from downscaling annual flows to daily flows did not capture the peak high flood flows. The second reason is that droughts generally have a greater and longer impact on water users in the SSRB than floods; while very little can be done to control a large flood event, it may be possible to adapt operations for drought conditions.

In similar fashion, five scenarios for the OSSK basins were chosen from the full set of 50 to show a spread of realistic options. Each climate scenario has an independent set of hydrological conditions and all scenarios were developed using the IJC entitlement flows. The 10th percentile of minimum flows was excluded to eliminate outliers of extreme low flows. All the scenarios provide annual average flows, downscaled to daily streamflow. This methodology shows the severe and extended droughts and earlier shift in the hydrograph expected as a function of climate change. The five chosen scenarios were:

- The 2yr Median scenario (the historical analogue) has some drought periods and some wet periods, but its purpose is to assess alternatives under historic-like conditions.
- The 1yr Max scenario is generally wetter and puts almost no drought pressure on the system. The overall intent is to ensure that no alternatives have negative impacts if the actual future ends up not being dire. Flood impacts cannot be properly assessed due to methodology limitations.
- The 1yr Min scenario has a key year of interest – 2033. This drought is much worse than 2000-01. Subsequent years (2034 and 2035) are also dry.
- The 2yr Min scenario has two consecutive dry years (2034-2035) with other low years as well. The years 2032 and 2033 are also dry.
- The 3yr Min is the worst scenario with two severe dry periods, one at the beginning of the time period and one later. The key years are 2027-2029.

For the most part, collaborative modelling done by the working group for the OSSK basins focused on the historic record and the 2yr Min scenario as it emphasized drought.

It was recognized that this methodology of taking annual flows to daily flows does not capture peak high flows well. To allow preliminary modelling of flood mitigation options, a daily flood inflow time series was developed for 1995 using a scaling factor that represents observed peak daily flow during the 1995 flood event. This time series was scaled up to daily peak flows that were based on observations upstream of the Oldman, Waterton, and St. Mary reservoirs to approximate a flood.

Adaptation Strategies

Bow River Basin

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

- N1. Implement Preferred Scenario with trigger
- N2. Adjust fill times for three largest TransAlta reservoirs (Minnewanka, Spray and Upper Kananaskis)
- N3. Reduce seasonal consumptive demand in Calgary
- N4. Implement seasonal consumptive reuse in Calgary
- N5. Move municipal licences from Highwood/Sheep system to Bow River
- N6. Increase winter carryover in Travers Reservoir
- N7. Implement additional demand reduction in irrigation districts.

Eight strategies emerged that may be less necessary under current conditions, but could be important components in adapting to a more severe future climate. Some of these would require changes in how water is managed, while others involve new infrastructure. These "drought" options, once in place, would also be expected to benefit the region when conditions change again to more closely match current and historic experience. Any new infrastructure and storage would need to be evaluated carefully, considering economic impacts, positive and negative environmental trade-offs and effects on the land and landowners:

- D1. Restore Spray Reservoir to full design capacity
- D2. Draw Ghost Reservoir down preferentially to 6.6 feet (2 metres) below normal pattern
- D3. Reduce minimum river flow through Calgary
- D4. Increase off-stream storage in the Western Irrigation District (WID) (Bruce Lake)
- D5. Manage return flows from WID through Crowfoot Reservoir
- D6. Increase Little Bow/Travers storage capacity
- D7. Increase on-stream storage downstream of Bassano (Eyremore Reservoir)
- D8. Operate irrigation district reservoirs to protect junior licences.

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

C1. Preferred Scenario (water bank + stabilized Lower Kananaskis Lake, or LKL) + reduce minimum flow through Calgary (from October to December, with low storage trigger)

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

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

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

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

C6. Stepwise combination for maximum drought adaptation.

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

N1: Implement preferred scenario

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

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

N6: Increase winter carryover in Travers Reservoir

N3, N4, N7: Conservation and demand reduction

Three strategies were suggested as having the most promise for adapting to the most severe drought conditions that occurred over three years of the 30-year period for the chosen climate scenario. These “drought” options, once in place, would also be expected to benefit the region if and when conditions change again to more closely match current and historic experience.

D3: Reduce minimum river flow through Calgary

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

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

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

Oldman and South Saskatchewan River Basins

During this phase of the project, participants suggested and explored a wide range of strategies, acknowledging that more work is needed to assess socio-economic and environmental benefits and costs. Some strategies were explored as responses to flood conditions, but most were in response to drought. Any new infrastructure and storage would require environmental impact assessments, cost-benefit analysis, socio-economic analysis, engineering feasibility studies, consideration of impacts on landowners and First Nations, and other investigations, recognizing that there are trade-offs.

