Water Storage Opportunities in the South Saskatchewan River Basin in Alberta

Submitted to:
SSRB Water Storage Opportunities
Steering Committee
Lethbridge, Alberta

Submitted by:
AMEC Environment & Infrastructure,
a Division of AMEC Americas Limited
Lethbridge, Alberta

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WATER STORAGE OPPORTUNITIES IN THE SOUTH SASKATCHEWAN RIVER BASIN IN ALBERTA

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July 2014

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Executive Summary

Water supply in the South Saskatchewan River Basin (SSRB) in Alberta is naturally subject to highly variable flows. Capture and controlled release of surface water runoff is critical in the management of the available water supply. In addition to supply constraints, expanding population, accelerating economic growth and climate change impacts add additional challenges to managing our limited water supply.

The *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009) identified re-management of existing reservoirs and the development of additional water storage sites as potential solutions to reduce the risk of water shortages for junior license holders and the aquatic environment. Modelling done as part of that study indicated that surplus water may be available and storage development may reduce deficits.

This study is a follow up on the major conclusions of the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009). It addresses the provincial *Water for Life* goal of “reliable, quality water supplies for a sustainable economy” while respecting interprovincial and international apportionment agreements and other legislative requirements.

The Red Deer River Sub-basin is open for new allocations. The Red Deer Sub-basin has disproportionately high number of junior urban municipal allocations that make this particular use vulnerable to deficits in low runoff years. Refining or modifying operation of the Dickson Dam may reduce or eliminate current or future deficits to the Water Conservation Objectives (WCOs) and junior consumptive users in the Red Deer Basin.

The Oldman, Bow and South Saskatchewan sub-basins are not accepting new applications. Sharing the use of TransAlta Corporation (TransAlta) hydro power reservoirs to meet in-stream and consumptive uses in the Bow River Sub-basin has shown some promise (The Bow River Project Research Consortium, 2010). The Oldman Sub-basin has commitments for substantial additional use on the Piikani and Blood First Nations Reserves, and in the Oldman River Reservoir area. Some of these commitments, in addition to the future increases in irrigation and non-irrigation water use in the Oldman Sub-basin may be difficult to fulfill without a means to make additional water available (AMEC, 2009).

The study focused the opportunities for new storage opportunities within the Oldman River Sub-basin. Operational modifications of existing reservoirs offer limited opportunity to reduce deficits in the Oldman River Sub-basin. Rationale for new storage within this basin is based on a high degree of allocation in this basin, high variability of water supply, and previous work that suggests new storage may improve water security to users, particularly junior private irrigation and non-irrigation licenses, to reduce deficits to in-stream objectives and First Nations developments.

Previous studies identified 48 undeveloped potential storage sites within the Oldman Sub-basin. Of the 48 sites, 42 sites could or would not be built for a number of reasons including site no longer existing due to construction of another site, site would impact USA, site is too small or provides no significant benefits, etc.

Three of the remaining six potential sites locations were modeled and the results compared to the base case to quantify any benefits received. The three sites are Kimball, a 125,815 dam^3 reservoir located on the Upper St. Mary River just south of the international boundary with the USA; Belly, a 493,393 dam^3 reservoir located on the Belly River just upstream of the confluence with the Oldman River; and Chin, an existing off-stream reservoir which would be raised to increase useable storage by 74,000 dam^3. The base case was based on the following conditions:

- Updated water license data.
- Demand database making a distinction between demands on regulated streams and those on unregulated streams.
- 2030 projected demands, including full irrigation district expansion within their existing licensed allocation (24% increase within the Oldman Sub-basin since 2009).
- Meeting commitments for projects on First Nation Reserves.
- Meeting commitments for other large private projects with water license applications.
- Meeting municipal needs for population projections to year 2030.
- Meeting current legislation and policy for apportionment, WCO and others. The current policy is that flows in excess of the WCO objective (MAX(0.45×Q_{nat} or 1.1× in-stream objective [IO])) and downstream priority licensed uses would be available for storage.

The Chin, Belly and Kimball (upper St. Mary) sites modelling results were analyzed to determine reductions in magnitudes and frequencies of deficits to junior licencees, WCOs, and First Nations. Irrigation district deficits were maintained at the acceptable levels observed in the Base Case scenario.

Developing storage at Kimball or expanding storage at Chin does not appear justifiable under the above criteria. There is little improvement to the WCO with either of these reservoirs. The reliability of supply to the junior private irrigation on the lower St. Mary River improves but consists of only 270 ha and has acceptable performance in the Base Case. The reduction in deficits to junior non-irrigation sourced from the lower St. Mary River may be over stated by the model because all or most of these users that are served through the works of Environment and Sustainable Resource Development (ESRD) and the irrigation districts have alternative arrangements for water supply security based on their own storage or district storage.

The modelling results for Belly and Kimball indicated that they are not suitable developments under ESRD's current WCO policy. The reservoirs would rarely fill, have frequent low levels and be ineffective during periods of drought when they would be most needed, as storage levels would be low or empty. The lower St. Mary, and West Raymond, and smaller Chin sites were not modelled because they would essentially realize similar (or worse) results as the Kimball and Chin scenarios. Additional modelling considered a change in the current ESRD policy. If the ESRD WCO policy was amended to require only 1.1×IO releases, then the Belly River site may be viable.

Modelling indicates that by contributing to consumptive needs along the Oldman and South Saskatchewan rivers, the Belly Reservoir Project allows the Oldman Reservoir to better meet consumptive needs upstream of the Belly River confluence, including the committed Summerview project. Although it may benefit the Piikani project, the Piikani First Nation has an agreement with the province that assures a water supply from the Oldman Reservoir is availalble. Modelling indicates that a reservoir sized between 160,000 and 324,000 dam^3 would adequately achieve some benefit for water for existing junior users and Piikani First Nation. Oversizing the storage capacity could possibly contribute to flood mitigation. The ramifications and required mitigation would need to be further explored if the WCO policy is amended and there is interest in developing the site.

The conclusion derived from the modelling results is that new storage sites in the Oldman River Sub-basin would not significantly benefit junior licencees or WCOs or support First Nations development if they are operated to adhere to the current licensing priorities and legislative/regulatory regime.

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1.0 INTRODUCTION

1.1 Background

In the early years of Alberta's development, the Dominion Government was responsible for managing water resources and for encouraging irrigation development under the *North West Irrigation Act* (Dominion of Canada, 1894). In 1915, the *Irrigation Districts Act* (Alberta, 1915) authorized farmer owned and operated irrigation co-operatives. Water use was governed by the principle of prior appropriation or "first-in-time, first-in-right" under both acts.

Responsibility for managing natural resources, including water, was transferred from the federal government to Alberta in 1930 and the province's *Water Resources Act* (Alberta, 1931) was passed. That legislation was replaced by the *Water Act* (Alberta, 1999), which provided greater flexibility and allowed new approaches to manage water where demand was high and supply was limited.

The *Water Act* (Alberta, 1999) is based on four principles:

1. Crown ownership of water and suppression of individual riparian rights;
2. Government control of the allocation and use of water;
3. An allocation process designed to promote development; and
4. A first-in-time, first-in-right priority system designed to protect existing development.

In August 2006, the Alberta Government approved a water management plan for the South Saskatchewan River Basin (SSRB) which includes the watershed or land drained by the South Saskatchewan River and all its tributaries located within Alberta. The plan recommended in-stream flow requirements to be the maximum of either 45% of the natural flow or 110% of the previously established in-stream objectives (IOs) for the Red Deer, Bow, Oldman, and South Saskatchewan river sub-basins. These new requirements are referred to as water conservation objectives (WCOs). At the same time, the Bow, Oldman, and South Saskatchewan river sub-basins were closed to any further allocation of water. A year later, a regulation was approved reserving all unallocated water in the Bow, Oldman, and South Saskatchewan river sub-basins for the following purposes only:

- For use by First Nations;
- To contribute toward meeting a WCO;
- For storage development if storage is used for protection of the aquatic environment or improving the availability of supply for existing license holders; and
- For applications still outstanding on the date the regulation was filed 13 August 2007.

1.2 Study Objectives

Water supply in the SSRB is naturally subject to highly variable flows and frequent low flows. Capture and release of surface water runoff is critical in the management of available water supply. In addition to supply constraints, expanding population, accelerating economic growth and climate change impacts add additional challenges to managing our limited water supply. Other challenges include the existing infrastructure, the level of water allocations, and the water licensing and regulatory framework impact water security in the basin.

Current estimated surface water consumption by all sectors in the SSRB in Alberta at 1.9 million dam^3, of which irrigation represents 84% of the total actual water use. Studies suggest that irrigation districts will maximize the use of their existing licensed water allocation through intensification and internal expansion. Increased use of these large, senior licenses will result in increased water withdrawals and thereby reduce water availability and increase deficits for junior licenses. Municipal and commercial demands will also increase but the impacts will likely be small compared to changes in demands for irrigation.

The *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009) identified re-management of existing reservoirs and the development of additional water storage sites as potential solutions to reduce the risk of water shortages for junior license holders and the aquatic environment. Modelling done as part of the study indicated that surplus water may be available and storage development may reduce deficits.

This study is a follow up on the major conclusions of the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009). It will address the provincial *Water for Life* goal of "reliable, quality water supplies for a sustainable economy" while respecting inter-provincial and international apportionment agreements and other legislative requirements. The study will evaluate the opportunities and impacts of potential storage sites within the SSRB by assessing social, economic, environmental, and operational constraints according to a thoughtful ranking method.

The *Water Storage Opportunities Study* will evaluate and summarize existing reports and basin modelling information on reservoir storage opportunities within the Bow River, Red Deer River, Oldman River, and South Saskatchewan River sub-basins. It will also provide technical evaluations of new storage development options.

The objectives of the study are:

- To provide a summary of current and future water requirements in the SSRB, including license purposes, priorities, amounts, frequency and magnitude of deficits, and the ability of users to manage water deficits.
- To provide a summary of the current and future water supply in each of the four sub-basins.
- To provide an overview of existing reservoirs within the SSRB, including information on licensee, licensed purpose, capacity, priority, and current uses and their role in water management.
- To summarize current operation practices and requirements of existing reservoirs and outline potential opportunities for their re-management.
- To present a rationale for additional storage.

- To compile a summary of potential sites within the SSRB, and criteria and weightings to compare sites.
- To model and evaluate the outcomes and results of key potential sites for their ability to:
  - Improve security of water to existing users.
  - Support downstream aquatic environment.
  - Support future needs of First Nations.
  - Mitigate impacts of climate change.
- To review recent work on the Bow River Sub-basin (the Bow River Operational Model [BROM]) and assess the results for new storage opportunities identified in that study in the context of this project.
- To provide a comprehensive set of conclusions and recommendations which may influence policy and provide advice to decision makers on future water storage development in the basin.
- To provide a summary of information gaps and recommendations for further work.

