4. Implementation and Support for an Adaptation Roadmap

The strategies that form the Adaptation Roadmap for sustainable water management in the SSRB were identified through a series of collaborative projects. Now the discussion must turn to advancing and implementing these strategies. This section of the report shares what has been collected so far from the various working groups in terms of implementation planning.

A consistent theme running through the discussion over the last six years has been the importance of advancing and implementing strategies now, in a proactive informed manner and in anticipation of future challenges rather than waiting for a crisis to drive a quick and reactionary response. A second repeating theme has been the need for flexibility in implementation. A number of the adaptive strategies outlined in the Roadmap apply to either flood or drought situations; these strategies will need to be implemented flexibly. For example, raising the winter carryover in existing irrigation-serving reservoirs, as seen in Level 1, would maintain higher winter water levels in irrigation reservoirs to allow higher potential to serve water demands during dry periods. This strategy is adapted for dry years and may not be necessary during wet, high snowpack years; indeed, in wet years this strategy would increase flood risk if high spring flows occurred. It was also reinforced that implementing some strategies can influence other strategies and the dynamics between them should be considered when deciding on implementation priorities.

Strategies presented for implementation in this plan generally appear in priority order; that is, within each Level, those regarded as the “most promising” appear higher on the list. Other strategies that were viewed as offering some benefits are subsequently listed. All strategies were presented in section 3.2 of this report. Those marked with an asterisk (*) are not currently modelled in the SSROM. For each strategy, in a bold italicized font, there is a discussion of benefits, barriers, actions needed for implementation, who should be involved and, where possible, potential timelines.

4.1 Level 1 Implementation

Level 1 strategies focus on using existing infrastructure without the need to build anything new. Ideally, several components of the Level 1 strategies would be implemented before the next water year begins—that is, by April 2016. Flexibility and the opportunity to make revisions as implementation proceeds will be crucial to success. Time is of the essence as another flood can occur during any given spring, or an ongoing drought can begin at any time and may already have started in 2015. Perhaps the key objective of the collaborative work by water managers and stakeholders on this and the many other projects on which this report is based is to provide some assurance to government that these strategies are practical, effective, and capable of step-by-step implementation in accordance with the informed guidance provided. The stakeholder groups engaged in these reports are interested and available to provide additional detailed information wherever needed.

Institute a long-term, flexible and comprehensive water management agreement for drought mitigation, flood mitigation, and watershed health with TransAlta, including: water bank for river basin management purposes, flexibly stabilizing Lower Kananaskis Lake and Kananaskis River, flood mitigation using Ghost Reservoir and other reservoirs, functional flow releases as needed for riparian and fisheries health, and adjusted fill times for Minnewanka, Spray, and Upper Kananaskis Lakes

Potential benefits:
Many of the benefits accruing from changing the operations of some portion of the TransAlta reservoirs upstream of Calgary were documented in the Bow River Project Final Report (Alberta WaterSMART, 2010). Other benefits have been identified and documented since that time in projects simulating real-time management under drought conditions, simulating climate change water supply scenarios, stress testing with 86 years of historic data using current and forecast water demands, modelling the 2013 and 2005 floods to assess mitigation options, applying Room for the River concepts for local and regional flood mitigation, and the current study integrating operations in the Red Deer, Bow, Oldman, and South Saskatchewan sub-basins.

Initially identified benefits were associated with the recommendation for an agreement for a water bank that reserves approximately 10% of the annual storage and flows within the TransAlta reservoirs for release in accordance with downstream needs, including improving environmental flows during low flow periods while minimizing shortages to junior and senior licence holders. These benefits included: greater assurance of flow minimums to support fisheries and aquatic and riparian ecosystems, adequate flow through Calgary to accommodate tertiary treated wastewater and raw water demand for forecast population growth, and generally improved environmental conditions from Bearspaw to downstream of Bassano to the confluence with the Oldman River. Added to the water bank proposal was stabilizing Lower Kananaskis Lake and adding functional flows to the Lower Kananaskis River to improve fisheries, environmental conditions, and recreational opportunities at relatively low cost.

Additional modelling confirmed that today's water management infrastructure could mitigate drought conditions to a significant extent for the first dry year. But even with some conscious decisions to carry over higher winter water storage, the second year of a drought brought serious shortages to licence holders and the possibility of reservoirs running dry, which did occur in the third year of a serious but not unrealistic drought. However, operating the reservoirs primarily for water supply rather than power demand-driven releases improved conditions and reduced shortages up to the point at which reservoirs were nearly empty.

Collaborative modelling of flood mitigation based on altering operations of the upstream reservoirs showed meaningful potential for reducing flood magnitudes downstream. However, a flood similar to the 2013 event still resulted in considerable flooding, although not as much as would otherwise be the case. For smaller floods, the reservoirs were able to substantially reduce or prevent downstream flooding. Project participants concluded that the reservoirs were not built for, nor are they capable of, eliminating all risk and damages from extreme events. Recent experience using only the Ghost Reservoir for potential flood mitigation during late spring and early summer has not proved entirely satisfactory. The voluntary lowering of Ghost in 2014 and the commercial agreement of 2015 between the GoA and TransAlta has been criticized for not being flexibly implemented to accommodate some summer village residents and water recreationists. Lowering only Ghost without including the operations of the other reservoirs in the agreement may have required a greater reduction of water levels in Ghost than would otherwise be necessary, with less flexibility in raising and lowering the water levels in Ghost. Adjustments to the bottom structure in the upstream portion of Ghost have been completed to prevent fish stranding in future low reservoir levels in the spring.

Additional apparent problems were identified with an increased risk of slumping along the non-concrete portions of the Ghost Dam structures. This has led risk managers at TransAlta to limit the rate of reduction in Ghost water levels to only 0.3 m (one foot) per day. This is much less than what was originally considered (potentially several metres per day), limited only by the initiation of flood level flows downstream. A reduction of only 0.3 m per day in the water level requires the reservoir to be held at a lower level for a longer period of time than would be the case if more rapid drawdowns were allowed. Technical "fixes" could be applied to the at-risk portions of the dams and dikes which could provide additional flexibility in operations. The operations could then be run according to more sophisticated reporting and forecasting of conditions, as described below. Regardless of the technical outcome, other upstream reservoirs need to be involved in annual flood mitigation actions and drought risk management, whether flood protection is needed in any given year or not, because they are all interrelated.

For normal conditions of water supply, extreme or prolonged drought, or moderate to extreme floods, TransAlta reservoirs can provide some highly valuable mitigation and improvements to what would otherwise be the case.

Implementing functional flows is part of this strategy and the aspects of implementation are described under the strategy "Adjust Dickson Dam operations."

Barriers to implementing this strategy:

- Clarifying and agreeing on the flexible, risk management decision-making criteria needed to determine reservoir levels and flow rates throughout the system to mitigate flood or drought, or improve environmental conditions while enabling licence users access to their allocations.
- Determining how to mitigate extreme floods while managing overall water supply and storage to meet needs of other users and maintain watershed health.
- Clarifying the governance and decision making related to reservoir management; e.g., who makes the final decision about whether to "fill or spill"[21] and where to do so?
- The lack of availability of solid and timely forecasting data, modelling tools, and shared information is a barrier to effective deal negotiation and operational decision making. Multi-factor assessments are needed that include multiple data sources; e.g., soil moisture content, snowpack, air temperature, precipitation, fish spawning periods, and other environmental conditions such as streamflow rates, phosphorous loading and dissolved oxygen.
- Meeting TransAlta's need to address cost, maintenance and liability issues related to dam safety, downstream flow rate, flood concerns related to infrastructure, potential loss of revenue and compensation from additional spillway use, timing of releases, ancillary services, and permitting requirements.
- Implementing a flexible and relatively stable level for Lower Kananaskis Lake and functional flows in the Kananaskis River below Pocaterra power plant may need to be part of a "best efforts" clause in the original agreement. More study on spillway capacity may be needed to fully stabilize the lake, but some operational improvements to improve fisheries and recreation should be expected during the study period.

[21] "Spill" or "spillage" refers to water directed down spillways rather than through turbines due to rapid lowering of reservoir levels.

- Once overall costs are known, determining the economic and environmental factors and who benefits from these strategies would be valuable to government decisions. Water management is a flexible and adaptive decision process based on numerous inputs and conditions. The environmental benefits, municipal and commercial flood protection, access to licensed water, and irrigation water supply can vary greatly within a year and across years, making it difficult to ascertain the "typical" or "average" value of benefits. What is clear, is that these valuable benefits will occur to a greater extent with a conscious and deliberate effort to achieve them in balance with the current, single purpose operations.

Action needed:

- Allocate more resources to develop reliable short-term forecasting to reduce unnecessary use of spillways rather than electricity generation spillage in anticipation of flood risk. Improved multi-factor forecasting enables a pre-release strategy to be implemented three or more days before an expected event rather than keeping reservoir levels low during the entire flood season, as was done in 2014 and 2015. Improvements in long-term (beyond 72 hours) forecasting capability and technology are also needed. These functions should draw on information from many new monitoring and data sources and be properly staffed, and the information should be integrated, assessed, and communicated in a timely manner.
- Ensure the provincial river forecasting group has adequate staff and communications capacity. Snowpack, soil moisture levels, reservoir levels, air temperature, and precipitation weather forecasts, both short and long term from local, provincial, federal, and US National Weather Service and other international information can be used to better manage flood and water supply dynamics while balancing risks.
- Establish a flexible, easily amended, and improved long-term commercial and operational water management agreement between the GoA and TransAlta on the Bow River as soon as reasonably possible and, at least in part, before the next water year (April 2016). This is essential so it can be tested, learned from, and gaps identified, remedied and improved under "normal" conditions rather than waiting until the next emergency, be it flood, drought or environmental degradation.
- Engage large water licence allocation holders, including municipal, irrigation, commercial, and recreational interests and other key water users in a structured collaborative manner prior to final approval of the GoA–TransAlta agreement. This will ensure rapid and smooth implementation by reducing the risk and numbers of concerns raised, appeals filed, and legal and political proceedings that could tie up this important new water management arrangement for years, leaving homeowners, municipal water supply, infrastructure, irrigation, and the environment at continuing risk from flood and drought.
- Create an interim governance process or structure to enable key licence holders and water interests to participate in water management decisions under the new agreement, supporting a final single-window decision maker directing and taking full accountability for reservoir operations.

Who should be involved:

- TransAlta
- GoA (with input from relevant departments)

- Bow River Basin Council (enabling some form of participation by the City of Calgary, Town of Canmore and other affected municipalities, irrigation districts, Ghost recreation users, Calgary River Community Action Group, and the Stoney and Siksika First Nations)

GoA and TransAlta have been engaged in on-again, off-again negotiations about water management on the Bow River for over five years. What is needed is a firm commitment by the GoA to get a deal done, and a clear mandate given to those at the negotiating table.

Timeframe:
This commercial and operational arrangement between TransAlta and GoA should be completed, at least in part, early in 2016 to provide sufficient time for reviews and approvals by potentially affected licence holders (in accordance with the *Water Act*) and with the intent to be in force for the 2016 water year beginning in April.

Raise winter carryover in existing irrigation-serving reservoirs; start with Travers which draws water from the Bow, then investigate feasibility for the St. Mary, McGregor and other reservoirs

Potential benefits:
The benefits from increasing the reservoir levels over winter are several, depending on various factors. First, these reservoirs can be drawn upon by irrigation districts in the early spring as needed, reducing the need to draw water from their respective rivers during early spring periods of low flow, thus improving environmental conditions in the rivers. Second, higher levels of winter carryover water provide an additional insurance policy against low snowpack and potential drought the following year. Third, filling up to near the FSL of the reservoirs in the fall is often an opportune time to do so since the irrigation season is over and little water is needed for other purposes.

Barriers to implementation:
Only a few barriers to increasing winter carryover in Travers and McGregor reservoirs are known.

- Consideration should be given to shoreline erosion and potential erosion buffers in some locations where local recreational residences and cottages have located, despite impinging on the primary irrigation purposes of the reservoir. Flexibility would be required in implementing this change so the operators can manage the reservoir fill and releases to minimize any negative impact on the downstream flow and the dependent aquatic resources.
- As with all reservoir operations in southern Alberta, there are risks of flood and drought in any given year, and how reservoirs are operated can affect the agricultural economy, ecosystems, and other water users and residents during these naturally occurring weather conditions.
- St. Mary Reservoir would require additional study to determine impacts on fish and aquatic habitat from higher winter carryover.
- Flood mitigation capacity trade-offs between the St. Mary and Oldman systems may be questioned. There is a social expectation for flood mitigation that depends on levels well below FSL in the reservoirs.

Action needed:

- Increase winter carryover for Travers Reservoir on a pilot basis beginning in 2016.
- Undertake additional engineering study for Travers and McGregor reservoirs to review dam safety and understand impacts on the shoreline, erosion, landowners, and aquatic ecosystems.
- Do additional modelling for the other reservoirs in the St. Mary and Oldman systems on the possible trade-offs between flood retention capacity, drought risk reduction and environmental improvements.
- Undertake studies on dam safety, shoreline impacts and aquatic ecosystem impacts for St. Mary and McGregor reservoirs as needed.

Decisions would need to be informed by improved and integrated forecasting. Flexibility in implementation is essential for success and must rely on a basin-wide, informed, information-sharing approach to daily decision making.

Who should be involved:

- Owners, beneficiaries, and regulators of the reservoirs, including the relevant irrigation districts, AEP, and AAF
- Local municipalities
- Adjacent affected landowners

Timeframe:
This strategy could be implemented quickly for Travers Reservoir and likely within five years for the others.

Implement further forecast-based shortage sharing (including agreed upon temporary reductions in diversions and voluntary assignments of remaining licence allocations in times of drought), within and between irrigation districts

Potential benefits:
Informal water licence sharing and formal short-term agreements to either share licensed water or assign licensed water from one licence to another have been fairly common in times of drought or periods when someone reduces crop plantings for a year for one reason or another. During a dry period when demand exceeds water availability, irrigation districts may issue water restrictions which affect individual farmers differently depending on their particular crop mix, timing of their planting, the water needs of the particular varietal planted, and other factors. This can quickly lead to informal trading of water rights and water use from those with higher value to those with lower value, or to greater need from less.