Five strategies were considered to have the most promise for offering adaptability and resilience in the face of more severe climate conditions, specifically drought. These strategies reflect a mix of approaches including potential new infrastructure, changes in operations and management of river systems, and collaboration in adjusting demands:

- Lower Belly Reservoir
- Minimum flow augmentation below reservoirs
- Kimball Reservoir
- Chin Reservoir expanded and fully balanced
- Forecast-based rationing.

Four strategies were viewed as having some promise and offering moderate benefits in dealing with drought or flood conditions. These approaches mostly involved changes in operations:

- Oldman Reservoir flood control operations
- Chin Reservoir balanced
- Chin Reservoir expanded, and expansion balanced
- Drought-modified Fish Rule Curves.

Six individual strategies, once modelled, were found to have limited promise and few benefits. Some of these were developed in response to flood and others to drought:

- 1m additional storage in existing St. Mary Reservoir
- Chin Reservoir expanded without balancing
- Downstream dry dam for flood control
- Simple triggered shared shortages
- Lower full supply level in all ESRD reservoirs by 2m when needed until July 1
- Storage reserve.

The OSSK basins are complex and dynamic systems and potential adaptation strategies would likely be implemented in combinations that reflect the needs of the basins and the appropriate degree of risk management. To examine how adaptation strategies might be layered to produce cumulative and offsetting impacts, the project modelled three strategy combinations. All combinations involve a mix of additional storage as well as changes in operations, and one combination also includes demand adjustments:

- C1. Chin Reservoir expanded + fully balanced + St. Mary augmentation
- C2. Chin Reservoir expanded + fully balanced + Kimball Reservoir + St. Mary augmentation

- C3. Chin Reservoir expanded + fully balanced + Kimball Reservoir + St. Mary augmentation + forecast-based rationing

Bow Implementation Plan

The objective of the proposed implementation is to support the Government of Alberta (GoA) in reaching an agreement with TransAlta and other key stakeholders and licensees in the Bow Basin to collaboratively manage the Bow Watershed as an integrated system to address all water management challenges. The agreement would be designed to include the Bow hydro system, the irrigation reservoirs, municipal use and other infrastructure. It would likely be managed as an integrated system, operated by the existing water managers, within the existing legislative framework, but with a collaborative decision framework with priorities set by operators and key stakeholders to include environmental, economic, health, and recreational criteria and, foremost, ensure the safety of the public during the inevitable next drought and flood.

Phase 1: Support an interim agreement between the GoA and TransAlta, endorsed by the major downstream licensees, to manage the upstream hydro system in the event of a potential or emerging flood situation during the coming water year. This agreement would be in place by May 2014.

Phase 2: Collaboratively implement a longer term agreement to manage the watershed, incorporating a flexible approach similar to the Preferred Scenario of the original BRP, but including the latest data and what was learned from the climate variability and flood mitigation collaborative modelling projects. This agreement would be in place for May 2015.

Policy Implications

The integrated river modelling tools and the associated collaborative process are now in place and available to inform policy and capital decisions as needed. This is evident in the recently completed basin-wide assessment of flood mitigation options for the Bow Basin following the 2013 flood. This work has actively informed the GoA's decisions on flood mitigation and would not have been possible without this SSRB Adaptation Project. This is evident again in the current discussion about the role of storage in the Oldman Basin; addressed through this SSRB Adaptation Project and the current ARD Storage Study.

The discussion of potential new storage in the Oldman system raised questions about the effectiveness of current policies regarding Water Conservation Objectives (WCO) and In-stream Objectives (IO), in particular with respect to new infrastructure. It appears many stakeholders would welcome a discussion of whether the current WCO and IO regime yields the intended benefits and whether they might be refined to be more reach-specific and outcome-specific.

This collaborative process, which involved interests and experts throughout the river system, effectively demonstrated its value and potential for informing river management policy, decisions about capital allocation and operational decisions. There is opportunity to transition this collaborative power from a project-based initiative into an ongoing function. This ongoing function would require definition of who is involved (e.g., major licence holders, resident water experts, WPACs, academic organizations), what it informs or influences (e.g., policy development, governance, operationalizing adaptive water management), how the collaborative function would operate (e.g., annual workshops, targeted working groups, data maintenance, development of suitable tools, appropriate support, funding) and where it resides (e.g., within GoA, arm's length from GoA, independent body).

This project highlighted the need for shared use and access to water management data and knowledge across the basin. The appropriate data and tools were fundamental to the success of this work.