1.3 The South Saskatchewan River Basin

The SSRB extends from the Rocky Mountain Continental Divide in Alberta and Montana into Saskatchewan where the South and North Saskatchewan rivers join to form the Saskatchewan River (**Figure 1.1**). The South Saskatchewan River begins at the confluence of the Bow and Oldman rivers; the Red Deer River enters it just east of the provincial boundary.

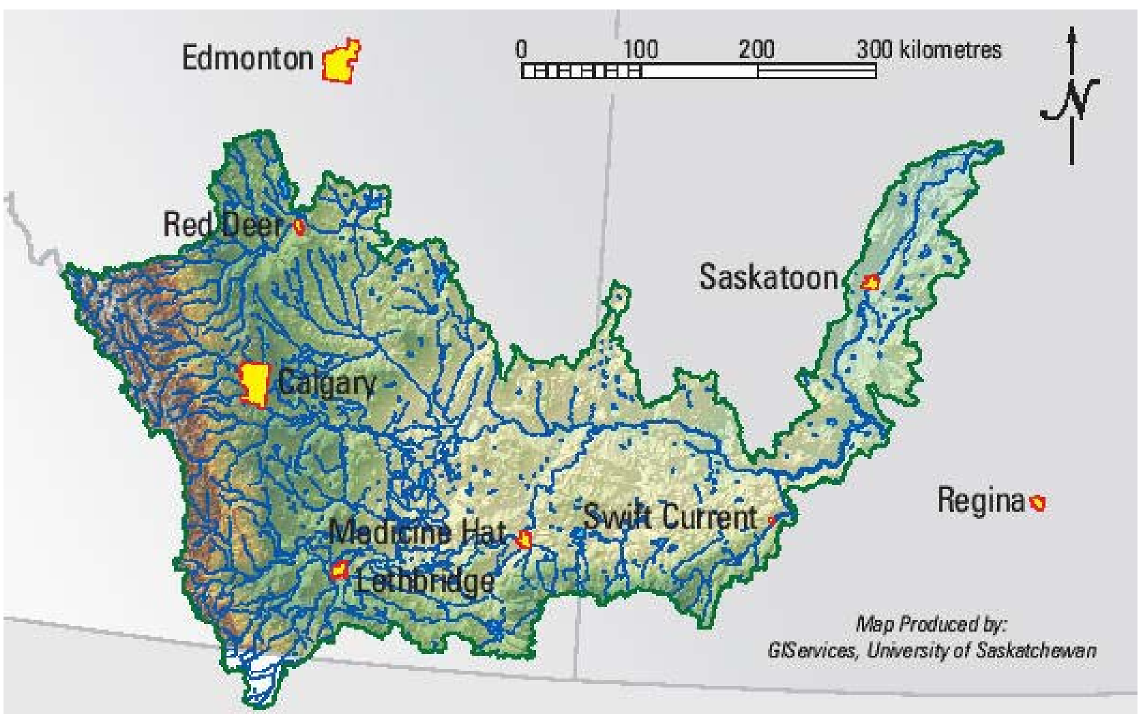


Figure 1.1 South Saskatchewan River Basin

The waters of the SSRB are shared with the United States and Saskatchewan. The sharing arrangements and Alberta's performance in meeting its obligations are discussed in the *South Saskatchewan River Basin Water Supply Study* (AMEC, 2009).

More than 1.6 million people live and work within the Alberta portion of the SSRB, almost 90% in urban areas including Calgary, Lethbridge, Medicine Hat, and Red Deer. In different ways and in varying degrees they all depend on water for household use, employment, waste disposal, recreation, as a power source, and for many other needs. Demand for water will continue to increase due to economic and population growth and may also be influenced by climate change.

Significant water storage reservoirs and diversion works exist within the SSRB in Alberta. They are owned and operated by the province (Alberta Environment and Sustainable Resource Development [ESRD]), TransAlta Corporation (TransAlta), irrigation districts, First Nations, and private entities.

Many of these reservoirs are for multi-purpose use such as:

- Maintaining in-stream flows for protection/enhancement of water quality and the aquatic ecosystem;
- Municipal and industrial water supply;
- Irrigation
- Improved water management;
- Flood control;
- Hydropower;
- Recreation; and
- Fisheries.

Variability of the monthly and yearly supply makes good water management critically important. Uncertainty about the effect of climate change on snow pack conditions and annual precipitation makes it even more challenging to predict future water supply and demand.

Overall, the terrain in the SSRB ranges from mountainous to semi-arid plains, with elevations from 3,500 to 600 m above sea level. Topographic and landscape features influence the hydrologic, meteorological, and historic characteristics of the various ecological regions within the sub-basins affecting the climate, stream flow, soils, vegetation, and settlement patterns.

In Alberta, the SSRB comprises four major sub-basins - the Red Deer River Sub-basin, the Bow River Sub-basin, the Oldman River Sub-basin, and the South Saskatchewan River Sub-basin (**Figure 1.2**). The sub-basin drainage characteristics are outlined in **Table 1.1**.

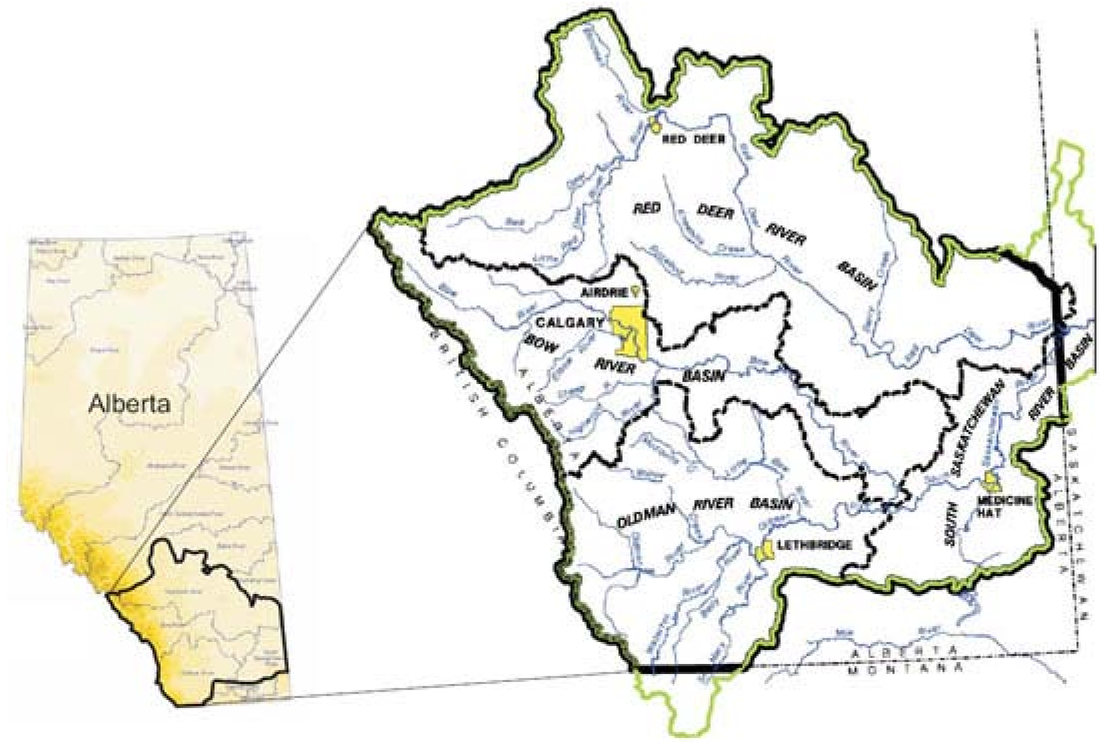


Figure 1.2 Sub-basins of the South Saskatchewan River Basin in Alberta

The Red Deer River Sub-basin is the largest in area, but only a small portion lies in the mountain and foothills regions. Because of this it has a lower mean annual flow volume and a runoff yield about one quarter of the volume and yield of the Bow River Sub-basin. Since the completion of the Dickson Dam and the creation of Gleniffer Lake in 1983, Red Deer River flows are now regulated, primarily to increase low winter flows to improve water quality in the river system.

Table 1.1
Drainage Characteristics of the Major Sub-basins in the SSRB

Sub-basin	Gross Drainage Area (km^2)	Effective to Gross Drainage Ratio	Effective Drainage Area (km^2)	Mean Annual Flow (dam^3)	Annual Precipitation (mm)	Runoff Yield (mm)
Red Deer River	46,800	69%	32,300	1,666,000	393	51
Bow River	25,300	76%	19,200	3,829,000	538	199
Oldman River	27,500	76%	20,900	3,343,000	488	160
South Sask. River	13,200	50%	6,600	4,000	278	1
Total SSRB	**112,800**	**70%**	**79,000**	**8,842,000**	**435**	**112**

The Bow River Sub-basin has the highest runoff yield primarily because a larger percentage of its area lies in the Canadian Rockies. Flow regulation and water use patterns have had a significant impact in the Bow River Sub-basin. Winter flows are increased significantly due to releases from hydro-electric reservoirs located upstream of Calgary while summer river flows are significantly reduced due to reservoir filling and diversions, predominantly for irrigated agriculture.

Historically, the Oldman River Sub-basin has been more susceptible to droughts than either the Red Deer River or Bow River sub-basins and the flows have been much more variable.
The portion of the sub-basin that is located in the Canadian Rockies is about half of that in the Bow River Sub-basin. Almost the entire drainage area of its three main tributaries; the St. Mary, Belly, and Waterton rivers, is effective and runoff yields are high. The combined flow of these tributaries represents 57% of the Oldman River's total flow. Summer flows have significantly decreased in the Oldman River Sub-basin due to flow regulation and withdrawals, dominated by diversions for irrigated agriculture.

The smallest of the four sub-basins within Alberta, the South Saskatchewan River Sub-basin is mostly undulating grasslands, has the lowest annual precipitation and little runoff.

1.4 South Saskatchewan River Basin in Alberta Water Supply Study

In the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009) simulation modelling was the key analytical tool used to explore the relationship between current and future water supply and demand in the SSRB. Modelling also provides some insight into how well the water supply and the existing infrastructure and its operation meet the current and projected needs.

The Water Resource Management Model (WRMM) was used for the modelling. The WRMM is a water management model that simulates water supply (hydrology) and demand. ESRD and others use the WRMM in managing and planning water resources in the SSRB.