Often this occurs between neighbours or relatives to optimize net return or crop production, shifting a limited water supply to more productive lands or higher value crops. This practice is enabled under the *Water Act* in the form of Assignments which do not require AEP approval, although notification is desirable, and reporting after the fact is required though often not enforced. Temporary licence transfers can be used for water sharing for longer than one growing season and require AEP approval.

It must be recognized that forecast-based rationing or reallocation for emergency use, which is already done informally within many irrigation districts, is not a strategy to be used all the time because it fundamentally shifts the risk profile for farmers. Further, it does not remove the need for increased storage in certain areas.

It may be prudent to determine in general terms the policy and procedures needed to enable greater use of shortage-sharing agreements in the event of a severe or prolonged drought or other conditions, making such agreements beneficial to water users while protecting the stream ecology. Waiting until a drought or other emergency arises to develop a plan, policy and procedures is often too late to most effectively manage people, resources, and outcomes. The concept of "black swan events"[22] should only apply to truly unforeseen circumstances, and not to events that have been shown to be not only commonly foreseen, but practically inevitable.

Barriers to implementation:

- Accurate meteorological forecasts, including snow pack, reservoir levels, soil moisture, and other information, available for use by all irrigation districts to inform water restrictions and the promotion of water assignments.
- Defining what "sharing" means and developing a fair and equitable way for everyone to share "the pain."
- Obtaining a commitment from users to share the shortages under certain pre-described and agreed upon situations.

Action needed:

- Provide support to irrigation districts to develop or access the forecasting data and tools needed to anticipate shortage-sharing needs.
- Provide a simple platform to transact and document water assignments and transfers within and between districts.

Who should be involved:

- AAF
- Irrigation districts

Timeframe:
Beginning in the 2016 water year, with two years to complete.

*Develop basin-wide shortage-sharing and reallocation frameworks to inform and enable severe drought mitigation**

Once rivers and streams run dry it is very difficult to recover any resemblance of the rich and diverse ecosystems they originally supported. At the same time, it is in everyone's interest to maintain and retain the economic base in southern Alberta, much of which relies directly and indirectly on the successful operation of the irrigated agriculture economy.

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[22] The theory of black swan events is a metaphor describing an event that comes as a surprise, has a major effect, and is often inappropriately rationalized after the fact with the benefit of hindsight. The theory was developed by Nassim Nicholas Taleb. Source: https://en.wikipedia.org/wiki/Black_swan_theory.

Making arrangements under the duress of an extreme drought period to voluntarily redistribute water allocations to derive maximum benefit from senior licences may result in suboptimal outcomes for our publicly owned water resource. Simply put, severe drought response plans should be prepared proactively, not in time of crisis. Redistribution to the most economically valuable uses for water during severe drought conditions seems logical since, once water conservation programs are applied, municipalities and industrial uses (including agricultural processing) likely have higher value than at least some forms of agriculture. The *Water Act* enables short-term and temporary reallocations for just such circumstances. However, as shown by the Australian experience, rational economics-based reallocations may not protect minimum flows to retain the ecological support system of a river. This may be a societal choice to maintain jobs and the economic support base of the population in a region, but such a trade-off should be based on some prior consideration.

Recognizing that drought is a recurring condition throughout the SSRB, it is prudent to plan for the next occurrence of this social, environmental, and economic threat. The extensive irrigation infrastructure built in the last century in the Bow, Oldman and Southern Tributary systems was intended to improve productivity and reduce risks to agriculture from drought and it has served the region well. But experience from the 2000–2001 drought shows that reservoir storage and infrastructure were not enough to ensure adequate water supply to all users and uses. A voluntary agreement among the senior licence holders to share water allocations was reached for the 2001 water year and proved successful in getting through that dry year. However, many participants have suggested that the agreement would not have held for another year of drought, and that water allocation in a future drought should not rely on the same voluntary sharing as seen in the past.

The benefits of reaching some level of agreement now on how water allocations might be shared or redistributed during the next drought could be substantial. Only regional and local water users and managers have a good understanding of where the various higher value water uses reside and these uses change from year to year. As agreed to in writing by all irrigation districts,[23] water for humans and livestock is a first priority in any serious shortage. But what of all the other uses, and how to determine which part of a municipal licence goes to human use versus the many other water uses contained in that licence? Some agreement on first principles and a documented plan for when and how licensees might collaboratively work towards minimizing damages from a prolonged or severe drought would be easier and more thoughtful, fair and equitable than simply waiting for the crisis to occur and then scrambling for some portion of the remaining water.

The alternative to reaching agreement by the licence holders is for the provincial government to implement its emergency authority to take over allocations and distribute water as and when it sees fit. Four questions arise for the licence holders and residents of the basin:

- Does the provincial government have the information readily available to allocate optimally and objectively to those most in need or to those with the highest value use for the remaining water?
- Once the drought is over would the costs to licence holders from the centrally controlled reallocation of their licensed water be repaid and how would costs and compensation levels be determined?

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[23] *Human Use of Water and Livestock Sustenance Declaration*. This declaration was adopted by the Alberta Irrigation Projects Association at its annual general meeting on December 6, 2010.

- Once the allocations are held by the provincial government for emergency purposes, would there be a reluctance to go back to the old system of seniority allocations, given that the emergency showed that it was unworkable under stress?
- And finally, what criteria would provincial government administrators apply to choose between minimum environmental flows versus agricultural, industrial and municipal water users under the most extreme drought conditions?

Thus, the Best Alternative To a Negotiated Agreement (BATNA)[24] among licensed water allocation holders is to entrust the complex water management system and their access to limited supplies of water to an unknown plan. A negotiated agreement completed prior to any crisis, that covers at least the principles, trigger mechanisms, general priorities, criteria to adjust environmental flows, and use of transfers, temporary transfers, and assignments may be worth considering.

A component of this strategy is to develop a framework for water sharing via reallocations, but not at the level of specific individual transfers, as these would change from year to year and even month to month. The proposed framework would include the requirement for a Water Shortage Response Plan (WSRP)[25] by existing junior licence holders and those with critical water needs year round above a certain size cut-off, such as residential developments, municipalities, industrial facilities, livestock operations and so forth. The purpose of WSRPs is to ensure:

1. *The applicant or licence holder develops full appreciation of the involved risk to the intended purpose of water use.*
2. *All possible opportunities (to cope with water shortage) are considered and analyzed in advance.*
3. *The proposed activity [in the licence] is sustainable during water shortage periods* (ESRD, 2014, p.1).

Widening the requirement for WSRPs from newly issued licences to all licensees in the Bow and Oldman watersheds will encourage and create the means to cope with water shortage risk. Requiring prearrangements for dealing with the risk of severe drought or shortages caused by other factors places initial responsibility for reducing shortage risk where it should fall—upon each licence holder in the basin. Requiring WSRPs is consistent with the Alberta Water Council's 2009 report, *Recommendations for Improving Alberta's Water Allocation Transfer System*, and with the recommendations from an advisory group to the Minister in 2009.[26]

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[24] The well-known acronym BATNA, is from the book *Getting to Yes: Negotiating Agreement without Giving In*, by Roger Fisher and William L. Ury, originally published in 1981.

[25] See *Preparing Water Shortage Response Plans*, 2014, by Alberta Environment and Sustainable Development, online at http://aep.alberta.ca/forms-maps-services/directives/documents/PreparingWaterShortageResponse-Apr23-2014A.pdf. See also *AENV Water Shortage Procedures for the South Saskatchewan River B*asin, revised April 2009, online at http://aep.alberta.ca/water/programs-and-services/south-saskatchewan-river-basin-water-information/documents/WaterShortageProcedures-SSRB-Apr2009.pdf

[26] Minister's Advisory Group, August 2009. *Recommendations for Improving Alberta's Water Management and Allocation,* online at http://esrd.alberta.ca/water/water-conversation/documents/RecommendationsWaterManagement-2009.pdf

The discussion of these measures was based on the most extreme drought conditions, not ordinary, regularly-experienced low flow conditions. The first steps would be for WSRPs to be implemented, none of which should affect established minimum flows and would be based largely on economic considerations among licence holders. These could include moving cattle herds or reducing demands for lower value purposes. However, as a last resort it was suggested and modelled that if a framework were in place that had negotiated criteria and an agreed-upon absolute minimum for adjusting environmental flows, or if there were at least a mechanism for such adjustments under extreme drought conditions, then considerable water may be saved. Without adjusting minimum flows to cope with extreme drought, no trade-offs may have been considered to protect social interests such as human use and jobs versus normal operations of existing standards for minimum flow rates. In other words, streams may run dry because the minimum environmental flow is maintained until the reservoirs are emptied rather than flow rates being reduced to the lowest possible flow to ensure at least some environmental water remains flowing in the river. Quickly moving to water trading and reallocation can save a lot of water for human, livestock, and job retention purposes. How much water can be saved for later environmental flows and other purposes would be a matter for future modelling and scenario testing, but it is reasonable to expect substantial water savings.

Barriers to implementation:

- Getting major water users to develop and agree upon the general principles to be followed in an emergency drought plan, and then commit to and follow the principles under extreme stress conditions.
- Ensuring a higher level of accurate and reliable forecasts on which to base the reductions and assignments.
- Gaining agreement on a process to better understand and adjust minimum flows under extreme conditions before it’s too late for the river ecology.
- Enforcing adherence to the agreed-upon temporary reductions and flexible use of assignments.
- Insurance and other considerations may be a barrier if they do not reflect the reality of how commercial arrangements for sharing might occur.
- There is no requirement for junior licensees or those with critical needs to develop a WSRP to deal with drought conditions.

Action needed:

- Access or create a background document summarizing the current situation with regard to shortage sharing, its history and practicality going forward.
- Collaboratively develop a principled and flexible framework for dealing with drought risk.
- Secure access to a tested and reliable water balance model to quickly and inexpensively demonstrate the effects of various options and plans to reallocate among licensed water users and uses.
- Develop a draft policy and planning framework to mitigate severe shortages.
- Provide adequate public engagement to review and advise on the draft policy.
- Implement a final version of a shortage-sharing framework and the conditions under which it may be triggered.
- As part of the long-term drought response plan, each licence holder above a certain size or with critical needs (human, livestock, industrial processes) must develop a formal WSRP and file it with AEP.

Who should be involved:

- Individual irrigators
- Irrigation districts
- Municipalities
- Water managers
- AEP
- Other licence holders as appropriate

Timeframe:
Because there is a drought precedent, this strategy could be undertaken in less than one year with expected completion of the framework by the water year 2017, to begin in April of that year, with filing of the WSRPs by the following water year.

*Restrict new greenfield development in the floodplains to reduce flood damage and develop strict regulations against changing the nature of brownfield developments**

Potential benefits:
Virtually all participants agreed that there may be a need for further buyouts in select locations in a fair, cost-effective and permanent manner to reduce damages from the next flood. There was more debate about additional development in floodplains and the issue seems to be around the definition of new development. Some interpreted the strategy as potentially preventing residences currently in the floodplain that are not part of the buyout plan from adding a garage or making other improvements to their property. Others viewed the intent as preventing new greenfield residential, commercial or other inappropriate developments in the floodplains.

Some new development may be acceptable in floodplains on the condition that no protection or compensation for flooding of the development would ever be forthcoming, or the development could be built in a “flood-proofed” condition. Such uses could include temporary fishing or kayaking camps with assured access in and out of the floodplain or park settings, hiking trails, and other similar uses that may be damaged or destroyed by flooding, but no lives would be put at risk. Whether to rebuild would be at the cost of the developer or owner.

If no development would be allowed, significant compensation may be required for the “rule change” as many near-river areas have been purchased by investors and are slated for development that is possible under the current rules. The same applies for regulation changes in brownfield areas.

Clearly defined restrictions are needed on changing the nature of existing development on floodplains. This is to prevent expensive new infrastructure from being built on floodplain sites with existing but different types of developments, or infrastructure that adds flood risk to taxpayers beyond what is already on the same site. An example of an unpermitted development might be building a multi-family residence on a site within the floodplain that already contains a single family residence.

Barriers to implementation:

- Lack of specific and clear definitions of what is meant by new development, greenfield development versus brownfield, and what is allowed.
- Lack of clearly denoted boundaries for the floodplain based on data agreed upon by all levels of government.
- Socio-economic cost.
- Past apparent preference to institute floodplain development guidelines instead of regulations.
- Poor optics and lack of public support from property owners and construction and development industries.
- Need to financially compensate landowners and investors with greenfield property that has established plans or permitting underway for development for their potential economic losses.

Action needed:

- Develop clarity of meaning and specific definitions to place into regulation of what is allowed and not allowed. This is essential for municipalities to have the backing to consistently enforce this strategy.
- Assess the financial implications of implementing this strategy, and decide who should bear this cost (the developer or landowner, municipality, provincial government or federal government).
- Form a small team of knowledgeable representatives from relevant provincial departments, city planners, and landowners and/or developers to draft definitions, review internally, create a communications plan, put out for comment, revise as needed and put into regulations governing land allocation decisions.

Who should be involved:

- Appropriate provincial government departments (e.g., Municipal Affairs, Infrastructure and Transportation, AEP)
- Municipalities with flood risk such as Calgary, Edmonton, Canmore, Drumheller, Fort McMurray, Peace River (and possibly others through the Alberta Urban Municipalities Association (AUMA) and the Alberta Association of Municipal Districts & Counties, or AAMDC)
- Landowners and developers as appropriate

Timeframe:

This strategy is complex and requires the engagement of many key stakeholders, which should be initiated in the near future. Draft regulations could be prepared over the coming year with municipal consultations providing the basis for a collaborative approach. A variety of studies may be needed to assess various potential outcomes from alternative actions suggested, with a public comment period and legislative debate, likely taking up to five years to complete.