Substantial effort by the project team and working group was required to access and validate GoA and non-GoA data. In some cases, aggressive data sharing agreements were necessary, particularly with ESRD. Access to data and coordination of data should not be a barrier to this type of collaborative integrated river management work, especially as the data used are typically regarded as public and non-confidential. Any effort to make the GoA and non-GoA databases, models and tools publicly accessible and usable through simple, common platforms would be of significant value. ARD's IDM2 project is an example of this type of public access being put into place. The newly created monitoring agency AMERA could be tasked with quickly moving to identify, gather and make data public.

Beyond data and tools, the expertise and experience of our resident water experts needs to be captured and systematized before they each retire. This project translated their wealth of knowledge into river models that reflects how the river is actually operated, performance measures that show how the river system can be understood and assessed, and adaptation strategies that should or should not be implemented. The collaborative working group sessions demonstrated the impact and appreciation for this cross-system learning, as a complement to the mentoring and training within organizations.

This work reinforced the importance of building system-wide adaptive resiliency now, before the system is unduly stressed. It began with a proactive discussion about the impact of climate change and variability on the SSRB's water resources, which led naturally to the identification and assessment of potential adaptation strategies. In each basin, specific strategies were identified that could be virtually tested and/or prototyped on the river, as a step towards full implementation. Examples of this include piloting the water bank concept on the Bow River via a short term agreement with TransAlta, and simulating a prolonged drought in the OSSK basins to explore and test governing principles for shortage sharing.

Finally, this work proved the value of taking an outcome-based approach to river management based on system wide perspectives. The broad set of outcome driven performance measures reminded and forced the working groups to consider the wide range of social, economic and environmental consequences of specific actions and strategies. The diversity of working group participants brought system-wide knowledge and interests that would not allow the work to take a narrow view of the river system. Combined, these attributes enabled the groups to find opportunities that would be missed if the rivers were managed for individual interests or for outcomes in individual reaches.

Scientific Achievements

The climate variability methodology developed by the Prairie Adaptation Research Collaborative (PARC) based at the University of Regina is being documented for journal publication. The methodology has also been presented to a number of technical forums through the course of the project, including:

- Sauchyn, D.J. 2013. Evaluating Hydrologic Impacts of Climate Change, Climate Change Technology Conference 2013, Montreal, 27-29 May 2013.
- Sauchyn, D.J. 2013. Come Hell or High Water: Municipal Resilience to a Changing Climate," Alberta Urban Municipalities Association Convention, Calgary, 20 November 2013.
- Sauchyn, D.J. 2013. Historical Climate Variability, Strengthening Economic Security of Irrigated Agriculture in the Oldman Basin, Lethbridge, 06 November 2013.
- Sauchyn, D.J. 2013. Modelling for Climate Variability, AESRD Environmental Modelling Workshop, Edmonton, 14 March 2013.
- Sauchyn, D.J. 2012. Climate variability impact on rural agricultural communities, Alberta Irrigation Projects Association AGM, Calgary, 27 November 2012.

- St. Jacques, J.M., D.J. Sauchyn, D. J. Thomson, A.M.S. Sheer, D.P. Sheer, M. Kelly, M. Van Ham, M.W. Nemeth and E. Barrow. 2013. Developing 21st century hydroclimate scenarios for the Bow River Basin, Alberta, Canada. 26th Pacific Climate Workshop, Pacific Grove, California, Mar. 3-6, 2013 (poster).
- St. Jacques, J.M. 2014. Variability and trends in western Canadian rivers. University of Regina First Nations, Métis and Inuit Research Showcase, March 28, 2014. (Talk was videotaped and will be available on the University of Regina website. It also will be transcribed and be part of an Open Access publication).

The collaborative process and associated tools have also been presented on a number of occasions, some directly related to this project, others related to the preceding Bow River Project in 2010.

- Michael Kelly, Michael Nemeth, A. Michael Sheer, Daniel Sheer "The Bow River Project: Collaboration For Improved Water Management." Water in a World of Seven Billion, May 10, 2012.
- A. Michael S. Sheer, Michael W. Nemeth, Daniel P. Sheer, Megan Van Ham, Michael Kelly, David Hill, Samuel D. Lebherz, "Informing Policy Decisions through Collaborative Modeling in the Bow River Basin." American Geophysical Union Science Policy Conference, April 30, 2012.
- A. Michael Sheer, "Collaborative Modeling and Policy in the Bow River Basin." American Geophysical Union Fall Meeting, December 7, 2011.
- A. Michael S. Sheer, Michael W. Nemeth, Daniel P. Sheer, Megan Van Ham, Michael Kelly, David Hill, Samuel D. Lebherz, "NR-18: Informing Policy Decisions through Collaborative Modeling in the Bow River Basin." American Geophysical Union Science Policy Conference, May 1-2, 2012.
- A. Michael S. Sheer, Michael W. Nemeth, Daniel P. Sheer, Megan Van Ham, Michael Kelly, David Hill, Samuel D. Lebherz, 2013. "Developing a New Operations Plan for the Bow River Basin Using Collaborative Modeling for Decision Support." Journal of the American Water Resources Association (JAWRA) 49(3):654-668.