In long-range planning studies, such as the *Approved Water Management Plan for the South Saskatchewan River Basin* (AENV, 2006) water supply is based on reconstructed natural flows (recorded flows plus historical uses, changes in storage and diversions) in the rivers for the entire SSRB. Against this, any water demand scenario for the SSRB can be tested.
The model tracks thousands of possible water diversions and determines possible implications for water users and river flows. The model is able to represent senior and junior licence priorities (based on in-stream flow conditions on licences), international and inter-provincial agreements on water sharing, policies (such as in-stream flow objectives), water evaporation and seepage, and water infrastructure (e.g., dams, canals, weirs) and the rules under which they operate. Results of simulations are usually

> **Licence priority** distinctions are adhered to in WRMM simulation modelling. In this study, **senior licences** are considered to be those that have no significant in-stream flow constraints. These are generally the older licences. **Junior licences** are those that have significant in-stream flow constraints that were established in the 1980s and occasionally modified since that time.
> The most recent in-stream flow constraints are termed WCOs which were established throughout the SSRB in 2006 (AENV, 2006).

shown as the numbers and patterns of years in which water supply was insufficient for licensees to meet their needs.

Inputs to the model include the physical system, the configuration of streams, canals and water management infrastructure, water supplies, consumptive and in-stream demands, licence priorities, water management policies, and infrastructure operating plans.

In the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009), the WRMM was configured as follows:

- Current actual and projected (year 2030) uses were used for most demands, rather than licensed demands (licensed allocation minus licensed return flow). Since actual uses are often less than water entitlements under existing licences, where possible the study assessed actual supply/demand relationships and impacts on source streams, rather than the relationship and impacts if licences had been used to their full legal entitlement.
- The IOs and WCOs, specified in the approved SSRB management plan and subsequent regulatory decisions, were used for all scenarios modelled.
- A climate change scenario was tested, using the most recent projection of climate impacts on water supply in the SSRB.

Four scenarios were formulated and modelled to identify water supply and demand issues. All four respect existing water licence priorities and priorities for the IOs and WCOs as established in the SSRB management plan. Scenarios 1 and 3 are pertinent to this study.

Water Conservation Objectives
Phase 2 of the SSRB Water Management Plan addressed the need for and magnitude of WCOs to protect all or part of the aquatic environment and other in-stream uses of water. The objective was to strike a publicly acceptable balance between environmental protection and consumptive use to support economic development and quality of life.

1.4.1 Scenario 1: Current Water Supply and Demand Levels

Scenario 1 is used as a basis of comparison for other scenarios. It is the existing situation with current water supply and demand. It does not include proposed, unlicensed projects nor does it include committed projects for the Piikani and Siksika First Nations. In keeping with licences issued to date, it includes full development in the Highwood/Little Bow Project and partial development in the Pine Coulee Project.

Irrigation demand for this scenario assumes the current level of on-farm (80% of optimal crop use) and irrigation district efficiencies and water application rates. Irrigation represents approximately 84% of the total use. The current net use is 1,981,100 dam^3. **Table 1.2** summarizes the demands.

Table 1.2
Scenario 1 - Current Estimated Actual Net Water Demand and Allocation in SSRB by Sub-basin (dam^3)

	Red Deer	Bow	Oldman	South Sask.	Total Demand in SSRB	% of Total Demand	SSRB [3] Allocation
Municipal	12,100	43,700	8,800	3,500	68,100	3.4%	776,400
Irrigation	48,900	748,200	826,200	42,600	1,665,900	84.1%	3,668,100
Livestock	18,000	8,000	16,000	8,000	50,000	2.5%	62,000
Commercial	1,000	7,300	5,000	700	14,000	0.7%	18,500
Petroleum	18,100	1,200	800	4,100	24,200	1.2%	66,800
Industrial	13,900	20,100	0	17,200	51,200	2.6%	71,400
Other	55,600	8,500	43,600	0	107,700	5.4%	304, 500
Total Net Use	**167,600**	**837,000**	**900,400**	**76,100**	**1,981,100**	**100%**	**4,987,700**

Note:
[1] Net demand = gross withdrawal from the source minus return flow.
[2] Based on AMEC, 2009.
[3] Total current allocation is 5,403,000 dam^3. Allocations that do not affect flows in the main-stream rivers were excluded in this study.

1.4.2 Scenario 3: Current Water Supply and Additional Increased Future Demand

Scenario 3 simulates increased estimated demand projected to the year 2030. It is based on:

- Population projections and current levels of per capita water use.
- Additional private irrigation projects to which the province has committed.
- Potential new infrastructure – enlarged Langdon Reservoir and a new Bruce Lake Reservoir, both within the Western Irrigation District (WID).
- A level of irrigation expansion within the irrigation districts that is believed to be sustainable.

The scenario factors in improved efficiencies reduced return flow and higher (more optimal) on-farm crop water applications. The irrigated area increased by 32% compared to Scenario 1 for the WID, Eastern Irrigation District (EID) and Bow River Irrigation District (BRID; Bow River Sub-basin) and 19% above Scenario 1 for the Mountain View, Leavitt, Aetna, United, Lethbridge Northern, St. Mary River, Magrath, Raymond, and Taber irrigation districts in the Oldman River Sub-basin.

The demands are shown in **Table 1.3**.

Table 1.3
Scenario 3 - Modelled Net Water Demand for Year 2030 in SSRB by Sub-basin (dam^3)

	Red Deer	Bow	Oldman	South Sask.	Total Demand in SSRB	% of Total Demand	SSRB[3] Allocation
Municipal	26,700	68,900	12,800	4,300	112,800	3.7%	776,400
Irrigation	112,900	1,256,600	1,214,700	43,900	2,628,100	86.5%	3,668,100
Livestock	33,800	15,100	30,000	11,300	90,200	3.0%	62,000
Commercial	1,700	12,300	8,400	1,300	23,700	0.8%	18,500
Petroleum	18,000	700	700	4,100	23,400	0.8%	66,800
Industrial	13,900	20,100	0	17,200	51,200	1.7%	71,400
Other	55,600	8,500	43,600	0	107,700	3.5%	304, 500
Total Net Use	**262,600**	**1,382,200**	**1,310,200**	**82,100**	**3,037,100**	**100%**	**4,987,700**

Note:
[1] Net demand = gross withdrawal from the source minus return flow.
[2] Based on AMEC 2009
[3] Total current allocation is 5,403,000 dam^3. Allocations that do not affect flows in the main-stream rivers were excluded in this study.

1.4.3 Key Study Findings

The following are the key findings from the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009):

- Alberta has consistently met its commitment under the Prairie Provinces Master Agreement on Apportionment.
- Future reductions in natural streamflow volumes are more likely than increases for all streams in the SSRB.
- Current actual surface water consumed by all sectors in the SSRB in Alberta is estimated at 1,981,000 dam^3, which is approximately 40% of the water allocated for use.
- In most of the basins, there is a high frequency of deficits to current junior water users and to the WCOs.
- By 2030 water use could increase from the current 1,981,000 to 3,040,000 dam^3.
  This magnitude of increase would occur if irrigation districts were to implement, under their existing license allocations, the level of expansion modelled in Scenario 3.
- Potential increases in future water use, primarily within the irrigation districts, would increase deficits to WCOs and junior users.
- Climate change is likely to reduce streamflows in the SSRB. Reduced streamflows would have a significant impact on irrigation district expansion in the Oldman River Sub-basin.

- Refining or modifying the operations of existing storage reservoirs in the Red Deer River and Bow River sub-basins could potentially reduce or eliminate deficits to the WCOs and junior consumptive users in these basins.
- Other non-structural measures include improved irrigation efficiencies, reduced return flows, market based water allocation transfers, and deficit sharing. The collective benefits of these measures would not likely completely address current and future issues.
- A preliminary review of the hydrology of the Red Deer River, Bow River, and Oldman River sub-basins indicates there is unused flow available at locations in each sub-basin. Additional storage and flow regulation can assist in reducing deficits to IOs, WCOs and junior consumptive users.

These key findings have led to this investigation of potential additional water storage in the SSRB as new storage could reduce deficits to existing users, address environmental needs, and mitigate against future impacts from climate change.

2.0 SUMMARY OF CURRENT AND FUTURE WATER SUPPLY AND DEMANDS

2.1 Water Supply

The unique topography and landscapes of the SSRB influence the climate, soils, vegetation, quantity and quality of stream flow, settlement patterns and population distribution. A relief map (**Figure 2.1**) indicates that the basin comprises mountainous terrain in the west, descending to foothills, parkland, prairie, and semi-arid plains in the east. The five principal eco-regions of the SSRB are shown and their characteristics are described in the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009).

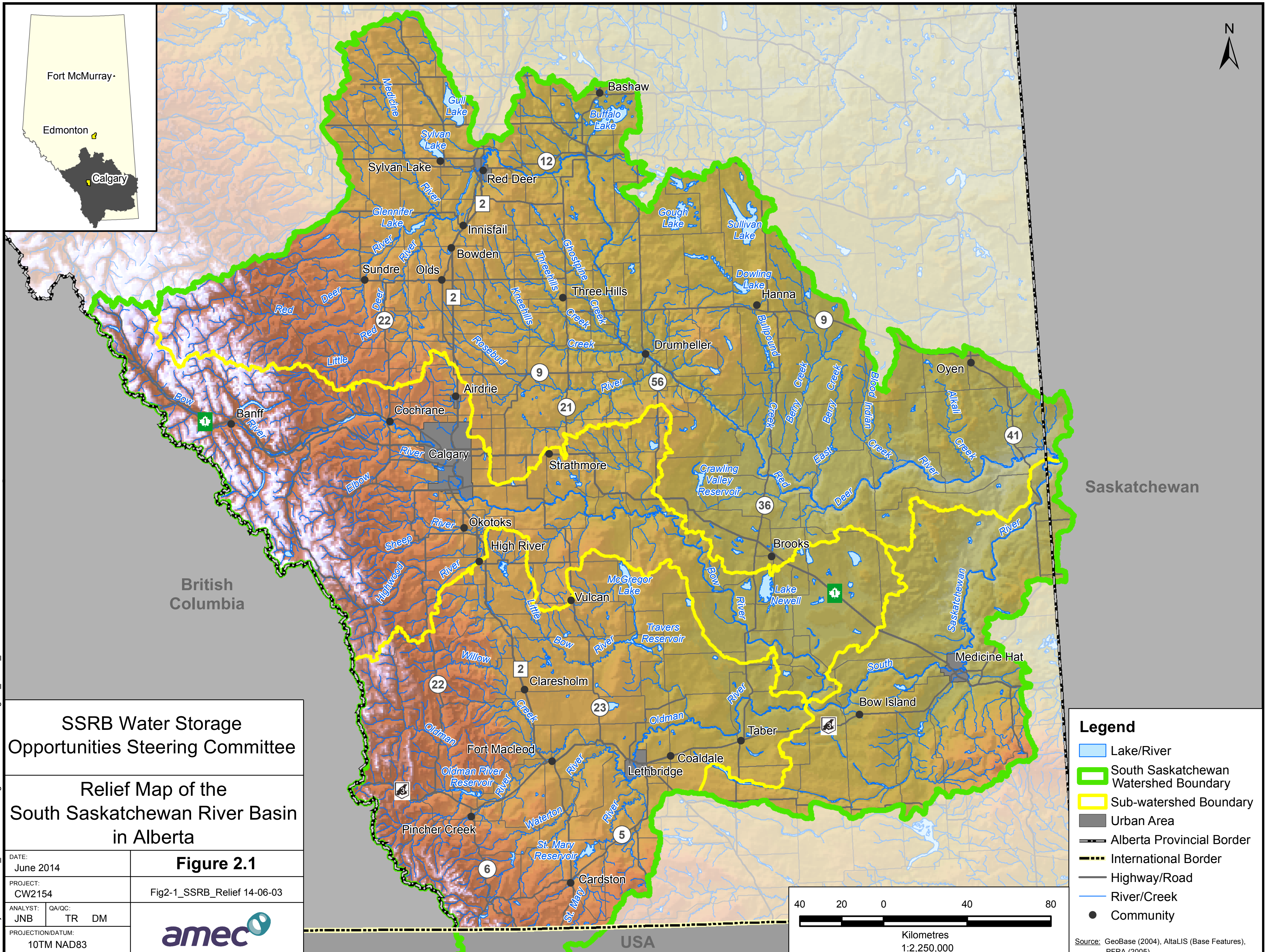
The SSRB in Alberta has a drainage area of 112,800 km^2 and has a median annual flow of about 8,842,000 dam^3. The SSRB is comprised of four sub-basins – the Red Deer River, Bow River, Oldman River, and South Saskatchewan River.