OTHER LEVEL 1 STRATEGIES

Increase St. Mary Reservoir operating FSL by 1 metre

Potential benefits:
Based on the surface area elevation curve in the current model, increasing the St. Mary Reservoir FSL by 1 metre adds approximately 57,000 dam^3 of additional storage to the Oldman sub-basin. This reservoir provides irrigation water and municipal water to a large area of southern Alberta and the additional security of supply could bring significant benefits in the event of a drought or a particularly dry period over one or more years.

Barriers to implementation:
- Concerns related to flooding and dam safety.
- Concerns related to erosion, aquatic health and landowner impacts.
- Limited study of the value of the potential benefits from the additional water in reducing agricultural risk, improving crop type, value, and productivity.

Action needed:
- Conduct dam safety review with various FSL increases up to 1 metre.
- Conduct shoreline impact evaluation.
- Engage local landowners on potential raise, benefits, issues and mitigation.
- Conduct digital elevation model to determine how much additional water would be contained in various increases up to 1 metre.
- Do additional water balance modelling under historic conditions to assess water allocation benefits.
- Adjust reservoir water licence to accommodate change in storage capacity and increased evaporation loss.

Who should be involved:
- Affected GoA departments, including AEP and AAF
- St. Mary River, Taber, Raymond and Magrath irrigation districts
- Local residents
- Other potential beneficiaries or negatively affected parties downstream

Timeframe:
Most additional studies can be done relatively quickly, although consultations with affected parties would require a few months. Permitting should be straightforward as it would be an expansion of the current facility and operated by government. The timeframe for implementation is 6-12 months and longer in cases where new licences are required.

*Effectively implement Alberta's Wetland Policy**

Potential benefits:
Effective implementation of Alberta's Wetland Policy would incorporate strategies designed to protect existing wetlands in areas that experienced high historical wetland loss and to restore wetlands where such restoration can provide the most environmental, social and economic value. Wetlands help

reduce flooding and soil erosion by storing runoff and slowing its downstream release. Wetlands are also recognized as ecologically important habitat areas for dozens of important birds as well as terrestrial and aquatic animals. The Alberta Wetland Policy has been approved and is in effect, but some participants were not optimistic about it being fully implemented and employed to restore or increase wetland acreage and functionality in the SSRB. Part of the concerns related to regulatory conditions against longer distance mitigation offsets that prevent wetland restoration in the areas with the most wetland losses and most in need of enhanced wetland functions—that is, the SSRB.

Other concerns related to wetland reduction due to improving irrigation efficiency by reducing evaporative losses, seepage losses, and inefficient flow rates by converting canals to pipelines. These conservation efforts may result in lost wetland areas even though these areas were artificially created in the first place. Clearly defining how such wetland losses are treated under the new policy was raised as a concern for irrigation districts and others with wetlands of an artificial or temporary nature.

Barriers to implementation:

- Overlap and potential lack of alignment of goals and objectives in relevant strategies, policies and frameworks; e.g., the Wetland Policy, Land-use Framework, *Water for Life* strategy, Climate Change plan, and flood mitigation initiatives all need to be aligned and communicated effectively to municipalities and others in a way that will enable them to advance these goals at the local watershed scale.
- Offset restrictions against restoring wetlands at some distance from where the wetland is disturbed or destroyed, even though the provincial priority area for wetland restoration is the SSRB, while many areas have abundant wetlands already.
- Clarity around converting irrigation canals to buried pipelines if artificially created wetlands along the canals have to be offset.

Action needed:

- Clarify wetland policy application to irrigation canals.
- Seek creative ways (e.g., through regional and provincial plans) to enable wetlands offsets to be restored, improved, and developed in the SSRB where 50–70% of wetlands have reportedly been lost.

Who should be involved:

- Ducks Unlimited Canada
- Impacted Municipalities
- Alberta Irrigation Projects Association and selected representatives from irrigation districts
- AEP, AAF, and the Alberta Energy Regulator
- Other agencies as needed (e.g., Alberta Departments of Transportation and Infrastructure)

Timeframe:

It should be relatively simple to provide information on how the Alberta Wetland Policy will be implemented, shared with the above groups, and clarified and agreed upon by the participants. The process and policy clarification can be completed by summer 2016 for budgeting and implementation in the 2017 construction season.

*Improve resourcing for and effectiveness of forecasting infrastructure, systems and teams**

Effectively planning for and managing responses to droughts and floods depends on good forecasts and communications. Improved forecasting underpins the success of many of the other strategies discussed in this report. Managing for floods, including releasing water in advance of a possible flood, needs to be carefully monitored and balanced with environmental flow management and with managing for drought. Reservoirs can serve multiple purposes but only with a sound basis for forecasting inflows as well as outflows, current reservoir levels, downstream demands, short- and medium-term ensemble precipitation forecasts, and several other factors described below. All of the collaborative sub-basin projects and the previous flood and climate change projects reinforced the need for the best possible streamflow and snowpack data, soil moisture content, temperature and meteorological forecasts to inform operational decisions. For all farmers, but especially for irrigators whose operations significantly affect water management, water supply information and forecasts are needed well before the start of the season to make decisions about crop types, seeding and other investment choices.

The existing system for forecasting weather, snowpack, river flow, dam releases, and flood hazards is complex and relies on skilled, dedicated and hard-working people in several provincial and federal agencies. Their work goes largely unnoticed until there is an emergency at which point they quickly become central figures in our efforts to understand what is occurring where and why, and what alerts and emergency functions should be contacted and brought into play. This often occurs precisely when monitoring stations are flooded or destroyed by debris, communications are disrupted, and locally-affected residents are seeking information from limited staff resources with many critical responsibilities to fulfill. The current system has served us well for many decades, but recent droughts and floods combined with large increases in populations at risk, greater demand for water use, and realistic concerns about climate change and extreme events have created an urgent need for allocation of more resources to this often neglected area. The monitoring stations and the data they collect over the long term are critical inputs to the ongoing forecasting and modelling work. The provincial and federal governments need to make a commitment to maintain, and significantly expand, these monitoring networks over the long term.

The good news is that a wide array of useful data sources exists. The problem is that many of these data sources are dispersed in their collection, used by separate agencies and organizations for single purposes, and are not integrated and applied in any organized or comprehensive manner. Thus there is an opportunity to fully integrate these various data series into a watershed-by-watershed management system. Scenarios, implications, probabilities, and possible management responses can then be empirically and rationally evaluated based on many factors applied together. The time to develop a more sophisticated and useful operations support system is now, before these long-time experts retire and move away.

Simply put, the elements of a world-class forecasting and management system are largely in place, but the number of climate gauges, the resources, and a plan to pull it all together are lacking. This is understandable as the perceived need for more comprehensive forecasting and management was not seen as urgent until the recent flood and follow-up studies illustrated how valuable forecasting will be in meeting future drought or flood challenges. Post-flood conferences and research have also shown the relative lack of resourcing available for integrating forecasting and operations compared to other jurisdictions such as Colorado.

Although the forecasting portion of this strategy applies equally to each sub-basin, there are notable differences. Given these differences, and the importance of this perspective of combining forecasting and total operations to mitigate flood and drought risk to Calgary, an initial focus should be on the Bow system, including all private and publicly owned and operated reservoirs. Benefits to the entire SSRB and all of Alberta will be achieved by implementing the forecasting portion of this strategy and the information system structure. However, the specific application of improved and integrated forecasting to reservoir operations would initially apply primarily to Calgary and other communities and licensees on the mainstem of the Bow all the way to Medicine Hat.

Perhaps the key thing to remember about risk management related to water is that it is continuously variable and thus requires real-time monitoring and reporting on an array of essential factors. Near real-time monitoring is important for other factors that may begin to play a critical role when conditions are most risky. Fortunately a template exists that describes the components of data and the technology needed to provide a best-in-class management system for the Bow River system. It is the New York City Operations Support Tool, illustrated in Figure 44.

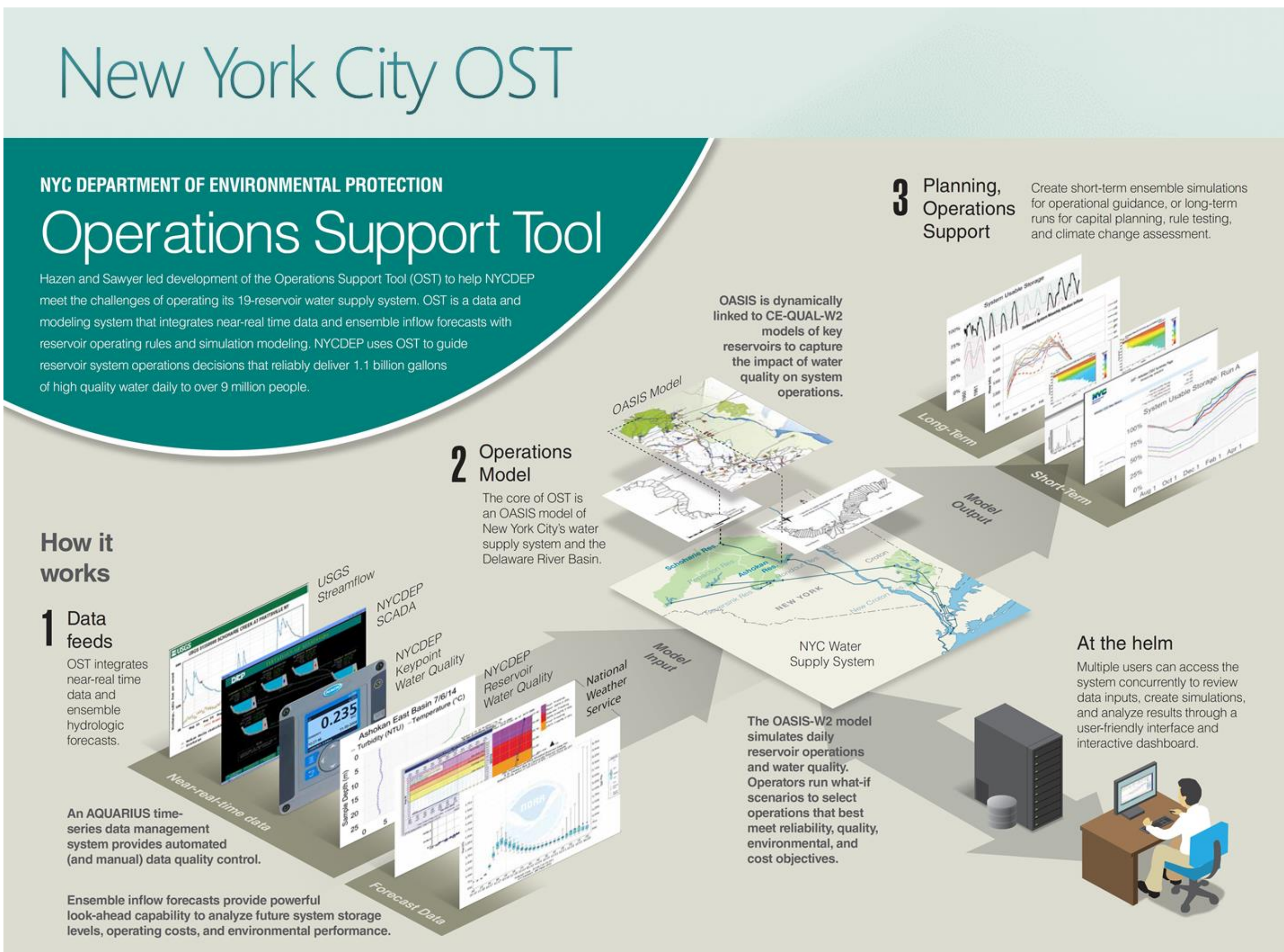

Figure 44: Example of a tool to support real-time water management operations

Source: Hazen and Sawyer, via HydroLogics Inc.

Given the extreme variability of our weather patterns and climate, the close proximity of large population centres to the water towers of the Rocky Mountains, and southern Alberta's irrigation-based economy, it is only prudent for our provincial, regional, and local leaders and water managers to be prepared for conditions known to have appeared in our short history of settlement in this region. As important, climate research has shown more dramatic risks in the prehistory of this region and the potential extremes that may arise from a changing climate.

Like the Room for the River concept, some adaptation of the template to fit the Alberta situation will be needed, but the basic structure of the technology is solid and applicable. Similarities are that the New York City system manages 11 upstream reservoirs used for multiple purposes prior to managing the drinking water supply and flow rates through the city. These reservoirs were originally constructed for different purposes and were only recently operated in an integrated fashion with the priority on water supply management, while still accommodating their original purposes. One major difference is that the flood and drought risk and threat to southern Alberta and Calgary in particular is much greater than for New York City. Thus there is an urgent need to build this relatively inexpensive component of the resilience and mitigation strategy on the Bow system.

Potential benefits:

- Electronic assemblage of many types of data from many and diverse sources (SCADA) into a useful ensemble of meteorological forecasts, river flow prediction and ready-to-use management tool for decision makers.
- Improved ability to adjust and adapt to changing weather and demand conditions, daily or hourly as required.
- Reduced risk of overcompensation by pre-emptive draining and holding of reservoirs at a low level, potentially leading to water shortages later.
- Improved capacity to account for multiple uses in water management decisions.
- Opportunity to become a centre of excellence in technology, governance and expertise in the rapidly growing global area of water management.
- Practical tool for scenario building, long-term planning, and science-, data- and probability-based infrastructure investment decisions.

Barriers to implementation:

- Diversity of agencies and organizations collecting needed data with competing interests.
- Lack of coordination and integration of data sources.
- Potential turf protection, lack of precedents for budget and data sharing partnerships, and claims of "ownership and proprietary data".
- Need for a focal point to champion need for the system (e.g., AEP's Resilience and Mitigation Branch, AEP's Operations Division, City of Calgary, irrigation districts, AI–EES).

Action needed:

- Hold a workshop to assess and determine forecasting and management vision and plans.
- Allocate funds to ensure access to current best in class models.
- Develop integrated decision-support tool based on New York City template. This could be a modification to tools already being used by the Province. These tools should be accessible to multiple stakeholders.