Conclusions

Water has been the lifeblood of southern Alberta since the region was settled, enabling the establishment of communities and diverse economic development to the benefit of the region and the province as a whole. Water management is not a new concept to many residents of the SSRB. Much has been done to build today's water systems to ensure safe, reliable water supplies for economic, social, and environmental needs. The SSRB Adaptation Project brought together those who know the region's water systems best to look for opportunities to further enhance the resiliency of the Bow and OSSK river basins.

Water management in southern Alberta will become increasingly critical in the face of existing and future pressures – population growth, economic expansion, competition for finite and shared resources and, not least of all, ongoing climate variability and change. The challenge will be to anticipate and respond to these pressures while retaining the features that enhance the region's quality of life and define its character.

The integrated and collegial process applied to this work enabled participants to work collaboratively and creatively, drawing on each other's expertise and insights to explore practical options for adapting to climate variability and change. Fundamental to the outcome was the use of a trusted set of performance measures, data and tools that reflected the transparent input and contributions from participants. Because of this project and the work that preceded it, there is now a much better, and more integrated, understanding of the river systems. This collaborative work has substantially enhanced our knowledge and understanding about:

- How the river systems are actually managed and operated by water managers, as compared with how water is allocated based on licence priority.
- The major issues and concerns that water managers, stakeholders and other interested parties watch for throughout the system (reflected in this work as the key performance measures).
- How streamflow might vary in the future due to climate variability and change, and what impact the changes in streamflow could have throughout the river system (as reflected in the development of climate scenarios).
- How potential adaptation strategies might benefit environmental conditions in the watershed and improve overall river management today, as well as build the resiliency of the basin if the risk of severe or prolonged drought warrants.

Given the collaborative experience of this initiative, it appears that high expectations exist within the water community and the opportunities for improved decision making and outcomes are real. Working together, engaged and committed stakeholders have created strong momentum and a sense of shared future. They identified practical and implementable solutions to improve resilience and adapt to current and future water management challenges.

Next Steps to Implementation

The value of both the collaborative approach and the modelling tool was demonstrated through the vital role they played in informing the flood mitigation decisions following the 2013 flood in the Bow Basin. The initiative described in this report provided the foundation that enabled a rapid and creative response to the flood crisis. Specifically, a specialized group of water experts, many of whom were already familiar with the BROM, was quickly assembled to assess the full range of flood mitigation options for the whole basin. The BROM was updated to become an hourly model for the 2005 and 2013 flood events to support analysis and discussion. This could not have happened if the BROM didn't exist and these people weren't used to working collaboratively. It is expected that the model and working group will continue to play a supporting role as the flood mitigation work continues.

Any action toward improving conditions throughout the Bow River System, whether for flood, drought or normal conditions, has as its starting point, an agreement with TransAlta to modify flow conditions. The various Bow projects were intended to outline criteria for altering those flow rates to improve beneficial use of the existing infrastructure on the Bow River System. The flood of 2013 added a new sense of urgency to the need for such an agreement to implement a coordinated and system-wide approach to watershed management in the Bow Basin. This agreement must consider the entire river system and watershed in order to improve conditions under "normal" conditions, and to avoid catastrophic unintended consequences during times of emergency.

The considerable body of knowledge and insight established through the SSRB Adaptation Project and the preceding BRP confirms that many timely and cost-effective actions could be taken now by parties who are key players in the Bow River Basin to adapt to climate variability and change. Foremost among these are:

- The Preferred Scenario could be prototyped quickly and on a cost recovery-only basis between TransAlta and the GoA, to test the potential of what might be a long-term benefit to the watershed and to water users and managers throughout the basin. The 2013 flood may have created the impetus for testing such an arrangement.

- The Bow River Basin Council (BRBC) can play a leading role in communicating the potential strategies identified for the Bow Basin, to hear from basin residents, and begin to explore those strategies that appear most promising.
- The ESRD policy group can use the project's findings to inform their policy direction and address the Bow challenges raised by Albertans in the recent water conversations hosted by the Government.
- Licence holders can look for opportunities to implement changes within their licence parameters and within the existing regulatory framework.