Hydrologic characteristics of each of the four sub-basins are given in **Table 2.1**. The gross drainage area (GDA) is the entire area that may be expected to contribute to flow in a stream at a specific location under very wet conditions. The boundaries of the GDA are usually defined as the drainage divide between adjacent watersheds. The effective drainage area (EDA) defines the area that may be expected to contribute to flow in a stream at a specific location during a median flow year (a year with an average return period of 2 years). The EDA excludes marshes and sloughs that trap water and prevent it from contributing to stream flow in median and lower runoff years. The EDA/GDA ratio is an indicator of how well a watershed is drained.
A watershed with a high EDA/GDA ratio usually has steeper slopes, more highly developed drainage patterns and less natural storage areas than a watershed with a lower ratio. An area is considered to be non-contributing or closed if there is no outflow even under extremely wet conditions. Sounding Creek Basin and the Pakowki Lake Basin, north and south of the SSRB, respectively, are examples of closed basins.

The 75^{th}, 50^{th}, and 25^{th} percentile flows provide an indication of the normal range of flows in the river systems. The 75^{th} percentile flows are those that would be exceeded in 25% of the years, on average. In these higher flow years, one would expect that there would be opportunities to replenish storage in reservoirs that could be used to supplement downstream flows in subsequent lower runoff years. The effective yield of a watershed is an indicator of precipitation and drainage conditions in a watershed. The watersheds with a high percentage of area within the high mountain and foothill regions (high precipitation and excellent drainage patterns) have the highest effective yields.

The coefficient of variation (CV) of annual stream flow serves as an indicator of the potential for flow regulation to secure annual water supplies for consumptive use as well as for the protection and enhancement of the aquatic ecosystem. In general, the higher the CV, the greater is the need for storage to make water available for use.

A brief discussion of the hydrologic characteristics of each of the sub-basins follows. Additional information can be found in the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009).



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SSRB Water Storage Opportunities Steering Committee

Relief Map of the South Saskatchewan River Basin in Alberta

DATE: June 2014

Figure 2.1

PROJECT: CW2154

Fig2-1_SSRB_Relief 14-06-03

ANALYST: JNB QA/QC: TR DM

PROJECTION/DATUM: 10TM NAD83

amec

Legend

- Lake/River
- South Saskatchewan Watershed Boundary
- Sub-watershed Boundary
- Urban Area
- Alberta Provincial Border
- International Border
- Highway/Road
- River/Creek
- Community

Source: GeoBase (2004), AltaLIS (Base Features), PFRA (2005)

Table 2.1
Statistical Characteristics of Stream Flow of Major Rivers in the South Saskatchewan River Basin in Alberta

	Red Deer River near Bindloss	Bow River near Mouth	Oldman River near Mouth[5]	Waterton River near Stand Off	Belly River near Mouth [5]	St. Mary River near Lethbridge	S. Sask. River at Medicine Hat[5]
Drainage Areas							
Gross Drainage Area (GDA) (km^2) [2]	46,800	25,300	27,500	1,730	3,580	3,530	56,400
Effective Drainage Area (EDA) (km^2) [2]	32,400	19,200	20,900	1,710	3,290	3,310	41,400
Ratio EDA/GDA	69%	76%	76%	99%	92%	94%	73%
Median Runoff Yield over EDA (mm) [3]	49	200	160	431	323	256	153
Annual Naturalized Flow							
75 Percentile Flow (dam^3)	2,195,800	4,513,600	4,163,100	858,600	1,242,400	1,014,500	8,494,400
50 Percentile Flow (dam^3)	1,603,800	3,833,100	3,342,800	736,500	1,062,500	848,900	7,123,800
25 Percentile Flow (dam^3)	1,164,000	3,306,600	2,659,500	634,000	895,900	742,100	5,938,600
Annual Variance of Naturalized Flow							
Mean (dam^3)	1,830,600	3,955,600	3,476,330	755,600	1,103,700	881,900	7,416,700
Standard Deviation (dam^3)	841,600	964,100	1,139,800	218,600	341,600	241,400	1,979,400
Coefficient of Variation (CV) [4]	46%	24%	33%	29%	31%	27%	27%

Notes:

1. All flow data are based on Alberta Environment and Sustainable Resource Development's reconstructed natural flows, 1912 to 2009.
2. GDA and EDA are taken from the Water Survey of Canada database.
3. Median Runoff Yield (mm) = Median Annual Natural Flow (dam^3) divided by the Effective Drainage Area (km^2).
4. CV = Standard Deviation (dam^3) divided by the Mean (dam^3).
5. Belly River near Mouth includes the tributary Waterton River flows, Oldman River near the mouth includes tributary Belly and St. Mary River flows, South Saskatchewan at Medicine Hat includes tributary Oldman and Bow River flows.

2.1.1 Red Deer River Sub-basin

The Red Deer River Sub-basin is the largest of the three primary sub-basins (Red Deer, Bow and Oldman). The effective drainage area of the Red Deer Sub-basin is 32,400 km^2, which is 69% of the gross drainage area. The effective-to-gross drainage ratio is considerably lower than that of the Bow and Oldman river sub-basins due to relatively flatter slopes and poorly developed drainage in some parts of the basin. There are two small glaciers in the headwaters of the Red Deer River; the Drummond and the Bonnet.

The median natural flow for the Red Deer River and its median runoff yield over the effective drainage area are much lower than for the Bow and the Oldman river sub-basins (**Table 2.1**). Its small area within the Rocky Mountain and Foothills eco-regions is a primary reason for a relatively low average annual precipitation, annual flow and runoff yield compared with the other two primary basins.

The CV of annual reconstructed natural flow is the highest of all the major sub-basins, including the southern tributaries of the Oldman River. The high variability in annual natural flow indicates that storage development and regulation of the flow would be helpful to better match available supply with demand on both a seasonal and annual basis. The Red Deer River has been regulated since construction of the Dickson Dam in 1983. The dam is operated primarily for flow regulation to make water available for consumptive use and to improve downstream water quality.

A comparison of plots of the weekly mean reconstructed natural flow and recent recorded flow provides an indication of how water use, diversions and reservoir regulation has impacted the flow regime. The weekly mean reconstructed natural flow and the recorded flow for the Red Deer River near Bindloss (near the mouth) for period 2000 to 2009 are shown on **Figure 2.2**. The period 2000 to 2009 was selected to approximate existing regulation and water use conditions. The figure shows the impact of flow regulation at Gleniffer Lake and downstream consumptive use within the basin. The recorded flow includes return flow of Bow River water from the WID and EID from May through September. **Figure 2.2** shows that winter flows are increased and the peak flow is decreased by regulation of Gleniffer Reservoir, but overall, there is little change in the flow volume because of the low level of water use in the Red Deer River Sub-basin and the contribution of return flows from the WID and EID.

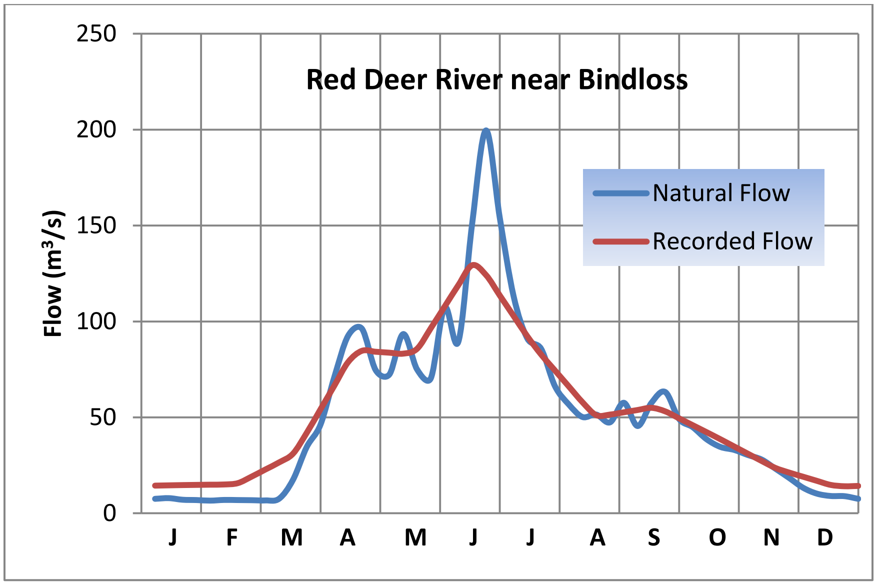


Figure 2.2 Red Deer River near Bindloss 2000 to 2009 Weekly Mean Flow

2.1.2 Bow River Sub-basin

The Bow River Sub-basin has a gross drainage area of 25,300 km^2 (**Table 2.1**). It is the smallest of the three primary sub-basins. Its effective drainage area is 19,200 km^2 which is 76% of the GDA. There are several large glaciers in the headwaters of the Bow River including the renowned Victoria Glacier above Lake Louise and the Bow Glacier above Bow Lake.