- Train people and apply decision-support and planning tools during normal times in preparation for next flood or drought conditions.

Who should be involved:

- Lead: AEP's Resilience and Mitigation Branch and forecasting group
- AEP Water Management Operations group
- AAF
- Environment Canada
- US National Weather Service
- TransAlta
- City of Calgary (Glenmore Reservoir, and possibly an Elbow River control structure)
- Other affected municipalities (e.g., Medicine Hat)
- Irrigation districts

Timeframe:
Initial workshop and plan development would require three months. Building the decision support tool would require one year. Integrating all the needed data in single system would require one additional year.

Adjust Dickson Dam operations to consider downstream needs (retain WCOs, functional flows, some new demands)

It was noted that, based on modelling, storage in Gleniffer Reservoir cannot meet all the medium- and long-term new demands that are forecast for the Red Deer sub-basin. However, some additional demands, functional flows, and most WCOs can be met with refined operations. This strategy has real potential for the next several years and some work is already underway.

Barriers to implementation:

- Need for additional streamflow monitoring and improved time of travel accuracy to guide operational knowledge on how to functionally control to meet WCOs.
- Need for some new data on streamflow-stream stage relationships to most efficiently provide functional flows.

Action needed:

- Need a precipitating event or senior government direction to drive the need for modifications to downstream operations.
- Develop a communications plan and infrastructure process.
- Engage Red Deer River Watershed Alliance (RDRWA) participants to build this into their water management plans.

Who should be involved:

- GoA (AEP and AAF)
- Downstream water users (Special Areas Water Supply, Town of Drumheller, and others as appropriate)

One suggestion is simply to let the operators provide for additional WCO and functional flow waters when appropriate without a specific implementation plan. If a specific plan is needed, local water and river users could be engaged via the RDRWA.

Timeframe:
Demand drivers are not high at this time. Full implementation could be done in less than three years, as operations are already being refined. In the meantime, functional flows could be implemented when conditions warrant and as advised by researchers.

Functional Flows

The use of functional flows is part of this strategy and has already been partially implemented in parts of the SSRB using releases from existing dams to support basic ecosystem functions (including riparian health, fisheries, and aquatic ecosystem health) in managed river systems. Options exist in all four sub-basins to implement this strategy. Work is already in progress below the Oldman Dam and in the Southern Tributaries, and there has been preliminary discussion about its use downstream of Gleniffer Reservoir in the Red Deer system. The strategy could also potentially be implemented downstream of Glenmore Reservoir on the Elbow and Bearspaw Reservoir on the Bow, although Glenmore and Bearspaw were not modelled for the purpose of functional flow releases in this project.

Potential benefits:
River systems downstream of control structures are subject to flow regimes that meet the needs of those operating the structures on behalf of the owners. In many cases on the Red Deer, Oldman and Southern Tributaries these control structures are owned and operated by the provincial government. Their primary purpose varies but generally includes multi-purpose water supply for municipalities, irrigators and other commercial and industrial uses. By their very nature, streamflow volumes and timing vary significantly from the calculated “naturalized” flow. In some cases and at some times, this can be beneficial to the ecological health of the river system. But often there are changes to the annual, weekly and daily flow rates that are not optimal for fish, riparian vegetation, or other factors that affect overall aquatic and ecosystem health.

Over the last several years, or decades in some cases, provincial dam operators have accommodated ecosystem needs by increasing flow rates or slowly ramping down flood flows to support such things as willow and cottonwood growth in riparian areas, seasonal fish spawning, supplementary releases during exceptionally low flow periods and others. These are generically called “functional flows.”

Recent studies by University of Lethbridge researchers in conjunction with AEP have demonstrated the effectiveness of these functional flows in various locations and circumstances. Functional flows are not needed all the time or even every year, so they can be built into operating plans when conditions are right. When water supply permits, these functional flows contribute to sport fishing, environmental health and aesthetics throughout the SSRB, and they provide cover for terrestrial animals from mice to foxes and deer, nesting sites for many types of birds and waterfowl, food for owls and diurnal raptors, and many other benefits.

Barriers to implementation:

- Specific elevation levels for effective and efficient use of functional flow water are not known in all suitable locations.

- Slowly ramping down flow levels after a flood tends to use more water than may be desired for a variety of reasons.
- Functional flow benefits aren't easy to document, making justification for releases above normal difficult especially if water supply later runs low.
- Accountability for decision making about functional flows may not be well determined or shared.

Action needed:

- Continue this work below the Oldman Reservoir and in the Southern Tributaries.
- Initiate functional flows on the Red Deer River in 2016 if conditions are suitable.
- Determine more precise flow rates and elevation levels required for effective functional flows.
- Test the effectiveness of pulsing the ramp period after a flood to save water for other uses.
- Investigate opportunities below other reservoirs (e.g., St. Mary, Glenmore, Ghost and Bearspaw).

Who should be involved:

- Dam operators (AEP, irrigation districts, TransAlta)
- AEP river and fisheries experts
- The science community (e.g., University of Lethbridge)
- Watershed Planning and Advisory Councils (WPACs) active in river systems appropriate to functional flows

Timeframe:

Functional flows on the Red Deer River could be implemented in the short term, beginning in the coming water year (2016).

*Advance Room for the River conveyance opportunities in the Bow and Red Deer sub-basins**

Potential benefits:

"Room for the River" is a phrase created by the Dutch as part of their most recent approach to water management and water security in the Netherlands. It was adapted to the Alberta situation and an extensive collaborative exercise was developed to identify and prioritize opportunities for flood mitigation on the Bow River from the Ghost Reservoir downstream, the Upper Elbow, and the entire Red Deer River system. Examples of conveyance opportunities noted in this process include removing debris between Sundre and the Dickson Dam where appropriate, selective aggregate removal where positive reduction in upstream flood levels could be achieved, and bridge redesign to alleviate constriction.

Barriers to implementation:

- Priorities have not been set comparing benefits and costs among various projects.
- Availability of existing site-specific hydraulic models for some locations to assess the benefit of various options is limited.
- Accountabilities, responsibilities and funding sources for conveyance efforts are dispersed among several government agencies and municipalities.

Action needed:

- Establish clear conveyance targets for specific reaches; these objectives will guide how much more room needs to be created.
- Conduct the next level of analysis to determine which of the Room for the River proposals and concepts are most workable and of highest priority.
- Form a working group in each sub-basin (Red Deer, Elbow, Bow) to assess priorities across watershed jurisdictions.
- Provide the necessary data in key river segments to enable comparison of the hydraulic impacts of competing projects.
- Clarify how funding would be achieved and what agency (or agencies) and individuals will be held accountable for inaction resulting in avoidable damages from future floods.

Who should be involved:

- WPACs with their many specific member participants
- Municipalities in the respective areas
- Alberta Departments of Environment and Parks, Municipal Affairs, and Infrastructure, and forestry staff in Alberta Agriculture and Forestry

Timeframe:

- An initial scan and consolidation of most promising options could be done by summer 2016, depending on data availability
- Completion of some already identified projects in 2016 to address known issues in key locations
- Detailing accountabilities and collaborating on getting things established by summer 2016
- Hydraulic modelling already initiated by GoA completed by 2018
- Ongoing implementation of high priority selections begun by fall 2016 for budgeting
- Initial work done before 2017 water year for selected critical infrastructure not already underway
- Longer-term project identified for completion within five-year program

*Advance Room for the River natural detention opportunities in the Bow and Red Deer sub-basins**

Potential benefits:

A great many participants in this project and in Room for the River projects have recommended that restoring wetlands, building new wetlands, or leaving more beaver dams in place in the headwaters region would have a positive impact on water management. Others suggested that such natural detention sites would all wash away in a large flood and so would have no long-term impact and perhaps a slightly negative impact as the stored water adds to the downstream flow. Nonetheless, everyone agreed that more natural wetlands in the upper Bow and Red Deer sub-basins would have a positive effect during dry periods and droughts and, for floods less severe than the 2013 event, could slightly reduce or delay flood flows downstream particularly on a local scale. These detention sites could also have a positive impact on water quality. Examples of natural detention opportunities include restoring wetlands in targeted areas and reducing linear footprint in the headwaters. These measures would have further benefit in low flow years where flows would be sustained later into the summer from these small detention sites.

Recognizing the benefits of this approach, AEP established the Watershed Resiliency and Restoration Program,[27] which includes support for restoring wetlands and riparian areas. This initiative is underway and funds have been allocated to evaluate, plan, and restore wetlands in some areas of the foothills and headwaters.

A complementary Room for the River approach to upstream retention is the prevention or slowing of runoff that has been artificially enhanced by human activities. Roads, power lines, deeply entrenched trails (linear disturbances), and unmanaged off-highway vehicle (OHV) use can all create new and rapid runoff in the foothills and headwaters regions. Recreational use of OHVs is not well-controlled. While many recreationists are responsible, careful users of the back country, some are not and it doesn't take many vehicles to create new pathways for water to run off at a rapid and destructive rate. In contrast, forest harvesting, oil and gas exploration and production, and other industrial uses of the Eastern Slopes are all regulated and controlled to mitigate undue runoff and protect water quality from siltation and spills.

Substantial benefits to water management and a healthy environment can be attained by selectively increasing wetland retention in the foothills and mountainous areas. But improvements to water quality and fish habitat, and slowed or reduced peak runoff can also be attained by better managing motorized recreationists in the Eastern Slopes. Many examples of controlled and successful management of motorized back-country recreation are available from similar areas in the US. It can be done by designating specific areas and trails for motorized recreation while minimizing the negative effects on runoff and other environmental values. Given the nature of our magnificent recreational areas so close to relatively large population centres, it should be a high priority to protect ecosystem integrity and reduce unnaturally powerful and swift flood runoff from the Eastern Slopes. Many organized OHV groups and organizations have volunteered their support, expertise and labour to improve the off-road conditions in these areas.

Barriers to implementation:

- Approved trails and recreational areas are needed first as adequate alternatives to the current wide-open, "go anywhere" situation.
- Locating and creating attractive and controlled off-road recreational trails and "mud-holes" is not simple, easy, or inexpensive.
- Once approved trails and off-road areas are in place, ongoing maintenance will require new human resources.
- Enforcement can be expensive and labour intensive.

Action needed:

- Strong government commitment to allocate the resources necessary to plan and implement new trails, new localized areas for off-road events and recreation, new signage, and additional enforcement activities.
- Recruit the many willing organizations devoted to off-roading and motorized recreation to engage with government, local residents, and industry to identify locations, build or improve trails, and self-enforce off-road recreation.

[27] See http://aep.alberta.ca/water/programs-and-services/watershed-resiliency-and-restoration-program/documents/WatershedRestorationProgramGuide-Aug-2014.pdf.

Who should be involved:

- AEP, AAF, Alberta Transportation
- Off-road and outdoor recreation organizations (e.g., Alberta Fish and Game Association, Trout Unlimited Canada, Alberta Off-Highway Vehicle Association)
- Local resident representation
- Eastern Slopes industries active in the region (e.g., forestry, oil and gas, power line companies)

Timeframe:

- Wetlands restoration initiative is underway now and will continue for five years
- Initial planning, recruitment of participants and collaboration of off-road recreation activities for the upper Ghost, Elbow, and Sheep watersheds during early 2016, with preliminary plans and agreements in place for these regions by fall 2016. It is critical not to let planning delay various short-term improvements already underway and being considered for the coming year
- Budgeting and field activities identified by 2017 and ongoing thereafter

*Further apply land use best management practices**

Potential benefits:

Many BMPs are available to help minimize impacts of land use change on water resources. BMPs that can be improved in the municipal sector include intensification of urban and rural residential footprints, and water conservation. A common standard for management of urban and rural residential footprints is the maintenance of current population density. This management practice could be improved by decreasing the footprint expansion required by population growth by 25%, a goal of the City of Edmonton. Optimistically, this percentage could go as far as 50%, which is Calgary's goal.

Similarly, maintaining and improving current per capita water use would be the basic practice for water conservation. This could be done by reducing per capita water use by 25%, or optimistically, 50%. It is important when setting these goals to consider what proportion of the municipal licence is for basic domestic water use versus water used for industrial and commercial activities in the city. Depending on the breakdown, a 30% reduction in domestic water use may or may not have an impact on overall municipal water use.

The natural resource extraction sector has land use management practices for reclaiming semi-permanent energy sector infrastructure, accelerated reclamation of transitory footprint, efficient footprint layout, and water conservation. Presently it is expected that semi-permanent energy sector infrastructure would remain over a 50-year period. There are several ways in which this could be managed differently. Reclamation of a well site 20 years after production would be a better land use management practice, while immediate reclamation would be the best management practice taking into account potential for applying new technologies to the existing wells. Reclamation of the transitory footprint could be accelerated as a BMP. A standard cutline has a life of 60 years. If the cutline had a life of only 40 years that would be an improved land use management practice, while a cutline life of 20 years would be the BMP (ALCES Group, 2014). In many cases, cutline width has been reduced from about six metres to one metre, and some technologies no longer need cutlines at all.

The historical rates of road growth to access new resource developments could be reduced to give land use footprints a more efficient layout. Coordinated planning can achieve a 25% reduction in road required to access new wells and harvest areas. For example, in-block roads can have a life of 40 years in regions with steep slopes, and a life of only 25 years in regions with moderate or flat slopes. In each region the lifespan could be reduced by 25%, regardless of steepness of slope. This lifespan could be further reduced by as much as 50%, or completely removed (ALCES Group, 2014). A study in northeastern Alberta concluded that road access could be reduced by 34% when energy and forestry companies coordinated their road planning (Schneider and Dyer, 2006).

Work is already underway to implement land use BMPs with the sub-regional planning that is occurring in support of the South Saskatchewan Regional Plan. Examples include the development of a Linear Footprint Plan and Recreation Management Plans, starting with Porcupine Hills and Oldman–Livingstone areas. The designation of the Castle Wildland Provincial Park to protect the area's ecological integrity is another example.