There are opportunities to build on how the fact that water in the OSSK basins is already being managed efficiently, effectively, and, to some extent, collaboratively. There is no one simple solution for adapting to climate variability in the OSSK basins. Refinement of how specific strategies could be applied in combination while planning and testing for implementation are the next key steps in adaptive, integrated river management. This should include:

- Arrange a one year pilot between ESRD and St. Mary River Irrigation District to test balancing Chin Reservoir with the ESRD reservoirs.
- Develop the full business case for expanding the storage capacity of Chin Reservoir and balancing with the ESRD reservoirs.
- Initiate a multi-year pilot to identify and implement further opportunities for opportunistic environmental flows, building on what is currently being done on functional flows for cottonwood regeneration.
- Run a live modelling simulation with all major licence holders, similar to that done on the Bow, to test procedures, agreements, and tools needed in the event of a prolonged drought, including, for example, operational details, forecast-based triggers for action, legal agreements and governance.
- Assess findings from the ARD Storage Study in combination with this project's findings to confirm opportunities, recommendations and next steps for potential new storage sites.

Although land cover and headwaters protection were not specific parts of the modelling, many participants stressed that sound watershed management includes protective and well considered land management practices throughout the headwaters region. Similar to other regions, building capacity, knowledge transfer and training will be a significant challenge over the next several years as so many senior water managers and regulators reach retirement age. The valuable collaborative interactions among the universities, irrigation districts, ESRD and others should be built into something more durable for longer term water and land management in southern Alberta.

This work has reinforced the fundamental importance of maintaining and building the resiliency of Alberta's river systems and the ecosystems and communities that rely on them in the face of growing demands and variable climate. Expectations are high within the water community and the opportunities for improved decision making and outcomes are real. Alberta continues to benefit from the commitment and involvement of the water community. Now is the time to move from "talk" to "walk" and implement water resource management strategies and solutions that build on what is already being done. This type of collaborative water management opportunity identification, assessment and implementation is fundamental to maintaining and building the resiliency of Alberta's river systems and the communities that rely on them in the face of growing demands and uncertain climate.

In the next several months the Red Deer, Bow, and OSSK river models will be integrated into a single model using the OASIS system. This tool will support discussions around integrated water management across the whole SSRB, not just by basin. It will be useful to consider apportionment implications under various historic and climate variability conditions as well as to integrate land use and land cover changes and consider how they may affect streamflow and water availability across southern Alberta.

As part of the continued work in the SSRB, a land cover and land use model will be applied over the entire SSRB, including the OSSK systems. This may provide additional insights into managing for drought and floods under the ever-changing conditions of weather and climate variability and for longer term extreme climate conditions.

Communications Summary

The project findings and materials have been broadly communicated through a number of channels:

- One on one meetings with over a hundred water experts and interested parties throughout the SSRB; many of these individuals became involved in the project's working groups, while others wished to be kept informed on a periodic basis.
- Many formal presentations to groups including BRBC quarterly forums, Canadian Water Resources Association conferences, meetings of the Alberta Irrigation Project Association directors, Calgary Regional Partnership meetings and council meetings, and Oldman Watershed Council science forums.
- Public distribution of project communications and reports via the WaterPortal (www.albertawaterportal.com).
- Distribution of materials, ideas and word of mouth comments by the more than seventy working group participants.
- Public access to the data sets and models developed by the project via the University of Lethbridge servers and HydroLogics servers.
- Outreach opportunities being pursued to share the final project findings including Carpe Diem, Canadian Water Network, and the Climate Change Community of Practice.

Project Reports

South Saskatchewan River Basin Adaptation to Climate Variability Project: Initial Assessment of the Current State of the Foundational Blocks to Support Adaptation in the SSRB. October 2012.

South Saskatchewan River Basin Adaptation to Climate Variability Project: Bow River Basin Integrated River Management Business Case. January 2013.

South Saskatchewan River Basin Adaptation to Climate Variability Project: Summary of Materials Related to Approach and Recommendations for Altering the Flow of the Bow River in a Pilot Year. January 2013.

South Saskatchewan River Basin Adaptation to Climate Variability Project: Climate Variability and Change in the Bow River Basin. June 2013.

South Saskatchewan River Basin Adaptation to Climate Variability Project: Adaptation Strategies for Current and Future Climates in the Bow Basin. June 2013.

South Saskatchewan River Basin Adaptation to Climate Variability Project: Phase II: Bow Basin Summary Report. July 2013.

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

All project reports are available on the Alberta WaterPortal: www.albertawater.com