The median natural flow for the Bow River at its mouth is 3,833,100 dam^3 (1912 to 2009), the highest of the three sub-basins. Its median runoff yield over the effective drainage area is 200 mm, about four times the yield of the Red Deer River Sub-basin. The Bow River Sub-basin has a very large Rocky Mountain area, which accounts for its high average annual precipitation (538 mm) and runoff yield. The Bow River has the lowest CV of the three primary sub-basins due to the regulatory effect of large natural lakes in the basin and supplemental flows from glacial ablation.

Figure 2.3 shows a plot of average weekly flows for the Bow River near its mouth from 2000 to 2009. The difference between the natural and recorded flows show the impact of flow regulation of six TransAlta hydro-power reservoirs as well as diversions for consumptive use, primarily for the WID, EID, and BRID. The six reservoirs are operated primarily for power production. During the 10-year period 2000 to 2009, annual diversions from the Bow River to the three irrigation districts ranged from 762,300 to 1,522,700 dam^3. The average annual irrigation districts' diversion during that period was 1,063,000 dam^3.

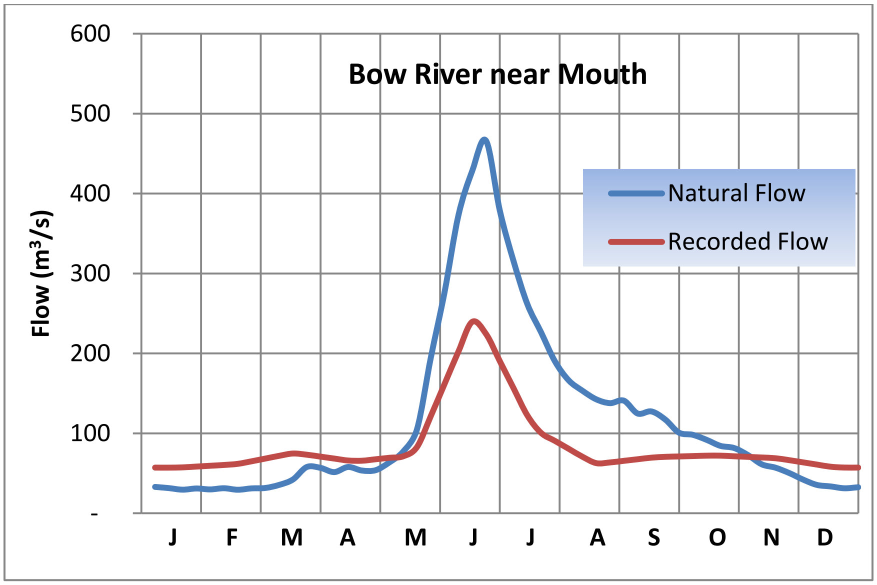


Figure 2.3 Bow River near Mouth 2000 to 2009 Weekly Mean Flow

2.1.3 Oldman River Sub-basin

The Oldman River Sub-basin has a gross drainage area of 27,500 km^2 (**Table 2.1**). Its effective drainage area is 20,900 km^2 which is 76% of the gross drainage area. The effective-to-gross drainage ratio is the same as the Bow River Sub-basin. There are glaciers in the Montana headwaters of the St. Mary River, a major tributary to the Oldman River.

The median natural flow for the Oldman River near its mouth is 3,342,800 dam^3 (1912 to 2009). Its median runoff yield over the effective drainage area is 160 mm, which is much higher than the Red Deer Sub-basin but lower than the Bow River Sub-basin. Its area within the Rocky Mountain eco-regions is about 50% of the corresponding area in the Bow River Sub-basin. Average annual precipitation in the Oldman River Sub-basin is about 488 mm.

Oldman River flows are highly variable from year to year with a CV of 33%. This variability is much higher than that of the Bow River but lower than the variability of the Red Deer River.

Figure 2.4 is a plot of average weekly flows for the Oldman River near its mouth from 2000 to 2009. The difference between the natural and recorded flows shows the impact of flow regulation of three provincial reservoirs (Waterton, St. Mary and Oldman reservoirs) and diversions for consumptive use, primarily for nine irrigation districts in the sub-basin. Diversions for the nine irrigation districts during the 10-year period 2000 to 2009 ranged from 721,200 to 1,245,700 dam^3. The average annual diversion during the period was 953,300 dam^3. Like the Bow River, the Oldman River has a single-peaked hydrograph. However, the Oldman River flows increase earlier in the spring, peak at higher flows and recede earlier to winter levels than the Bow River.

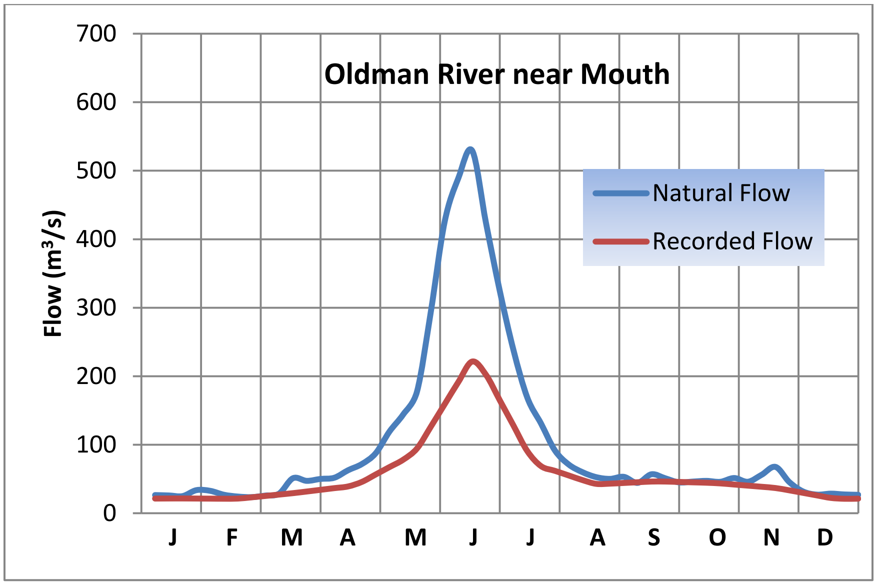


Figure 2.4 Oldman River near Mouth 2000 to 2009 Weekly Mean Flow

The St. Mary and Belly rivers are important tributaries of the Oldman River, and the Waterton River is a major tributary of the Belly River. The headwaters of these three rivers are in both Montana and Alberta. Almost the entire drainage area of each stream is effective and the runoff yields are very high. The combined flow of the three rivers support an extensive amount of development south of the Oldman River between Lethbridge and Medicine Hat, including the water requirements of eight of the nine irrigation districts in the Oldman River Sub-basin and many communities and industries within those districts. The flow of the three streams constitutes 57% of the mean flow of the Oldman River near its mouth.

2.1.4 South Saskatchewan River Sub-basin

The South Saskatchewan River Sub-basin has a gross drainage area of 13,200 km^2 of undulating grassland. Its effective-to-gross drainage area ratio is the lowest of the four sub-basins at about 50%, due to flat slopes and poorly developed drainage. Average annual precipitation in the South Saskatchewan River Sub-basin (278 mm) is the lowest of all four sub-basins. The sub-basin's contribution to runoff to the South Saskatchewan River is negligible in most years. The exceptions are years like 2010 when heavy precipitation in the Cypress Hills during June resulted in unusually high flows in Ross, Bullshead, and Seven Persons Creeks causing extensive flood damage in Medicine Hat and nearby communities.

The flow for the South Saskatchewan River at Medicine Hat is essentially the sum of the Bow River and Oldman River at their respective mouths. The median annual natural flow of the South Saskatchewan River at Medicine Hat is 7,123,800 dam^3. Recorded flows are affected by the collective impact of all infrastructure and water uses in the Bow and Oldman river sub-basins (**Figure 2.5**). Typically, the South Saskatchewan River rises slightly in late March and early April because of snowmelt runoff on the plains, but the highest flows typically occur in

June, with relatively low flows from August through April. The CV for natural flow is 27% which, as expected, is between the CVs for the Bow and Oldman rivers at their respective mouths.

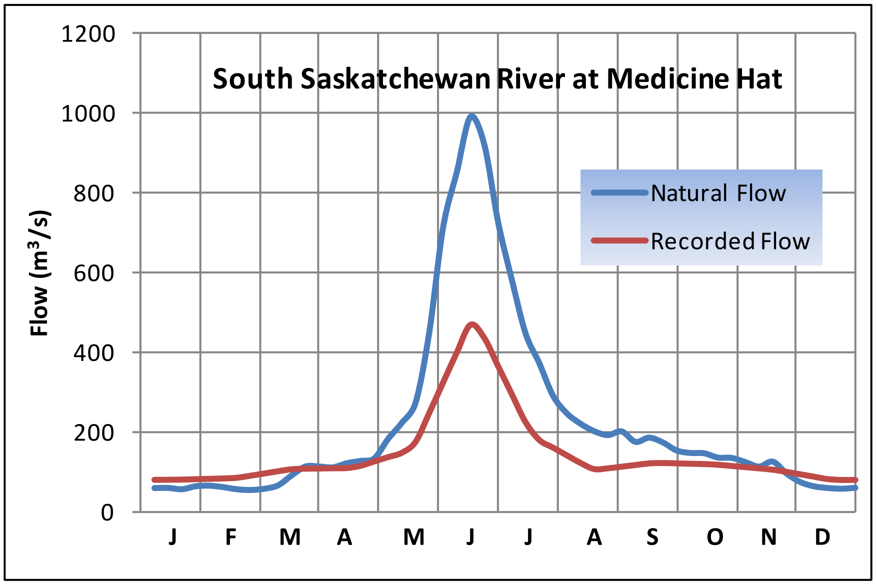


Figure 2.5 South Saskatchewan River at Medicine Hat 2000 to 2009 Weekly Mean Flow

2.1.5 Climate Change Impacts

The *South Saskatchewan River Basin in Alberta Water Supply Study* (AEMC, 2009) study concluded that climate change is likely to reduce streamflows in the SSRB. If stream flow volumes decreased, deficits to irrigation district demands in the Bow River Sub-basin would increase, but performance would be acceptable for all expansion scenarios considered in that study. However deficits to district irrigators in the Oldman Sub-basin would exceed the tolerable limits at the scenarios with the highest level of expansion.

If stream flows decrease, the WCO indexed to streamflow would increase. The ability to meet these reduced WCOs would improve throughout the SSRB. If stream flows decrease, deficits to junior water users throughout the entire SSRB would significantly increase.