Barriers to implementation:

- Multiple uses require multiple best practices, and integrating cumulative effects and prioritizing approaches is a complex process.
- Regulatory change is a lengthy and complex undertaking.
- Enforcement of non-industrial uses is complex and dispersed.
- Creating partnerships among diverse groups to optimize BMP voluntary compliance is time-consuming and costly.

Action needed:

- Assemble general best practices literature on resource use types found in the headwaters and foothills of the SSRB.
- Convene a series of workshops on improving or adapting best practices for various resources uses (e.g., OHVs, forest products, grazing, ranching, residential and recreational developments).

Who should be involved:

- Lead: South Saskatchewan Regional Plan Secretariat
- Individual industries active in the sub-basin as well as their umbrella associations that can share information and urge the adoption of BMPs by their members
- Municipalities and their associations (AUMA and AAMDC)
- Provincial government agencies with regulatory or management responsibilities (Alberta Energy Regulator, AEP, AAF, Transportation, Municipal Affairs)
- Stakeholder groups as appropriate to the topic (e.g., Trout Unlimited Canada, Alberta Wilderness Association, OHV associations, Fish and Game Association)

Timeframe:

- One year to conduct workshops and develop plan for implementation
- Regulatory approaches and guidelines implemented in the following year
- Enforcement resourcing and prioritization in the next budget year

Promote further municipal conservation relative to what is being done now

While much less than irrigation licences, municipal water allocation licences are among the largest diversions in southern Alberta. However, because most of the flow is returned to the river from which it came, they have less impact on water quantity than one might expect; water quality impacts are considered of greater concern.

Despite the fact that most municipal water usage is based on long-life infrastructure, it is probably the area of greatest potential for improvement based on technological development. Stormwater runoff management, water treatment facilities, water reuse technologies, highly efficient water heating systems, low and no flush toilets, efficient showerheads, smart controls and others have been subject to rapid and impressive technological developments over the past two decades. More is expected and, more importantly, the consumer appeal and steady market penetration of existing highly water efficient technologies holds considerable promise for reducing the urban water footprint.

Other promising developments for conserving municipal water use include better technologies to evaluate and find water main leakage. Repair and replacement of old water mains, improving stormwater systems, and ensuring a separation between the two continues to improve overall efficiency of urban water use. Commercial water use within municipal licence allocations has also seen substantial improvement in water efficient technology. More efficient heating, ventilation, and air conditioning systems save some incremental water use in high rise buildings, while greater density of population residences, more urban xeriscape lawns and parks, rooftop gardens and green roofs reduce runoff and ultimately reuse rainwater more effectively. Many golf courses have found ways to reduce their net water use, including more efficient automated and soil-water-conscious sprinkler systems, drought tolerant grasses, and more natural “rough” areas. Adoption of all these technologies leads to considerable optimism for urban water conservation, reuse and effective management.

Reducing net water use by municipalities can result in substantial taxpayer savings by delaying or eliminating the need for additional water treatment facilities both for incoming and outgoing water. Other benefits from additional urban water conservation include improved natural river systems, higher river flow rates during critical dry or hot periods, reduced risk to fish populations, greater natural wetlands retention adjacent to source water bodies, and less need to draw down source water reservoir storage thus reducing risk and prolonging water supply during drought periods. Many other less direct benefits are derived from urban water conservation efforts, and the rapid development of water-smart technologies makes their application economically attractive.

Return flows in summer vary but participants generally agreed that a further 20% reduction in net municipal water use during summer months, when demand is greatest and treated water return flows are lowest, would be a challenging but achievable goal. The goal of 5% during the winter months reflects the much lower overall water use by municipalities in winter and higher rates of return flow, likely approaching or exceeding 90%.

Enormous and commendable efforts are underway throughout the SSRB to improve every municipal aspect of water use. These efforts should be encouraged and rewarded while recognizing that new technologies continue to emerge; the challenge to improve and to reduce risk and costs is ongoing.

Barriers to implementation:

- Balancing efficient use or reuse of water that reduces return flow with a compensating reduction in raw water intake from what it would otherwise be, to avoid harmful effects to the aquatic environment due to net lower flow rates downstream.
- There may be technological limits on how far municipal conservation can go without incurring impractical overall costs.

Action needed:

- Improve the information available to small and medium sized municipalities regarding the latest technologies available.
- Continue to improve the availability of information and incentives to residential developers and particularly to homebuyers, renovators, renters, and consumers of water efficient devices that can improve their quality of life and family budgets.
- Periodically review and upgrade the water conservation, efficiency, and productivity plans of the AUMA and AAMDC and the technologies they contain and recommend.
- Look to leading municipalities such as Okotoks for practical technologies appropriate to the water risk and environmental conditions found in Alberta.
- Develop and disseminate comparisons of water conservation strategies used by various municipalities, developers, and renovators.
- Initiate, continue, or expand recognition for innovative municipal water conservation achievements into existing awards categories within such organizations as AUMA, AAMDC, Emerald Awards, Urban Development Institute, Alberta Low Impact Development Partnership, and others.
- Require a simple assessment of current best practices when reviewing area structure plans and specific developments using municipal water licences.
- Determine what further policy options related to demand management the GoA and/or municipalities should be considering.

Who should be involved:

- Larger municipalities generally have the resources to keep up with the rate of new technology in the use, treatment, and consumer applications of water.
- The Urban Development Institute and individual development companies for residential, commercial and industrial developments play a key role in water conservation.

Timeframe:

Participants generally viewed this overall strategy as one of continuous improvement, encompassing hundreds and perhaps thousands of large and small improvements throughout the municipalities in the SSRB. Reaching the 20% summer and 5% winter objectives should be achieved within 10 years.

4.2 Level 2 Implementation

*Redesign operations and expand, where beneficial, existing reservoirs in the upstream Bow for water supply and watershed health**

As described in section 3.2.4, this strategy involves re-purposing and possibly expanding existing TransAlta reservoirs in the upper Bow, changing their priorities toward public interest outcomes and maximizing revenues from hydropower as an important but, in some instances, secondary matter. In most cases the total amount of power generated from this renewable resource would remain the same since the same total amount of water would be released. But in the re-purposed strategy, timing of storage levels and water released through the turbines would be governed by considerations of flood and drought risk, environmental effects, and year-round assured water for people and other commercial water uses in addition to considering short-term power prices.

This strategy differs from the watershed management agreement described in Level 1 which included using approximately 10% of the upstream storage and supply for other purposes. However, the difference is not as great as it may seem. Modifying Bow hydropower operations to mitigate flood damages may appear only to affect the Ghost Reservoir, but in fact all the other reservoirs are affected to some extent, depending on various internal TransAlta forecasts and strategies to meet commitments and maximize revenues from the remaining stored water. Taking the Level 1 TransAlta strategy to its logical conclusion would engage all of the reservoirs to provide the additional flexibility and resilience needed to serve multiple purposes during the course of any given year. Water supply from snowpack, glacial melt, rain, and groundwater flows varies dramatically from year to year. Managing only the Ghost Reservoir in the general public interest for flood protection or for drought mitigation utilizes only a small portion of the water supply resource available. An agreement with TransAlta to keep them financially whole while using their entire system for multiple public interest purposes may be more effective than working with only parts of the total system.

A number of factors need to be considered and addressed as part of implementation:

- Ensure instream flow needs and obligations are met under all normal conditions and under more extreme conditions than would otherwise be the case.
- Manage supply and flow rates during the winter to reduce the risk of ice dams forming in Canmore, Cochrane, and Calgary.
- Enable overall integrated management of upstream reservoirs with provincially-owned and irrigation district reservoirs to minimize flood risk at predetermined flow rates and elevations.
- Minimize drought risks from what they would otherwise be, recognizing that these steps can only mitigate conditions up to a certain level of severe or prolonged drought.
- Improve environmental conditions in normal times (including both a water quantity and a water quality component, as quantity is not always a direct surrogate for environmental conditions), while enabling licensed access to water.
- Provide the flexible agreement to conduct the needed studies to determine any feasible expansion or different operations in the public interest (e.g., restoring Spray Reservoir to its original design capacity; flexibly stabilizing Lower Kananaskis Lake).
- Improve recreational opportunities for environmentally sound uses of the upper Bow River.
- Enable greater monitoring and control over cumulative effects in the watershed.
- Implement several components of the South Saskatchewan Regional Plan (e.g., headwaters protection, minimum environmental flows, improved recreational opportunities).

- Provide the basis for a collaborative governance process engaging key stakeholders.
- Significantly and measurably improve on all three of the *Water for Life* goals.

Barriers to implementation:

- Confidentiality relating to certain of TransAlta's pricing forecasts and other business operations.
- Commitments to meet existing water licences must be built into the operations.
- Uncertain forecasting accuracy of weather patterns, snowpack, river flow, soil moisture content, precipitation distribution, cropping data, and air temperature.
- The fact that reservoirs are located in protected areas could make expansion difficult.
- Potential opposition from recreational and other users.
- With the current economic challenges in Alberta, step-by-step implementation needed.

Action needed:

- Study options and benefits and collaboratively model flexibility and resilience characteristics and potential unintended consequences of the redesigned operations and flow regimes.
- Determine governance requirements and new operational roles.
- Develop an understanding of how risks and liabilities are structured and the impact of changes under redesigned direction of operations.
- Assess potential impact on shorelines, fish habitat, dam safety upgrades (if needed), and other positive or negative environmental components.
- Develop an integrated database of various factors related to decision making on water storage and release including ensemble forecasting and other Alberta data sources similar to the New York City upstream water management system (see Figure 44).
- Design an acceptable agreement between the GoA, TransAlta, and downstream water users.
- Clearly communicate benefits and how environmental, recreation and other issues will be addressed.
- Develop costs and benefits from modelling and economic assessments.[28]
- Provide early and frequent opportunities for public comments, upgrades, and constructive participation.

Who should be involved:

- TransAlta
- Government of Alberta (AEP, AAF, and other departments as appropriate)
- First Nations in the region
- Affected irrigation districts
- City of Calgary
- Parks Canada
- Municipalities in the region
- City of Medicine Hat

[28] The City of Calgary's triple bottom line approach is one example of cost-benefit analysis that takes into account the cost of environmental impacts, socio-economic costs, and others (http://www.calgary.ca/CA/cmo/Pages/Triple-Bottom-Line/Triple-Bottom-Line.aspx)

- Other groups would be directly involved on an as-needed basis (e.g., Alberta Transportation, Parks Canada, Trout Unlimited and other positively or negatively affected interest groups)

Timeframe:
A potential timeframe for implementing this strategy is less than one year for an initial agreement for the 2016/17 water year; one year for an adaptive comprehensive agreement; and seven to ten years for full implementation and development.

Expand (74,000 dam^3) and fully balance Chin Reservoir (285,000 dam^3) (OSSK sub-basin)

Chin Reservoir is part of the St. Mary River Irrigation District (SMRID) and is an off-stream storage site downstream from the St. Mary Project headworks at the provincially-owned Ridge Reservoir. Before entering Chin Reservoir, main canal flow serves a hydro generation facility operated by Irrigation Canal Power Cooperative Ltd. (Irrican), which has a generation capacity of 11 megawatts. At present, Chin Reservoir is managed by SMRID and is not part of AEP's balancing system.[29]

Potential benefits:
- Because Chin has access to more of the watershed by being further downstream, it will have a large benefit and good chance of refill.
- Expanding and fully balancing Chin would improve storage on the other upstream reservoirs, thus keeping more water closer to the headwaters and available to support ecosystems and human water uses throughout the system.
- Irrigation shortages would be decreased and the irrigable period extended during drought.

Barriers to implementation:
- Loss of autonomy and control on the part of SMRID.
- Limits to existing canal capacity and infrastructure and the costs of necessary upgrades and expansion.
- Existing cabins around Stafford Reservoir would be a barrier to expansion.
- Licensing may pose some difficulty but new licences are allowed for reservoirs providing economic and/or environmental benefits.
- Complexity of balancing other operational requirements.

Action needed:
- Undertake engineering studies of existing and proposed new infrastructure.
- Conduct water supply studies to determine fill risk and demand growth.
- Review and revise existing operational agreements.
- Undertake negotiations related to hydro generation.

[29] The "balancing system" means that AEP reservoirs in the OSSK sub-basins are proportionally balanced; that is, each reservoir attempts to maintain the same percent full as the others. To do this, reservoirs with excess storage (storage above the percent full of the others) are preferentially drawn on to meet demands that are able to draw from multiple locations; for example, the Oldman River past Lethbridge can draw from the Oldman, St. Mary and Waterton reservoirs, while the Ridge system can draw from Ridge, St. Mary and Waterton reservoirs.

Who should be involved:

- Irrican Power
- Affected irrigation districts
- AEP
- AAF
- Town of Taber
- Affected Hutterite colonies
- Affected First Nations

Timeframe:
A potential timeframe for implementing this strategy is one year for feasibility and determination whether to proceed at all, two more years for overall assessment (e.g., geophysical, design, costing, environmental impact assessment), two years for permitting, and five years to build (10 years in total).

Build new SAWSP and Acadia Valley off-stream storage (35,000 dam^3 SAWSP + 45,000 dam^3 Acadia = 80,000 dam^3 total) (Red Deer sub-basin)

Potential benefits:
The addition of SAWSP and Acadia Valley off-stream storage facilities would allow irrigation and other demands to be expanded substantially in the Red Deer sub-basin. These reservoirs would allow for greater capacity to meet a growing population and associated demands on the Red Deer system without having large environmental costs. This strategy was well-investigated in previous studies as well as in this project.

Barriers to implementation:
Few barriers exist to implementing this strategy but adding this storage to the Red Deer system would require that demands are expanded to ensure the reservoirs are used to their full capacity. At this time, it is difficult to establish a positive cost-benefit for new infrastructure, but that may change in time. Therefore, it will be important to ensure adequate resourcing is available to support additional development in this part of the sub-basin.

Action needed:

- Design the system in such a way that it remains efficient, environmentally and economically viable.

Who should be involved:

- The owners, beneficiaries, and regulators of the reservoirs, including relevant irrigators
- AEP
- AAF
- Local municipalities and Special Areas irrigators as appropriate

Timeframe:
This strategy is already being explored and should be implemented when demands grow enough to require additional water storage.

OTHER LEVEL 2 STRATEGIES

*Pursue more extensive relocation and buyouts in the Bow and Elbow River floodplains to reduce risk and reduce the need for upstream mitigation structures**

Potential benefits:
Relocation and buying out properties in the floodplain is the most effective—and the only permanent—flood mitigation solution. Relocating non-critical infrastructure provides an opportunity to mitigate future flood damages and, although potentially costly at the onset, this is a long-term strategy that may be less costly in the long run. It would benefit those who own properties in the floodplain by removing potential future risk, but this strategy is not without challenges.

Barriers to implementation:
- The willingness of landowners to sell their land is perhaps the largest barrier to implementing this strategy.
- Realizing that upstream or local level mitigation cannot completely remove the risk of flooding is important, although upstream mitigation does reduce risk and may present a barrier to the full implementation of this strategy.
- The cost of implementing this strategy in well-established, densely populated urban areas such as parts of central Calgary and downtown may be substantially higher than upstream mitigation measures. It is an extremely difficult discussion and substantial resources are already being applied to maintain infrastructure in the floodplain. For the Elbow River, this strategy may not be cost-beneficial with the SR1 reservoir at Springbank in place. Similarly, for the Bow, upstream mitigation may be more cost-beneficial than buyouts.

Action needed:
- Improve education and awareness around the costs and potential risks of living or maintaining infrastructure in the floodplain.
- Develop policy and allocate funding to implement this strategy within all levels of government.

Who should be involved:
- Various departments within the GoA including AEP and Municipal Affairs
- Developers
- Landowners
- Municipal governments

Timeframe:
Work on this strategy can begin immediately recognizing that it will take a while to implement, given the time needed to address factors such as how to proceed, what compensation should be offered, what to do with "bought-out" land, and so on. Once initiated, this effort should continue into the future as populations grow.

*Build a series of new off-stream storage facilities in the Oldman sub-basin**

Potential benefits:
The Oldman sub-basin is already fully allocated. Therefore, new off-stream storage would help to reduce the stress on the system overall, as long as the storage was situated where local demands could be easily met. Small storage facilities offer many benefits in terms of supplying water locally; they also provide wildlife habitat, recreation opportunities, and reduce the demand on larger on-stream facilities.

Barriers to implementation:

- Proper environmental and economic analyses should be conducted to ensure additional storage is viable and does not negatively affect important environmental values.
- In the prairie environment, water quality in smaller reservoirs is often of poorer quality, with moderate to high nutrient levels and, often, high organic matter content. This can make it challenging for municipal drinking water systems to treat the water using present technology and standards.

Action needed:

- Undertake further study regarding the most appropriate location and sizing for these structures.
- Undertake full cost-benefit analyses.
- Conduct modelling analyses at the screening level to identify a range of potential benefits.

Who should be involved:

- Irrigation districts
- AEP
- AAF
- Local land owners

Timeframe:
Investigation into potential sites could be conducted in the near term. Implementation of this strategy could occur over the next several years and as demands require.

*Build a series of new off-stream storage facilities (~80,000 dam^3) in the Red Deer sub-basin**

Potential benefits:
An additional 80,000 dam^3 of storage would allow all sectors in the Red Deer sub-basin to grow along with irrigation. This would provide increased flexibility to diversify growth and maintain healthy instream aquatic ecosystems.[30]

Barriers to implementation:
- In the prairie environment, water quality in smaller reservoirs is often of poorer quality, with moderate to high nutrient levels and, often, high organic matter content. This can make it challenging for municipal drinking water systems to treat the water using present technology and standards.

Action needed:
- Assess at the screening level, potential off-stream storage locations.
- Undertake study to determine costs and potential limitations to ensure there are viable options in preparation for growth.

Who should be involved:
- City of Red Deer and other municipalities
- Red Deer River Municipal Users Group
- Red Deer River Watershed Alliance

Timeframe:
This expansion should accompany additional demands on the system, which means growth in the Red Deer sub-basin would be required prior to implementing this strategy. That said, investigation into potential storage sites could occur immediately, and implementation could occur as demands require.

[30] If further study demonstrates that off-stream storage sites would not be possible or effective, then a midstream facility on the Red Deer system should be moved from Level 3 to Level 2.

4.3 Level 3 Implementation

Build new on-stream storage low in the Bow system, below Bassano Dam (~Eyremore site, ~477,000 dam^3)

Eyremore Reservoir was identified as a potential strategy to capture flows below Bassano in the lower portion of the Bow system, which could then be released to meet the environmental needs of the lower river. The reservoir could also offer potential flow augmentation during dry periods downstream, meet minimum flow needs at Medicine Hat, and provide flood mitigation benefits to downstream users by storing flood water to reduce peak flows at Medicine Hat. The reservoir would also enable the EID and possibly upstream users to access water during periods when they would otherwise be prevented from doing so due to the 400+ cfs minimum flow release agreement below Bassano Dam.

Potential benefits:

- Increased flexibility of the water management system by supplementing downstream flow.
- Allows upstream reservoirs in the OSSK sub-basins to remain at a higher level, potentially alleviating occasional extreme low flows in the Bow River between Calgary and Bassano.
- Flood mitigation for Medicine Hat.
- The proposed location for Eyremore Reservoir is such that when a large rainfall occurs in the headwaters, it would take days for the first flood water to reach this reservoir. This allows days to initiate a release from storage to mitigate downstream flooding, thus removing weather forecasting from the equation. If a flood event does not materialize, water would be kept in storage for possible drought mitigation later in the year.
- Potential low flow mitigation for Medicine Hat.
- Reduction in shortages for irrigation districts.
- Capturing some of the higher than natural winter flows to optimize environmental flows.
- Reducing risk to downstream river ecosystems and threatened lake sturgeon below Bassano Dam.
- Potential use for functional flows below the reservoir.
- Increased capacity to manage Bow and Oldman systems together for resilience in drought and flood periods.
- Potential for hydropower generation.

Barriers to implementation:

- High capital cost compared to alternative mitigation options.
- Long regulatory process and time for construction.
- Likely to be significant resistance to new storage in any location.
- Disruption to aquatic ecosystem function in the reservoir footprint.
- Integrating water management from headwaters to confluence would improve benefits of Eyremore, including revised TransAlta operations as described elsewhere in this report.

Action needed:

- Comprehensively investigate the relative costs and benefits of such a large on-stream facility.
- Model in more detail to evaluate benefits from optimizing operations of the proposed reservoir in conjunction with upstream operations during various flow scenarios.

- Obtain agreement by affected parties to proceed.
- Undertake engineering studies and formal applications.
- Undertake permitting process.
- Design, engineer, build, and operate if decision is made to proceed with this strategy.

Who should be involved:
- EID, BRID, WID
- TransAlta
- City of Medicine Hat
- Government of Alberta

Timeframe:
Given the need for various studies, negotiations, and permitting, 10 years is a likely timeframe if the project is determined to be in the public interest.

OTHER LEVEL 3 STRATEGIES

Build new off-stream storage in the Western Irrigation District (~Bruce Lake, ~51,000 dam^3)

Potential benefits:
The WID has little substantial storage available and thus relies on nearly constant diversion from the Bow River as and when water is needed throughout its system, whether for environmental flows, municipal use, or crop irrigation. Having more storage within the WID could prevent or reduce its diversions during periods when water is most needed in the Bow for environmental flow purposes. As and when more residential and commercial or industrial development occurs within or near the WID, demand for a continuous supply of water will increase. Given known historic conditions, never mind prehistoric or possible new conditions due to climate change, additional storage within the WID may be able to provide a more reliable water supply for residents and agricultural purposes without further impairing environmental conditions in the Bow through Calgary and downstream. Bruce Lake would not eliminate risk due to drought, either to farmers in the district or to Bow River conditions, but under some conditions would provide some benefit.

Interestingly, most of the return flow from the WID goes to the Red Deer River and these flows are occasionally important in meeting the WCOs on that river. Bruce Lake under some conditions could extend the water supply to irrigators during a period of drought, and may also marginally benefit the Red Deer system if environmental conveyance flows are maintained.

Barriers to implementation:
- Cost: land acquisition and oil and gas wells and rights are expensive to purchase or mitigate.
- Although benefits are occasionally significant, the water supply created by this new storage is not always needed.

Action needed:
- Undertake additional modelling to determine under what conditions Bruce Lake provides what level of benefits to which users, including environmental uses, but this is a low priority.

Who should be involved:

- WID
- AEP's Resilience and Mitigation Branch

Timeframe:
As and when participants believe more information is needed

Build new on-stream storage in the Southern Tributaries of the Oldman sub-basin, balanced with other reservoirs (~Kimball site, ~125,800 dam^3)

Potential benefits:
The Kimball site was selected for evaluation primarily as a means of providing benefit if the water users in the US were to take their legal entitlement from the St. Mary River. This reduction in flow into Alberta would substantially reduce the amount of water available for environmental flow and for irrigators. A reservoir at the Kimball location just downstream of the US border showed benefits only if there were some modifications to the current WCO and instream flow needs requirements. At present, the introduction of a new reservoir would require a new WCO (rather than the lower IO requirement) to be enacted. If the existing WCO applied to the entire St. Mary River, no benefits to irrigators or other water users beyond environmental flows would result. Few participants believe that such a reservoir would be built without showing economic benefits to the region. If the WCO were adjusted and applied instead only to the stretch between Kimball and the existing St. Mary Reservoir (as would be expected) there is considerable advantage to having this reservoir in place if and when the US decides to take the full annual flow volume to which it is legally entitled.

Barriers to implementation:

- Cost versus benefits under current regulatory conditions.
- Benefit is small unless and until the US takes its maximum quota of water.
- Potential international dispute depending on how close to the border the reservoir extends.
- Potential loss of key aquatic habitat for species at risk.

Action needed:

- Further explore how environmental protection can be assured or improved without applying the WCO to new or existing reservoir operations.
- Reconsider the reservoir location, size and operating conditions if the US indicates possible reduction in cross-border flows.

Who should be involved:

- Affected irrigation districts
- AEP, AAF
- Other interests as appropriate to specific issues under consideration

Timeframe:
No current drivers for further study.

Build new storage midstream in the Red Deer sub-basin (~Ardley site, ~400,000 dam³)

Potential benefits:
As described previously, the Ardley site chosen for modelling purposes was located downstream from the city of Red Deer and upstream of the Buffalo Lake diversion. The Ardley Reservoir was modelled with a maximum storage of 700,000 dam^3 (based on Alberta Environment, 2008), with 300,000 dam^3 reserved as empty storage for flood mitigation. This results in a 400,000 dam^3 live storage facility.

Modelling showed this reservoir would not be needed for many years until the total net demand on the Red Deer system reached about 440,000 dam^3. Alternative reservoirs to support the proposed expansion of irrigation acreage were considered to be of greater value and were recommended as an earlier build. The Ardley site did show considerable drought mitigation potential when increased future demand began to reveal shortages to new licences that would be junior to the WCOs. Because of the large potential storage and routine use of only about 60% of the total, flood mitigation downstream was substantial and Dickson Dam could be used more effectively, reducing risk to the WCO flows at Bindloss.

Barriers to implementation:
- No demonstrated need for the extra storage at this time.
- Cost to build and operate.
- Environmental trade-offs between effects of the storage site versus improved low flow and WCO support potential.

Action needed:
- Monitor growth of licence demands, success in meeting WCOs and licence demands from altered Dickson Dam operations, but no further action at this time.

Who should be involved:
- AEP
- Alberta Environmental Monitoring, Evaluation and Reporting Agency for licence demands, monitoring, reporting

Timeframe:
Ongoing for monitoring licences, WCO compliance, and shortages

Reduce minimum flows through municipalities and other downstream users as an exceptional measure in drought years to slow the draining of upstream reservoirs

This strategy was only considered for severe drought conditions in which the ecology of the affected river system is threatened by reservoirs running extremely low with little expectation of refill in the short term. A previous study of the Bow River system under climate change effects showed the upstream reservoirs running dry in the second or third year, depending on the scenario. Such a condition during any time of the year could lead to catastrophic results to ecosystem services and basic functioning of the river ecology. The Bow River, as an example, obtains about 80% of its total flow volume from melting snowpack, some of which is stored in the upstream TransAlta reservoirs and a small amount in the Glenmore Reservoir. Under severe drought conditions with minimal winter snowpack and lack of rainfall in the upper watershed, in the second year of these conditions, the reservoirs are soon depleted below the level at which they can release water. Groundwater is normally also depleted under such dry conditions, and as a result the rivers can drop to flow rates that cannot support the existing ecosystem.

Under these circumstances it was important to seek any and all potential responses available to retain water, not only for environmental purposes, but to extend the time available for other critical uses for the remaining water. Only Calgary was modelled for various reductions in minimum flows since it has by far the largest population in the SSRB. The minimum flow of approximately 1250 cfs is generally agreed to be a flow rate at which it is environmentally acceptable for current effluent release rates from the City's sewage treatment facilities. Temporarily dropping the flow rate through Calgary to 900 cfs or even less for short periods was thought to be acceptable, and some additional water was reserved for storage and later release. This strategy is considered a short-term, stop-gap measure and may not conserve enough water to get through the drought, depending on when precipitation is expected. Effectively implementing this strategy depends, as do so many other strategies for flood and drought mitigation, on an improved forecasting and real-time modelling system similar to the New York City system described earlier.

Potential benefits:

- Extending the time available for minimal flow releases from upstream reservoirs under extreme drought conditions
- The alternative of doing nothing increases the risk of zero flow in the river resulting in long-term or irreversible consequences to the river ecology

Barriers to implementation:

- Lack of real-time modelling of upstream storage, flow rates, forecasting and other data needed to determine when, by how much, and for how long minimum flows could be reduced.
- Drought conditions are unpredictable and subtle in their onset, thereby reducing the sense of urgency needed to understand when and how this strategy might be most effectively deployed.