The Prairie Adaptation Research Collaborative (PARC) has been developing climate change scenarios for some time. General Circulation Models (GCMs) simulate Pacific Ocean temperatures, which drive the Pacific decadal oscillation (PDO). The PDO is one of the main factors which control precipitation and streamflow patterns in southern Alberta and reflects complex atmospheric connections. Streamflow change can be estimated as a function of the ocean-atmosphere oscillations that drive the natural variability of the regional climate and hydrology. Recent work done as part of the *Southern Saskatchewan River Basin Adaptation to Climate Variability Project* using GCMs evaluated several climate scenarios in attempt to determine what future changes in the water supply may be expected. From the modelling, it was projected that spring will occur earlier in the year throughout western North America, including southern Alberta (approximately 8.6 days earlier); in particular snow melt runoff timing will advance. This advance in peak flow would have serious implications for reservoir and irrigation management during the growing season.

2.2 Water Demand

In Alberta's portion of the SSRB water is used for a variety of purposes to sustain the economy, quality of life and environmental values.

Water use in the SSRB could increase substantially by 2030 through continued licensing in the Red Deer River Sub-basin, and approval of licence applications, follow-up on committed projects, and expansion of water use within existing allocations in all four sub-basins. A primary conclusion from the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009) is that potential increases in future water use, primarily within the irrigation districts, would increase deficits to in-stream flow needs (WCOs) and to junior licence holders. This study is a continuation of the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009) by further examining opportunities to modify the operation of existing storage, and/or constructing additional storage to mitigate deficits at the projected 2030 demand level.

> In this study, **mainstem demands** refer to demands on regulated streams that can be met by releases from an existing or a possible future storage reservoir. They exclude demands that are sourced from unregulated tributaries to the mainstem streams. Demands supplied from irrigation district infrastructure rely on diversions from storage of mainstem water during non-irrigation periods. For this reason, they are considered mainstem demands.

A review of *Water Act* licences is an appropriate starting point for estimating water demands. Licences define the sources, locations, and purposes of water use in the basin, and provide an indication of the magnitude of water uses. The ESRD database used in the 2009 AMEC study made no distinction between demands on regulated and unregulated streams and was out of date by 2013. This would affect the demand distribution throughout the sub-basins and prevent quantification of the benefits that could accrue through operational changes or development of new storage. A significant effort was required to update and improve the database.

Water allocations and demands for irrigation districts, private irrigation, urban municipal users, and other users were determined for each mainstem reach and tributaries. The process involved reviewing, sorting, and compiling data from ESRD's Licence Viewer. The results of the review, current volumes allocated for various purposes, and estimates of future (2030) water use are provided in **Tables A.1, A.2, A.3** and **A.4** in **Appendix A**. The results are discussed below for each of the four sub-basins.

2.2.1 Red Deer River Sub-basin

The Red Deer River WRMM modelling reaches, their main tributaries, provincial control structures, urban municipal and other key water users are shown in **Table 2.2**. The modelling reaches define the geographical areas for estimating water demands along the river and interpreting the results of simulation modeling. Water demand estimates by river reach, priority and purpose are shown in **Table A.1** in **Appendix A**. A summary of water allocation for irrigation, and allocation and demand for other uses, in the Red Deer River Sub-basin is provided in **Table 2.3**.

Table 2.2
Red Deer River Mainstem Reaches, Tributaries, Control Works and Key Water Users

Red Deer River Reach	Tributaries	Provincial Control Works	Cities, Towns, Villages
Upstream of Gleniffer Reservoir	Panther River, James River, Raven River, Burnt Timber Creek, Fallentimber Creek		Sundre
Gleniffer Reservoir to upstream Medicine River	Little Red Deer River	Dickson Dam	
Medicine River to upstream Blindman River	Medicine River		Red Deer, MV RWSC, NRD RWSC
Blindman River to Joffre	Blindman River	Gull Lake Diversion, Joffre Industrial Projects	
Joffre to Nevis		Buffalo Lake Diversion	
Nevis to Delburne		Special Areas Water Supply Project (SAWSP) Diversion (future)	Stettler, H12/21 RWSC, SM RWSC
Delburne to Drumheller	Ghostpine Creek, Kneehills Creek, Threehills Creek		Drumheller, A RWSC, Three Hills, Trochu, Morrin, Munson
Drumheller to upstream Sheerness Diversion	Rosebud River		
Sheerness to upstream Berry Creek	Bullpound Creek	Sheerness and Deadfish Diversions	HK RWSC
Berry Creek to Bindloss	Berry Ceekr, Blood Indian Creek, Alkali Creek		
Bindloss to Sask border	Kennedy Creek	Acadia Irrigation Diversion (future)	Empress

Table Notes:
Regional Water Service Commissions (RWSC):
- MV = Mountain View (Innisfail, Bowden, Olds, Didsbury, Carstairs, Crossfield);
- NRD = North Red Deer (Blackfalds, Lacombe, Ponoka);
- H12/21 = Highway 12/21 (Bashaw, Alix, Clive);
- SM = Shirley McClellan (Big Valley, Rochon Sands, White Sands);
- A = Aqua (Irricana, Acme, Beiseker, Carbon, Linden);
- HK = Henry Kroeger (Hanna, Oyen, Youngstown, Cereal, Craigmyle, Delia).
- Some of the communities served are future expansions.

There are no irrigation districts in the Red Deer River Sub-Basin.

The Red Deer Sub-basin is unique in that it has three levels of licence priorities. Referring to **Table 2.3**, the “yellow” priorities are assigned licences that do not have significant in-stream flow constraints (by today’s standards). The “blue” priorities represent licences that post-date the priority of Dickson Dam (August 1977). Dickson Dam has been operated to meet the Red Deer IOs. The operator of the project (ESRD) can exercise its licence priority when necessary to ensure the IOs can be met. The third level (purple) is the most junior of the three priorities and applies to the allocations that are subject to the WCOs established with a priority date 1 May 2005 (AENV, 2007a, 2007b, 2007c).

The Red Deer is the only sub-basin that has no irrigation district allocation, although both the WID and EID irrigate large portions of land within the sub-basin using Bow River water. Also, the Red Deer Sub-basin has received in the order of 100,000 dam^3 annually of return flow from the WID and EID in recent years (AMEC, 2009; Prairie Provinces Water Board, 1995).

There have been a number of regional municipal projects developed in the Red Deer River Sub-basin, all subject to the WCOs. The Red Deer River is the only sub-basin with projects subject to WCOs. Recorded data indicate that they would experience winter deficits if the WCOs were enforced. This was confirmed in the modelling done in 2009 (AMEC, 2009).

Table 2.3
Summary of Water Allocations/Demands in the Red Deer River Sub-basin

Main-stream Reaches/Tributaries	Private Irrigation		Urban Municipalities (Cities, Towns, Villages)			Other Purposes[4]	
	Allocation (dam^3)	Irrigated Area (ha)	Allocation (dam^3)	2030 Actual Demand (dam^3)	2030 Actual RF (dam^3)	Allocation (dam^3)	Return Flow (dam^3)
Mainstem Red Deer River	13,240	3,216	25,373	61,168	32,351	6,019	301
	53,736	9,612	37,325			76,265	1,650
	79,127	16,296	24,781			38,674	
Red Deer River Tributaries[5]	15,810	5,732	-	-	546	53,127	5,460
Total Red Deer Allocations/Demands	161,913	34,885	87,479	61,168	32,897	177,186	7,411

Notes:
1. Senior priority licences not subject to significant in-stream requirements.
2. Junior priority licences subject to Dickson Dam operation and IOs.
3. Junior priority licences subject to WCOs. Applicable to licences issued after May 1, 2005.
4. “”Other Purposes” include water management, industrial, commercial, habitat enhancement recreation, and stock watering projects.
5. Municipal return flows originate from communities on tributaries. Their water sources are aquifers.

Licence allocations within the Red Deer Sub-basin are evenly distributed among private irrigation, urban municipal, and “other” purposes. Allocations for other purposes are much higher in the Red Deer Sub-basin than in the Bow or Oldman river sub-basins. This is largely due to the number of waterfowl projects in the eastern part of the basin, and industrial/ commercial projects associated with the Joffre-Prentiss petro-chemical complex. A significant statistic for the Red Deer River Sub-basin is that about 73% of its mainstem allocation volumes have a priority of either junior IO or junior WCO. This is a much higher proportion (absolute volume 305,000 dam^3) of junior priority than the Bow and Oldman river sub-basins. It is also significant that many of the allocations that are junior to the WCO are for recently established regional water supply projects delivering Red Deer River water to urban municipalities. Based on the 2009 AMEC study, these projects would be vulnerable to water supply deficits in water-short years, primarily in the winter months.

About 17% of Red Deer River Sub-basin allocations are sourced from unregulated tributaries, which is significantly higher than the proportion of tributary development in the Bow or Oldman river sub-basins. New projects identified in the Red Deer Sub-basin include:

- The SAWSP project in the special areas – future allocation about 40,000 dam^3, including 3,237 ha of irrigation. A licence application has been submitted. A formal environmental impact assessment is being conducted.
- The 10,900 ha Acadia Irrigation Project – future allocation about 43,000 dam^3. A preliminary design has been carried out (MPE, 2005a) and an application has been submitted.
- Private irrigation development along the Red Deer River valley – future allocation 7,350 dam^3. A preliminary study of irrigation potential has been conducted (Acres, 1988). It is anticipated that about 1,100 ha will be developed by private initiatives.

2.2.2 Bow River Sub-basin

The Bow River WRMM modelling reaches and their main tributaries, provincial control structures, urban municipal and other key water users are shown in **Table 2.4**. In this sub-basin, the Highwood River tributary is modelled as well as the mainstem Bow River. Water use estimates by river reach, priority and purpose are shown in **Table A.2** in **Appendix A**. A summary is provided in **Table 2.5**.