Action needed:

- Undertake integrated modelling of actual reservoir storage, river flows, and improved forecasting systems to inform when such an extreme measure is likely to improve overall environmental conditions well before the reservoirs run dry.
- Incorporate groundwater studies to improve accuracy of flow rates under drought conditions.
- Undertake additional study by municipalities, particularly Calgary, of what the flow rate can be reduced to and over what period of time as a risk reduction strategy to mitigate irreversible damage to the river ecology.

Who should be involved:

- City of Calgary
- AEP's Resilience and Mitigation Branch
- TransAlta
- Fisheries, river ecology experts, and modellers with accurate water models

Timeframe:

Most of the data are in place to study what conditions might lead to implementing this strategy. With a few months of work, a small team with clear study terms could identify, assess and recommend criteria for when to consider this strategy, when to put plans in place and when to trigger the strategy.

5. Closing Remarks

The results of this project reflect the importance of thinking about and planning for how we respond to climate variability and change in the SSRB. They provide a Roadmap to stimulate enhanced and new approaches to water and watershed management in the basin that can be implemented before we face imminent crises of flood or drought. When extreme situations arise, there may be very little we can do to mitigate or respond. The strategies put forward in each of the three levels demonstrate what we can do with today's infrastructure and management, and what more could be done to build the adaptive capacity of the water management system in the SSRB. The Roadmap is intended to first, develop resilient and adaptive capacity to be able to respond to a range of different situations, and second, raise social awareness of potential flood and drought risks in support of efforts to get water management arrangements in place now.

Working collaboratively, knowledgeable and experienced water users and managers from across the SSRB identified many opportunities to optimize the legal and physical infrastructure already in place to support continued population and economic growth with improved environmental health in the basin. Flexibility in implementation will be critical for success with many of the strategies for the SSRB so that adjustments can be made to refine and adapt the concepts. Although good data and models are the foundation for informed decision making, political priorities and economic conditions are also key factors.

A number of activities are already in progress to make the SSRB more resilient in the face of climate variability. This project and its predecessors identified a number of additional strategies for increasing the adaptive capacity of the basin. Level 1 strategies should be advanced and implemented now and were viewed as the most feasible and practical options across the SSRB. Water management decisions are informed by risk and hazard assessments, regulations, science, political decision making, and economic conditions. All of these elements will need to align to see a true shift in the adaptive capacity of the basin. The regulations, science, public awareness, sense of urgency and Adaptation Roadmap are in place. What is needed now are local, watershed-based choices in coordination with provincial leadership to move forward in a step-by-step, reasoned and practical manner before the next weather extreme or a changing climate brings a new water crisis to southern Alberta.

The Level 1 results of the Adaptation Roadmap demonstrate that there is flexibility within the SSRB water management system to make beneficial changes without incurring significant economic, environmental, or social cost. This work shows that flexibility must be maintained within the water management system to mitigate potential negative consequences of new (and old) operations. Operational and decision-making changes should further integrate forecasting into a meaningful and data rich framework. This is particularly important given that each year is likely to present a unique situation and new water management challenges. The various strategies included in Level 1 encompass an adaptive management approach to manage year-to-year variability and long-term change in hydrologic conditions. Practical and feasible adjustments, such as a long-term watershed management agreement for the Bow, raising winter carryover in irrigation reservoirs, restricting greenfield development in the floodplain, and further effort in defining and promoting shortage sharing do not necessarily require major infrastructure investments or other expensive or socially disruptive steps.

Level 2 provides many benefits to water users while maintaining ecosystem integrity with relatively little cost, given that infrastructure projects are off stream and operational changes are the main focus. Level 2 results in increased adaptive capacity for the SSRB during low flow and drought periods. Buyouts in the floodplains increase long-term ability to withstand flood events by minimizing the potential risk of damage. Drought adaptation as part of Level 2 is tied largely to changes in reservoir operations and increased water storage capacity. Changes to the operations of headwater reservoirs in the Bow sub-basin enable water to be managed more effectively for water supply higher in the system, offering a wider range of potential benefits downstream without significantly reducing power generation. Interestingly, balancing Chin Reservoir with other irrigation-serving reservoirs also results in more water being stored higher in the system. The Chin Reservoir expansion increases overall capacity and ability to meet water demands later in the irrigation season. Similarly, increasing the storage capacity of the Red Deer sub-basin allows current and future demands to be met while maintaining WCOs and not further compromising the ecological health of the river.

The new storage through Level 3 substantially increases capacity for dealing with low flow periods and has the potential to increase adaptive ability during flood events. The Level 3 strategies would require a high level of infrastructure investment throughout the SSRB, and further detailed analysis would be needed to determine the feasibility and effects of these projects. Operations would have to be well-defined to optimize the use of these storage facilities. Parts of Level 3, such as reduced minimum flows during the most extreme drought periods, could be tested using additional modelling in the near term with the intent of refining the location and types of operations that may be needed to effectively implement this strategy during real-life drought situations.

Parallel to the development of the Roadmap, a short set of messages has been repeatedly reinforced throughout the collaborative work since 2010:

- Activity already underway to develop and promote a market system for temporarily trading or assigning water within irrigation districts and between licensees should continue to be supported. Licence transfers and trades to optimize use of existing licences is a way to manage water shortages, but people need to understand what their options are and how to take advantage of those options.
- The Bow River has a real and immediate need for a water bank that reserves approximately 10% of the annual storage and flows within TransAlta's reservoirs for release in accordance with downstream needs, including improving environmental flows during low flow periods while minimizing shortages to junior and senior licence holders. Establishing a mechanism for managing the water bank for flood and drought should be a high priority. This should be part of a broad watershed agreement between the GoA and TransAlta that includes the elements described in the pertinent Level 1 strategy of the Adaptation Roadmap.
- Each sub-basin needs a framework, beyond what is available today, for sharing shortages. Such frameworks should be developed soon, during "normal" conditions so that they are ready to implement before the next drought crisis arrives. Work is needed to determine what components such a framework should have and who needs to be part of it.
- Building on what is already being done, there are a number of practical and immediate actions that can be taken by watershed groups, irrigation districts, municipalities and others in coordination with the Province to expand the adaptive capacity of the SSRB using the infrastructure, regulations and policy in place today. These proactive efforts, for example piloting a higher winter carryover in Travers Reservoir, assessing the dam safety impact of a

higher operating FSL on St. Mary Reservoir, and modelling the hydraulic impacts of Room for the River conveyance opportunities along the Bow River, are each important steps in either implementing adaptation or preparing for implementation as warranted by the conditions in the basin.

Participants and collaborators contributed an enormous amount of time and expertise to this project and to the work on the sub-basins. Their insight and experience were invaluable to the success of these projects, and their enthusiasm for the collaborative process was remarkable. Alberta WaterSMART is deeply grateful to the individuals and organizations that played a part in building this Roadmap to take water management in the SSRB into the future.

This Roadmap provides a solid foundation on which to determine, refine and implement appropriate actions, adapt the plans, and invest in the science needed to better prepare the SSRB's water management system to respond when new demands and challenges arise.

We hope GoA will consider this report and find a permanent home for the Roadmap—someone to advance and own the Roadmap for the benefit of all Albertans. And we trust individual water managers, watershed groups, and water users will act on this opportunity to champion and support the advancement of effective water management strategies for their stakeholders and their watersheds.

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Appendix A: Reports Prepared for the SSRB

All of these reports are available on the WaterPortal at http://albertawater.com/work/research-projects.

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Appendix B: Project Contributors

These tables list the organizations and individuals that generously gave their time, energy and expertise to this work through many SSROM and sub-basin working group meetings. Being on this list does not mean that they necessarily supported all of the identified strategies. Any errors or omissions are those of the authors, not the contributors.

Contributors to the SSRB Integration Project

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Appendix C: A Brief History of the OASIS Modelling System

Simulation models have long been used in water resources management, starting with the increasing availability of mechanical calculators in the late 1940s and 1950s. In those days, simulation models were built in spreadsheets – physical paper sheets covered with numbers filled in manually, cell by cell, by very patient and careful engineers and their assistants. With the advent of computers, most simulations began to be written in programming languages, most notably FORTRAN. Each simulation was an independent program, and considerable time, care, and skill were required to manipulate assumptions and evaluate alternatives.

Beginning in the late 1970s general purpose simulation models began to be developed. HEC5, developed by the US Army Corps of Engineers, was one of the most successful of these programs. HEC5 allowed the user to input the parameters of pre-programmed forms of operating rules and other model features (e.g., size of facilities, changes in demands) as data rather than requiring program changes. Others, notably the Texas Water Development Board and John Labadie at Colorado State University, used the same general structure for a “general purpose” simulation, but used formal optimization techniques, the Out-of-Kilter algorithm (OKA) in particular, to describe the form of the operating rules. This increased computational efficiency at the cost of requiring that the operating rules be described in a very specific and often limiting form. Alberta Environment’s WRMM model was initially (and largely still is) limited to utilizing the forms of rules that can be solved using an OKA.

By the mid-1990s, HydroLogics Inc. had developed its own OKA based modelling system. That system was used to model the combined Federal and State water systems in California and the Yellow River in China, as well as numerous other applications. HydroLogics was well aware of the limitations of that modelling system. A project for the Alameda Water District in central California required more complex rules than could be handled with the OKA. HydroLogics substituted a Mixed Integer Linear Programming solver for the OKA, enormously increasing the flexibility in specifying rule forms and greatly enhancing computational efficiency. Still, some FORTRAN programming was required to enter new forms of rules.

The South Florida Water Management District’s (SFWMD) system contains about 150 structures, each with its own rules. The rules have many, many forms. In order to model that system, HydroLogics created a language for entering forms of operating rules as data, instead of requiring program modifications. The language, OCL (Operations Control Language) is very simple, has very few keywords, and a “natural syntax” based on the way in which operating rules are usually described – by operators and in manuals. This made the development of the SFWMD system model much, much more efficient. The resulting, fully data driven simulation system was named OASIS. 20 years later, it is still the state-of-the-art for water resources simulation model development.

The development of OASIS and OCL was guided by practical professionals with well over 100 years of combined experience in management of water resources. As a result, the model:

- automates the use of nonlinear functions to describe management rules and system responses,
- has built in features for dynamic linkages to other models,
- is designed specifically to utilize almost any form of external data without programming changes,

- automatically performs evaluation of operations based on hydrologic and meteorologic forecasts, including ensemble forecasts,
- stores all data and output in standard data base formats accessible to other programs
- can be run independent of its GUI (graphical user interface),
- includes post-processing programs to access and plot easily any and all model variables, including user defined variables,
- has extensive debugging features, and
- has an integrated gaming mode for testing real-time operational modification of rules, for operator training, and for educational purposes.

OASIS has been extensively for evaluating alternative management plans in places that include: South Florida, North Carolina, Kansas, New York City, Delaware River Basin, Susquehanna River Basin, Federal and State combined system in California, Lakes Rotoiti and Rotorua in New Zealand, South Saskatchewan River Basin in Alberta, Salt River Project in Arizona, and many others.

Many of these models explicitly incorporate or link to other models. The New York City System model, for example, includes:

- 24 managed reservoirs,
- operating rules based on real time National Weather Service Forecasts,
- dynamic linkages to hydrodynamic water quality models – simulated water quality is used to control operations on a time-step by time-step basis,
- snow-pack driven flood control operations with operating curves dependent on snowpack,
- full simulation of complex inter-state water allocation decrees and agreements, and
- hydropower operations and evaluation.

The NYC model has been used to support negotiations over modifications to inter-state operating agreements, to develop real-time responses to flood and water quality events, as well as for in-house development and enhancement of standard operating rules. Hundreds of millions of dollars of benefits have resulted in the form of increased reliability, elimination of proposed new water intake facilities (by meeting water quality constraints with existing facilities, and environmental benefits. The model has been so useful that a custom GUI has been developed to automatically obtain data needed to support daily operations from the NYC data system and from other sources on the web, and to streamline daily operator interaction with the model.

OASIS has also been used extensively to support dispute resolution processes. This kind of Computer Aided Negotiation has been widely applied:

- Susquehanna River Basin – New York, Pennsylvania, Maryland
- Cape Fear and Roanoake Basins in North Carolina
- Lakes Rotoiti and Rotorua in New Zealand
- Stanislaus River in California
- South Florida

Appendix D: SSRB Sub-Basin Model Descriptions

The text in this appendix provides more detailed descriptions of each of the sub-basin models mentioned in section 2.3. Schematics for each model were shown in that section.

The Bow River Operational Model (BROM)

The first component of SSROM, the Bow River portion was the result of the Bow River Project Consortium's work in 2010. It encompasses the Upper Bow system (primarily TransAlta storage reservoirs), major irrigation systems, major municipal uses, and all junior licensees. It also contained initial data for the downstream Saskatchewan River after the Bow/Oldman confluence. This was later replaced and refined in the OSSROM model. The Highwood/Sheep system was developed early on as a sub-model and integrated into BROM (despite major sections arguably belonging in the Oldman system) as it forms one of the major inflows to the lower Bow River.

Inflows for this system came from weekly naturalized data in WRMM, converted to daily (see BROM report for weekly-daily conversion details). Demands were sourced from WRMM or the IDM as appropriate, and scaled down or replaced by actual use data at the discretion of individual stakeholders. Based on conversations with those stakeholders, it was determined that water in this system should generally be distributed as follows:

1. Junior licences (it was found that these licences are so small that the IDs generally don't bother to call on them)
2. Municipal demands (voluntary agreements already exist ensuring the primacy of anthropocentric use over agricultural)
3. Major Irrigation Districts (WID, EID, BRID – roughly in that order)

The major irrigation districts perform some limited licence sharing, in which demands are given priority if they are unable to draw on irrigation district storage. Thus, although BRID is broadly junior to EID, there are some circumstances in which EID would forego some entitled water (choosing instead to rely on storage) in order to allow BRID's river-dependent demands to be met.

TransAlta, although rather junior in the system, has no requirement to utilize storage for purposes other than its own. Thus, when senior users call on their licences, they can at most call for natural inflows to pass through. TransAlta storage in the SSROM model attempts to follow a "normal pattern" that represents average elevation over the 2000-2010 period in each respective reservoir.