Table 2.4
Bow River Mainstem Reaches, Tributaries, Control Works and Key Water Users

Bow River Reach	Tributaries	Provincial Control Works	Irrigation Districts	Cities, Towns, Villages
Upstream of Bearspaw Reservoir	Pipestone River, Cascade River, Spray River, Kananaskis River, Ghost River, Jumpingpound Creek			Lake Louise, Banff, Exshaw, Canmore, Cochrane
Bearspaw Reservoir to upstream Elbow River				Calgary
Elbow River to upstream WID Weir	Elbow River, Nose Creek			Calgary
WID Weir to Bonneybrook WWTP		Western Headworks	WID	Rockyford, Standard
Bonneybrook WWTP to upstream Fish Creek				
Fish Creek to upstream Highwood River	Fish Creek			
Highwood River to upstream Carseland Weir	Highwood River, Sheep River	Women's Coulee and Little Bow Diversion Works		Turner Valley, Black Diamond, Okotoks, Longview, High River
Carseland Weir to upstream Bassano Reservoir	West Arrowwood Creek, East Arrowwood Creek, Crowfoot Creek	Carseland-Bow River Headworks	BRID	Champion, Lomond, Milo, Vauxhall
Bassano Reservoir to Mouth		Bassano Dam (EID)	EID	Tilley, Brooks, Bassano, Rosemary, Duchess

Table Notes:

1. Women's Coulee and Little Bow Diversion Works divert Highwood River water to the Little Bow River for irrigation and other purposes.
2. WWTP = Waste Water Treatment Plant
3. Bassano Dam is owned and operated by the EID. It supplies water for irrigation and a number of communities, industries, recreation uses and wetland projects within the District.
4. Irrigation Districts (ID): W = Western, BR = Bow River, E = Eastern

Table 2.5
Summary of Water Allocations/Demands in the Bow River Sub-basin

Main-stream Reaches/Tributaries	District Irrigation Allocation (dam^3)	Private Irrigation		Urban Municipalities (Cities, Towns, Villages)			Other Purposes[3]	
		Allocation (dam^3)	Area (ha)	Allocation (dam^3)	2030 Actual Demand (dam^3)	2030 Actual RF (dam^3)	Allocation (dam^3)	Return Flow (dam^3)
Mainstem Red Deer River	1,606,490	14,897	3,897	366,368	272,057	206,915	60,954	16,169
	86,344	45,458	10,078	7,234			63,383	549
Red Deer River Tributaries	-	8,941	4,295	117,570	67,824	54,258	35,658	14,905
Total Red Deer Allocations/Demands	1,692,833	69,296	18,271	491,172	339,881	261,173	159,994	31,623

Notes:
1. Senior priority licences not subject to in-stream requirements of significant magnitude (by today's standards).
2. Junior priority licences subject IOs applicable to licences issued since 1983.
3. “”Other Purposes” include water management, industrial, commercial, habitat enhancement recreation, and stock watering projects.

Allocations and water demands in the Bow River Sub-basin are dominated in volume by licences issued to irrigation districts, most of which are senior licences. In recent years the Bow River districts have withdrawn much less water than their full allocations, at least in part because they have become more efficient (AIPA, 2009). Simulation modelling conducted in the 2009 AMEC study, found that with their existing allocations and continued improvements in efficiencies. The Bow River districts could expand their current irrigated area by about 30% without significant impact to themselves. Such increased usage by the districts would adversely impact WCOs and junior licensees.

District irrigation represents about 70% of total mainstem allocations in the basin. This is followed by about 20% for urban municipalities, 7% for other purposes,and 3% for private irrigation. The City of Calgary is the dominant urban municipal use. Waterfowl conservation, primarily within irrigation districts is the primary “other” use. The volume of water allocated on tributaries to the Bow River is low, accounting for only about 7% of total allocations. This accounting of allocations does not include diversions from the Highwood River to the Little Bow River. Diversions are made as required to meet licensed demands in the Little Bow Basin, which is a tributary of the Oldman River. During the 2008 to 2011 period, Highwood River diversions to the Little Bow River have averaged 47,000 dam^3. Diversions from the Highwood River are subject to Highwood in-stream flow constraints. An operation plan for the diversion works has been worked out in a lengthy process involving government officials and a public advisory committee with representation from both the Highwood and Little Bow sub-basins (Highwood Diversion Plan Public Advisory Committee, 2006). In this study, the Highwood-Little Bow system is modelled separately from the Bow River in accordance with the approved operation plan and in-stream flow constraints.

Allocation volumes (and hence demands) are markedly different in the Bow River Sub-basin than in the Red Deer River Sub-basin, but are very similar to the Oldman River Sub-basin.

Expansion of 12,000 ha of irrigation on the Siksika Indian Reserve has been identified as a new project within the sub-basin.

2.2.3 Oldman River Sub-basin

Oldman River WRMM modelling reaches and their main tributaries, provincial control structures and key water users are shown in **Table 2.6**. In addition to the mainstem Oldman River, five tributaries are modelled:

- Waterton, Belly, and St. Mary rivers (commonly referred to as the southern tributaries);
- Willow Creek; and
- Little Bow River, including Mosquito Creek.

Table 2.6
Oldman River Mainstem Reaches, Tributaries, Control Structures and Key Water Users

Oldman River Reach	Tributaries	Provincial Control Structure	Irrigation Districts	Cities, Towns, Villages
Upstream of Oldman Reservoir	Crowsnest River Castle River			Municipality of Crowsnest Pass, Pincher Creek, Cowley
Oldman Reservoir to Brocket	Pincher Creek	Oldman River Dam		Pincher Creek
Brocket to Upstream LNID Weir	Beaver Creek, Indianfarm Creek			
LNID Weir to Willow Creek		LN Headworks	LNID	Fort Macleod, Nobleford, Barons, Claresholm, Granum
Willow Creek to Upstream Belly River	Willow Creek	Pine Coulee Reservoir		
Belly River to Upstream St. Mary River	Belly River Waterton River	Waterton Dam Belly River Diversion MVLA Headworks	UID, MVID, LID, AID, BTAP	Cardston, Hill Spring, Glenwood
St. Mary River to U/S Little Bow River	St Mary River	St Mary Dam SMP Headworks	MID, RID, SMRID, TID	Lethbridge, Coalhurst, Coaldale, Picture Butte, Magrath, Raymond, Stirling, Taber, Barnwell, Bow Island, Warner, Foremost
Little Bow River to Mouth	Little Bow River Mosquito Creek	Little Bow Diversion Women's C Div Twin Valley Dam Travers Dam		Vulcan, Carmangay, Nanton

Table Notes:
- Res = Reservoir; SMP = St Mary River Project; Women's C = Women's Coulee
- Irrigation Districts: LN = Lethbridge Northern, U = United, MV = Mountain View, L = Leavitt, A = Aetna, M = Magrath, R = Raymond, SMR = St Mary River, T = Taber, MVLA = Mountain View, Leavitt, Aetna.
- BTAP = Blood Tribe Agricultural Project. It is not an irrigation district, but an integral component of the SMP Headworks System.

In the Oldman Sub-basin, junior water-use projects are currently subject to the IOs rather than the WCOs. The IOs along the Oldman River are currently being met because of the flow regulation provided by the Oldman River Dam.

Water allocations for irrigation districts, private irrigation, urban municipal users, and other users were determined for each mainstem reach and tributaries. The results are presented in **Table A.3** in **Appendix A**. A summary of allocations by reach is presented in **Table 2.7**.

Like the Bow Sub-basin, the Oldman allocations are dominated by district irrigation. District irrigation represents about 84% of total mainstem allocations in the Oldman Sub-basin. Private irrigation accounts for about 11%, and urban municipalities and other purposes for 2.5% each. Allocations on unregulated tributaries to the Oldman River account for only about 4% of total allocations. A large portion of the urban municipal allocations are for the City of Lethbridge and other communities supplied through the works of the city. A number of communities within or near irrigation districts are supplied water through the works of ESRD and the districts.

Potential new projects within the Oldman River Sub-basin include:

- Piikani First Nation Reserve allocation for 43,200 dam^3. The agreement among the Piikani Nation and the Governments of Canada and Alberta does not specify for what purpose the allocation is to be used. It is known that the Piikani First Nation is interested in irrigation development on the Reserve. For the purposes of this study, it is assumed that the entire allocation is used for irrigation development.
- A reservation of 13,600 dam^3 for undefined development in the Oldman Reservoir area, often referred to as the Summerview Project. The reservation could be used for any purpose. For this study it is assumed that the entire volume is used for irrigation.
- Irrigation expansion on the Blood Indian Reserve of 2,400 ha. The additional area of irrigation is to complete the long-standing commitment to develop 25,000 acres (10,117 ha) of irrigation on the Reserve. Currently, approximately 7,700 ha are developed.

2.2.4 The South Saskatchewan River Sub-basin

South Saskatchewan River Sub-basin WRMM modelling reaches and their main tributaries are shown in **Table 2.8**. Water allocations for the Ross Creek Irrigation District, private irrigation, urban municipal users and other users were determined for both mainstem reaches and key tributaries. The results are presented in **Table A.4** in **Appendix A**. A summary of allocations by reach is presented in **Table 2.9**.

Table 2.8
South Saskatchewan River Mainstem Reaches, Tributaries, Control Structures and Key Water Users

South Saskatchewan River Reach	Tributaries	Provincial Control Structure	Irrigation Districts	Cities, Towns, Villages
Upstream of Medicine Hat	Bow River, Oldman River			
Downstream of Medicine Hat	Seven Persons Creek, Bullshead Creek, Ross Creek	Gros Ventre Creek Diversion, Cavan Lake Reservoir	Ross Creek	Medicine Hat

Allocations in the South Saskatchewan River Sub-basin are evenly distributed among private irrigation, urban municipalities and other purposes, a distribution that is similar to the Red Deer River Sub-basin. A small amount of water has been allocated to the Ross Creek Irrigation

District. Medicine Hat and Redcliff comprise the municipal allocations. The "other" allocations are primarily agricultural related.

About 42% of the mainstem allocations are subject to the minimum in-stream flow constraint (IO) of 42.5 m^3/s which was established in 1978. Allocations sourced from unregulated tributaries account for about 30% of total allocations, the largest proportion of all four sub-basins.

Table 2.9
Summary of Water Allocations/Demands in the South Saskatchewan River Sub-basin

Main-stream Reaches/Tributaries	District Irrigation Allocation (dam^3)	Private Irrigation		Urban Municipalities (Cities, Towns, Villages)			Other Purposes[3]	
		Allocation (dam^3)	Area (ha)	Allocation (dam^3)	2030 Actual Demand (dam^3)	2030 Actual RF (dam^3)	Allocation (dam^3)	Return Flow (dam^3)
Mainstem Red Deer River		7,759	1,786	366,368	23,860	16,624	17,472	1,727
		22,508	5,583	7,234			10,872	,1299
Red Deer River Tributaries	3,701	16,970	5,059	117,570	-	-	11,572	62
Total Red Deer Allocations/Demands	3,701	47,237	12,428	491,172	23,860	16,624	39,916	3,088

Notes:
1. Senior priority licences not subject to in-stream requirements of significant magnitude (by today's standards).
2. Junior priority licences subject to IOs applicable to licences issued since 1983.
3. “”Other Purposes” include water management, industrial, commercial, habitat enhancement recreation, and stock watering projects.