Although several minimum flow requirements exist in the system, the major two for the Bow River occur immediately past Bassano (11.3 m^3/s or 400 cfs) and into Calgary (35.4 m^3/s or 1250 cfs). The flow into Calgary isn't a legally entitled minimum flow per se, but rather representative of a consistent voluntary minimum applied by TransAlta.

The Oldman and South Saskatchewan River Operational Model (OSSROM)

OSSROM was the second major model developed and encompasses the Oldman River and Southern Tributaries (St. Mary, Belly, Waterton, and Saskatchewan Rivers). It also includes the Willow Creek and Chain Lakes system, although this is generally operationally separate. Willow Creek use has preference for all Willow Creek inflows. The Saskatchewan River portion of BROM was expanded upon and refined in OSSROM, and replaced BROM data for that part of the river during the eventual SSROM integration.

Inflows for this system came from weekly naturalized data in WRMM, converted to daily (see BROM report for weekly-daily conversion details). Demands were sourced from WRMM or the IDM as appropriate, and scaled down or replaced by actual use data at the discretion of individual stakeholders. Based on conversations with those stakeholders, it was determined that water in this system should generally be distributed as follows:

1. Municipalities,
2. Small demands
3. Irrigation lacking licence priority information
4. Large Irrigation Districts

Within the large irrigations districts, proper licence priority was applied using available licence information.

In contrast to the Bow, most storage in this system is directly managed by Alberta Environment and Parks. Thus the operations of the major OSSROM reservoirs are much broader in scope. Generally speaking, the reservoirs in this system are "balanced" (i.e., they attempt to maintain proportional storage). This means that St. Mary and/or Waterton reservoirs will attempt to meet needs downstream of Lethbridge if Oldman storage falls too low.

The major exception to this operation is Chin reservoir. Under current operations, Chin attempts to stay as full as possible all the time. The major constraint to this is the canal limitations in routing water to Chin, and the preference to route water only through the turbines in drops 4, 5, and 6.

Similar to the Bow, several minimum flow requirements exist and are modelled within the OSSROM system. The major driving flows, however, exist past Medicine Hat (28.32 m^3/s or 1000 cfs) and at several locations along the Oldman River utilizing the 80% of Fish Rule Curve (FRC) threshold. The FRC minimums primarily draw water from Oldman Reservoir, though inflows from other sources along the way are considered. At Medicine Hat, the minimum represents the lowest flow that still allows the city easy withdrawal. Ideally the minimum flow at the location would be 42.5 m^3/s (1500 cfs), but discussion with stakeholders concluded that is a target rather than an operational constraint. This is particularly important since the minimum flow from the Bow is only 11.33 m^3/s (400 cfs). The Oldman system must thus, in extreme droughts, make up the remaining 17 m^3/s (600 cfs).

One other important piece to note in the OSSROM systems is the international cross-border flows in the St. Mary River. The International Joint Commission reached an agreement on what the minimum flows from the United States must be, although historically the flows have rarely come close to these minimums. In order to maintain conservative assumptions it was decided to apply only the minimum "entitlement" flows in the base conditions for OSSROM.

The Red Deer River Operational Model (RDROM)

The RDROM was the final individual model constructed prior to the SSROM integration. It covers the area beginning at Vam Creek and extends all the way to the mouth and confluence with the Saskatchewan River. The model also includes a few smaller streams, such as Fallen Timber Creek and the Little Red Deer. In the initial RDROM modelling effort, interactions with the Bow (such as irrigation district return flows) were assumed static. Following SSROM integration, these returns became variable based on Bow River operations.

Although nominally “simpler” than the other systems, the Red Deer River presented a number of unique challenges not present in the other systems. Inflows remained based on Alberta Environment and WRMM data, but the Red Deer proved much more reliant on the First in Time, First in Right (or FITFIR) system. To that end, approximately 72.5% of water use was allocated using a strict licence priority system. The remaining 27.5% consisted of too many individual licences to remain in scope, and were thus left in the rough demand “groups” that the original WRMM maintained. As the Red Deer system remains an open basin with room for more licences, participants decided to generally consider operations in the context of full licence allocation. Water in the Red Deer system is thus provided as follows:

1. Senior Irrigators (identified by and remaining in WRMM blocks)
2. Major Demands (identified by and remaining in WRMM blocks)
3. Senior Licences (by licence date priority, pre- 17-Apr-1982)
4. Mid-Licence Irrigators (identified by and remaining in WRMM blocks)
5. Junior Licences (by licence date priority, post- 17-Apr-1982)
6. Junior Irrigators (identified by and remaining in WRMM blocks)
7. Minor Demands (identified by and remaining in WRMM blocks)

In contrast to the Bow and Oldman/Southern Tributaries, the Red Deer River only has one substantial source of available storage in the system - Gleniffer Reservoir, upstream of the city of Red Deer (Buffalo Lake is treated as a demand, see the Red Deer Report for more details). Gleniffer is not operated for traditional water supply, however. Storage in the Red Deer is primarily operated to maintain the Water Conservation Objectives (WCOs) in the system. That means that Gleniffer generally stores water in the spring, summer, and fall with the intention of releasing it over winter and maintaining a WCO minimum release of 16 m^3/s.

As an open basin, RDROM also experimented more with growth than the other systems. To that end, both specific (SAWSP, Acadia Valley) and generic growth was enabled in the model. Generic growth was modelled as occurring proportionally throughout the system. Importantly, however, all new demands are considered Junior to the WCO. At present, nearly all current demand is senior to the WCO.

The WCO represents the major driving minimum flow in the Red Deer system. Immediately below Gleniffer Reservoir it is maintained at 16 m^3/s. At the bottom of the system, however, it is only 16 m^3/s in the winter (Nov 1 to Mar 31), dropping to 10 m^3/s during the spring and summer (Apr 1 to Oct 31). For existing licences where the WCO is junior, the downstream minimum flow utilizes the older instream objective of 4.25 m^3/s for non-irrigation use or 8.5 m^3/s for irrigators.

Appendix E: Additional Background on the Frankenflow Time Series Derivation

To derive the Frankenflow streamflow dataset, an extreme high and low flow analysis was carried out using hydrometric monitoring site data along the Oldman, Bow, and Red Deer rivers. Sites were grouped into Headwater, Mid-Plains/Prairie, and Confluence catchments based on their drainage area and proximity to their mountain headwaters. High flows were defined by annual maximum daily flows, while low flows were defined by annual minimum 7-day average flows, and extreme events were calculated by fitting data to a Log-Pearson Type III distribution. Maximum flows generally peak at the furthest downstream, confluence catchments, except for the Red Deer River, where flows are significantly greater at its Mid-Plains/Prairie site (Drumheller).

Grouped probability analysis finds that the probability of extreme high flows is between two and four times higher in the Mid-Plains/Prairie catchments than in the headwater or confluence catchments. This is a function of significantly higher correlations between high flows at the Mid-Plains/Prairie catchment sites. Maximum flow correlations do not translate to extreme low flow conditions, suggesting that the probability of all sub-basins flooding is substantially higher than all three sub-basins being in drought conditions. This analysis suggests that the Frankenflow time series must use SSRB-wide low flow years for defining droughts – where not all sub-basins are necessarily in the worst drought on record. The analysis also suggests that a combination of years can be used for defining floods – where all three sub-basins are in the worst flood on record. However, for consistency, we used an SSRB-wide analysis to define droughts and floods. A ranking analysis was used to assess streamflow records for the whole SSRB, where the highest and lowest annual flows were determined.

Appendix F: Additional Adaptation Strategies

PART 1: SSRB Integration Project

The strategies in Part 1 were identified in the SSROM project as having less promise. Those marked with an asterisk (*) are not currently modelled in the SSROM.

Bow sub-basin:

- Raise full supply levels in Barrier and/or Upper Kananaskis Reservoirs*
- Construct a channel for the Highwood River through the town of High River*
- Restore Spray Reservoir to full design capacity*
- Reduce minimum flow through Calgary in severe drought*
- Manage return flows from WID through Crowfoot Reservoir*
- Increase Little Bow/Travers storage capacity* (This change was already underway at the time of the project)

OSSK sub-basin

- Build a Lower Belly Reservoir*
- Build Meridian Dam downstream of Medicine Hat *
- Oldman reservoir flood control operations*
- Raise St Mary Reservoir by 1m by increasing the dam height
- Build new reservoir for flood control downstream on Oldman River*

Red Deer sub-basin

- Dry dams for flood control in the main steam and tributaries*
- Expand Dickson Dam
- Higher level of protection for aquatic ecosystem e.g. 85% natural flow threshold *
- Investigate the need for berming between the Clearwater and Raven rivers to prevent a catastrophic overflow *

All strategies identified in Parts 2, 3 and 4 are listed in the following sections.

PART 2: Bow sub-basin project

Adaptation strategies for current and future climates in the Bow sub-basin are noted in the following list (Alberta WaterSMART 2013).

Strategies to benefit the watershed under normal conditions

- Implement preferred scenario with trigger
- Adjust fill times for three largest TransAlta reservoirs (Minnewanka, Spray and Upper Kananaskis)
- Reduce season consumptive demand in Calgary
- Implement seasonal consumptive reuse in Calgary
- Move municipal licences from Highwood/Sheep system to Bow River
- Increase winter carryover in Travers Reservoir
- Implement additional demand reduction in irrigation districts

Strategies for adapting to severe drought conditions

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

Combined strategies

1. Preferred scenario (water bank + stabilized Lower Kananaskis Lake) + reduce minimum flow through Calgary (from Oct to Dec with low storage trigger)
2. Preferred scenario (water bank + stabilized Lower Kananaskis Lake) + adjust fill times for three largest TransAlta reservoirs + increase winter carryover in Travers Reservoir
3. Preferred scenario (water bank + stabilized Lower Kananaskis Lake) + move municipal licences from Highwood/Sheep system to Bow River + implement additional demand reduction measures in Calgary and in irrigation districts
4. Preferred scenario (water bank + stabilized Lower Kananaskis Lake) + adjust fill times for three largest TransAlta reservoirs + increase winter carryover in Travers Reservoir + increase off-stream storage in the WID (Bruce Lake)
5. Combination 4 + increase on-stream storage downstream of Bassano (Eyremore Reservoir)
6. Stepwise combination for maximum drought adaptation

PART 3: OSSK sub-basin project

Strategies in the following list emerged from the OSSK sub-basin project (Alberta WaterSMART 2014). They are categorized as having varying degrees of promise and some were also identified in the SSROM project.

Strategies with most promise

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

Strategies with some promise

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

Strategies with limited promise

- 1m additional storage in existing St. Mary Reservoir
- Chin Reservoir expanded without balancing

- Downstream dry dam for flood control
- Simple triggered shared shortages
- Lower FSL in all AEP reservoirs by 2m when needed until July 1
- Developing a storage reserve

Combined strategies

- 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

The following ideas also emerged from the OSSK project, some of which were modelled in very limited detail and others were not pursued at all for various reasons. A number of these offer local opportunities to improve resiliency.

- Allocate water for increased urban growth and development
- Castle River (Canyon Site) Reservoir
- Dam upstream of Cardston/Lee Creek
- Double municipal licence demands and double return flows
- Expand LNID acreage by 30%, reduce return flows from 18% to 5%
- Expand RID acreage by 20%, reduce return flows from 15% to 5%
- Expansions to Ridge
- Further use of Irrigation District licence amendments
- Headwaters tourism opportunities
- Hydro development opportunities
- Increase canal capacity on diversion from Belly to St. Mary
- Increase flow at Lethbridge
- Increase on-farm efficiencies in irrigation districts
- Kenex site in LNID
- Oldman Dam case study
- Plug and play demands
- Possible flooding of non-urban land
- Regional impacts of oil and gas
- Reservoir at Taylorville site (SMRID)
- Restore and improve river flows on Southern Tributaries
- Risk management for expansion
- Several small reservoirs
- Spillway on St. Mary main canal
- Stafford spillway to Oldman River
- Surcharge canals for short periods under high demand conditions
- Transfer from BRID canal
- Upper Belly Reservoir
- Upper Oldman (Gap) Reservoir
- Use all reservoirs for original purposes (i.e., storing water for use)
- Water reuse opportunities
- West Raymond Reservoir

PART 4: Red Deer sub-basin project

The strategy ideas in the list below were identified in the Red Deer sub-basin modelling project (Alberta WaterSMART 2015).

Strategy ideas related to managing demand

- Demand thresholds of 335,000 dam^3, 445,000 dam^3, and 550,000 dam^3 with WCO reductions
- SAWSP and Acadia Valley new demands and current allocations
- Conservation of water through best management practices and increased efficiency.
- Effects of Temporary Diversion Licences
- Distribution of shortages
- Back calculate possible growth (population and economic) that could occur without environmental degradation
- Back calculate the maximum growth possible prior to construction of new infrastructure

Strategy ideas to enhance environmental flows

- Dynamically adjusting the WCO to provide water for environmental flows
- Functional flows for riparian vegetation
- High level of protection for aquatic ecosystems (e.g., 85% Natural Flow threshold)
- Make the WCO the most senior priority
- Flow stability and flow augmentation to benefit fish communities
- Wetland restoration (through effective policy implementation)

Strategy ideas related to infrastructure operations

- Dynamic operations of Dickson Dam to meet downstream demands and WCO
- Downstream storage for water supply
- Dickson Dam release buffer for meeting demand
- Off-stream storage for irrigation
- Expanding Dickson Dam storage
- Modifications to Dickson Dam structure

Strategy ideas for flood mitigation

- Increase local flood protection
- Dry dams
- Upstream dams in places where dry dams have been proposed

Of these, seven individual water management strategies were shown to have the most promise, and some were also explored as part of the SSROM project:

- Implementation of functional flows
- Dickson Dam operations to meet WCO (downstream focus)
- Dickson Dam operations to meet WCO and new demands (downstream focus)
- Additional storage
- Local flood protection
- Water conservation
- Application of land use best management practices
- Effective implementation of Alberta's Wetland Policy