2.3 Summary

With respect to water supply in the four sub-basins of the SSRB, it is observed that:

- As noted in the AMEC 2009 study, the runoff characteristics of the four sub-basins of the SSRB are markedly different.
- The Red Deer and South Saskatchewan river sub-basins have relatively low unit yields compared with the Bow and Oldman River sub-basins due to lower precipitation and poorly defined drainage patterns.
- The Bow and Oldman sub-basins have similar unit yields and median annual flow, but the Oldman and Red Deer rivers flows are more highly variable than the Bow River flows, making them more susceptible to periodic droughts.
- A comparison of plots of the weekly mean reconstructed natural flows and recorded flows for the Red Deer River Sub-basin shows winter flows are increased and the peak is decreased by regulation of Gleniffer Reservoir, but overall, there is little change in flow volume due to its low level of water use.

- In the Bow River Sub-basin the difference between the natural and recorded flows show the impact of the six TransAlta hydro-power reservoirs.
- In the Oldman River Sub-basin, the natural and recorded flows show the impact of the flow regulation at the three provincial reservoirs and the diversion for consumptive use primary by the nine irrigation districts in the sub-basin.

With respect to water demand, it is observed that:

- Demands in the Red Deer and South Saskatchewan river sub-basins show a similar pattern comprising an approximate equal distribution of private irrigation, urban municipal, and “other” uses. Demands in the Bow and Oldman river sub-basins are heavily dominated by irrigation district uses, most of which are senior licensed uses.
- The Red Deer River Sub-basin is open for new allocations. The Red Deer River Sub-basin has a disproportionately high number of junior urban municipal allocations that make this particular use vulnerable to deficits in low runoff years. Refining or modifying operation of the Dickson Dam may reduce or eliminate current or future deficits to the WCOs and junior consumptive users in the Red Deer River Basin, as discussed in Section 0.
- The Oldman, Bow and South Saskatchewan river sub-basins are not accepting new applications. Sharing the use of hydro power reservoirs to meet in-stream and consumptive uses in the Bow River Sub-basin has shown some promise (The Bow River Project Research Consortium, 2010). The Oldman River Sub-basin has commitments for substantial additional use on the Piikani and Kainai First Nations Reserves, and in the Oldman River Reservoir area. Some of these commitments, in addition to the future increases in irrigation and non-irrigation water use in the Oldman Sub-basin may be difficult to fulfill without a means to make additional water available (AMEC, 2009).
- Water allocations and uses in the SSRB are unequivocally dominated by irrigation. With potential expansion district irrigation and development of committed private projects and projects in the application stage and possibly climate change, irrigation demands will become even more dominant (**Table 2.10**). Irrigation district withdrawals may increase by about 60% in the Bow River Sub-basin, and by about 40% in the Oldman River Sub-basin. Private irrigation withdrawals could more than double in the Red Deer River Sub-basin and may increase by about 30% in the Oldman River Sub-basin if existing licence applications are approved and if committed projects are implemented.

Table 2.10
Current and Projected 2030 Irrigation Water Withdrawls, Return Flows and Use in the SSRB

Sub-basin	Current Irrigation Use				2030 Irrigation Demands			
	Irrigated Area (ha)	Withdrawal (dam^3)	Return Flow (dam^3)	Net Use (dam^3)	Irrigated Area (ha)	Withdrawal (dam^3)	Return Flow (dam^3)	Net Use (dam^3)
Red Deer River Sub-basin								
Private Irrigation	16,500	57,800	0	57,800	18,600	65,100		65,100
Potential New Projects								
SAWSP					3,200	12,900	1,500	11,400
Acadia					10,900	43,700		43,700
Red Deer Total	16,500	57,800	0	57,800	32,700	121,700	1,500	120,200
Bow River Sub-basin								
District Irrigation	220,700	877,500	219,400	658,100	287,000	1,398,700	293,700	1,105,000
Private Irrigation	33,800	131,800	10,000	121,800	33,800	131,800	10,000	121,800
Potential New Projects								
Siksika					12,000	43,200		43,200
Bow Total	254,500	1,009,300	229,400	779,900	332,800	1,573,700	303,700	1,270,000
Oldman River Sub-basin								
District Irrigation	277,900	841,300	151,400	689,900	330,300	1,192,100	155,000	1,037,200
Private Irrigation	48,900	151,100		151,100	48,900	151,100		151,100
Potential New Projects								
Piikani					17,300	43,200		43,200
Summerview					5,400	13,600		13,600
Kainai					3,000	9,100		9,100
Oldman Total	326,800	992,400	151,400	841,000	404,900	1,409,100	155,000	1,254,200
South Saskatchewan River Sub-basin								
District Irrigation	324	405		405	846	1,700		1,700
Private Irrigation	12,400	49,700		49,700	12,400	49,700		49,700
South Sask. Total	12,724	50,105		50,105	13,246	51,400		51,400

Notes:

- Sources: Current irrigation district demands (AARD, 2011); 2030 irrigation district demands (AMEC, 2009, scenario 3); Private irrigation demands – current study.
- Bow River private irrigation includes diversions from the Highwood River to the Little Bow River.
- Oldman River private irrigation excludes Little Bow irrigation supplied primarily from Highwood River diversions.

3.0 OVERVIEW OF EXISTING RESERVOIRS

Significant water storage reservoirs and diversion works exist within the SSRB. They are owned and operated by the Government of Alberta (ESRD), TransAlta, irrigation districts, First Nations, and private entities. The following section provides an inventory of the significant existing reservoirs, noting licensee, location, and purpose.

Reservoirs are listed in the sub-basin from which their water source derives. The actual physical location of the reservoir may be within a different sub-basin.

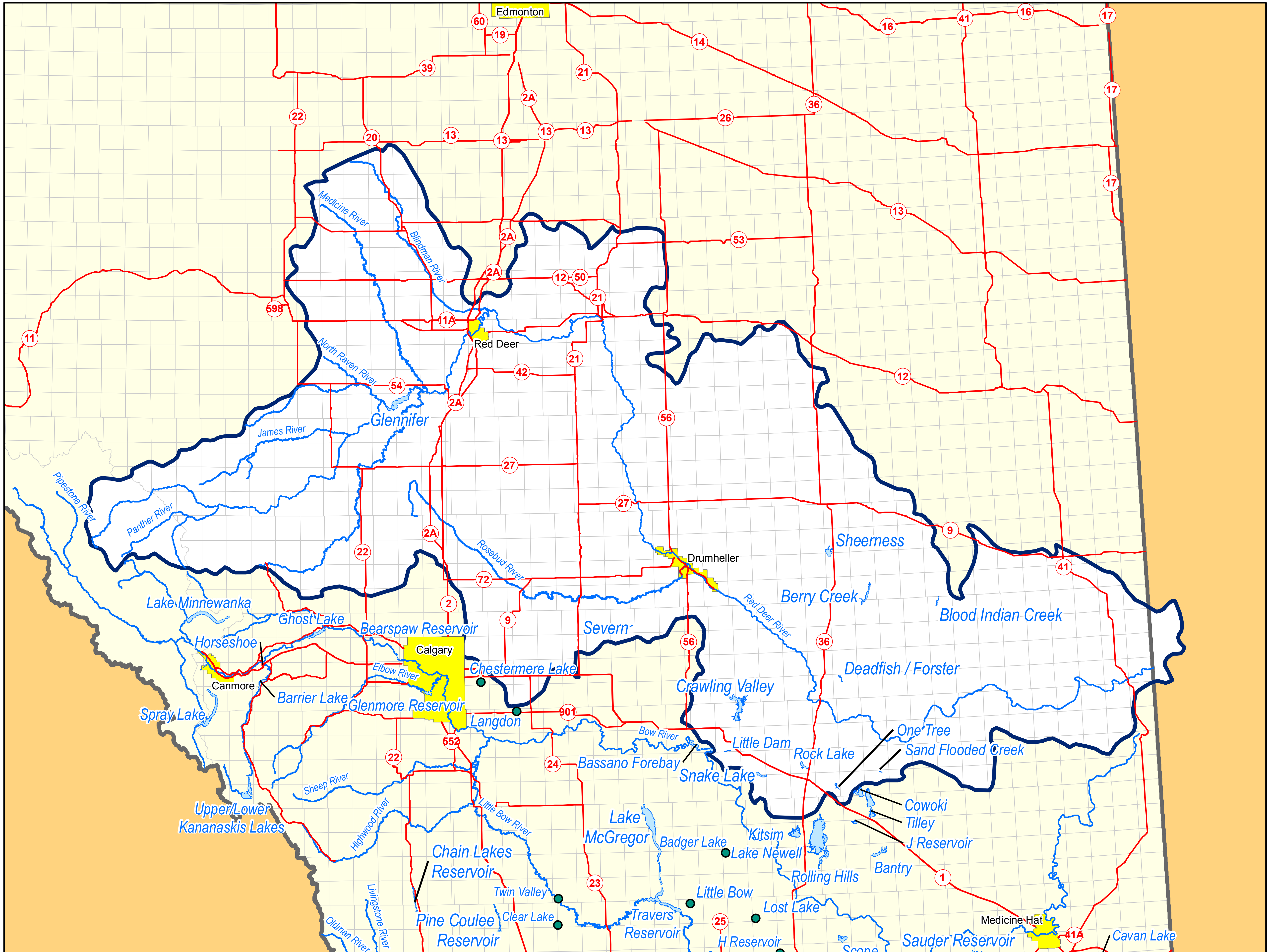
3.1 Red Deer River Sub-basin

The significant existing Red Deer River Sub-basin reservoirs are listed in **Table 3.1** and shown on **Figure 3.1**.

Table 3.1
Existing Reservoirs – Red Deer River Sub-basin

RESERVOIR	BASIN LOCATION	STORAGE (Dam^3)	ON / OFF STREAM	LICENSEE	LICENSED PURPOSE
Gleniffer (Dickson)	Red Deer	202,900	On	GoA	Storage, Flow Control
Severn	Red Deer	1,035	On	GoA	Recreation, Domestic
Sheerness	Red Deer	32,000	Off	ATCO	Industrial Cooling
Forster	Red Deer		Off	GoA	Irrigation, Stock water
Berry Creek	Red Deer	18,500	On	SAB	Irrigation, Stock water
Blood Indian Creek	Red Deer	4,930	On	SAB	Stock water, Recreation

Legend:
GoA – Government of Alberta
SAB – Special Areas Board



Legend

- Municipal Boundary
- Primary Highway
- Reservoir
- Lake/Reservoir
- River
- River Basin
- Provincial Boundary

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Water Storage Opportunities in the SSRB

Red Deer River Basin

DATE: August 2013	**Figure 3.1**
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3.2 Bow River Sub-basin

The significant existing Bow River Sub-basin reservoirs are listed in **Table 3.2** and shown on **Figure 3.2**.

Table 3.2
Existing Reservoirs – Bow River Sub-basin

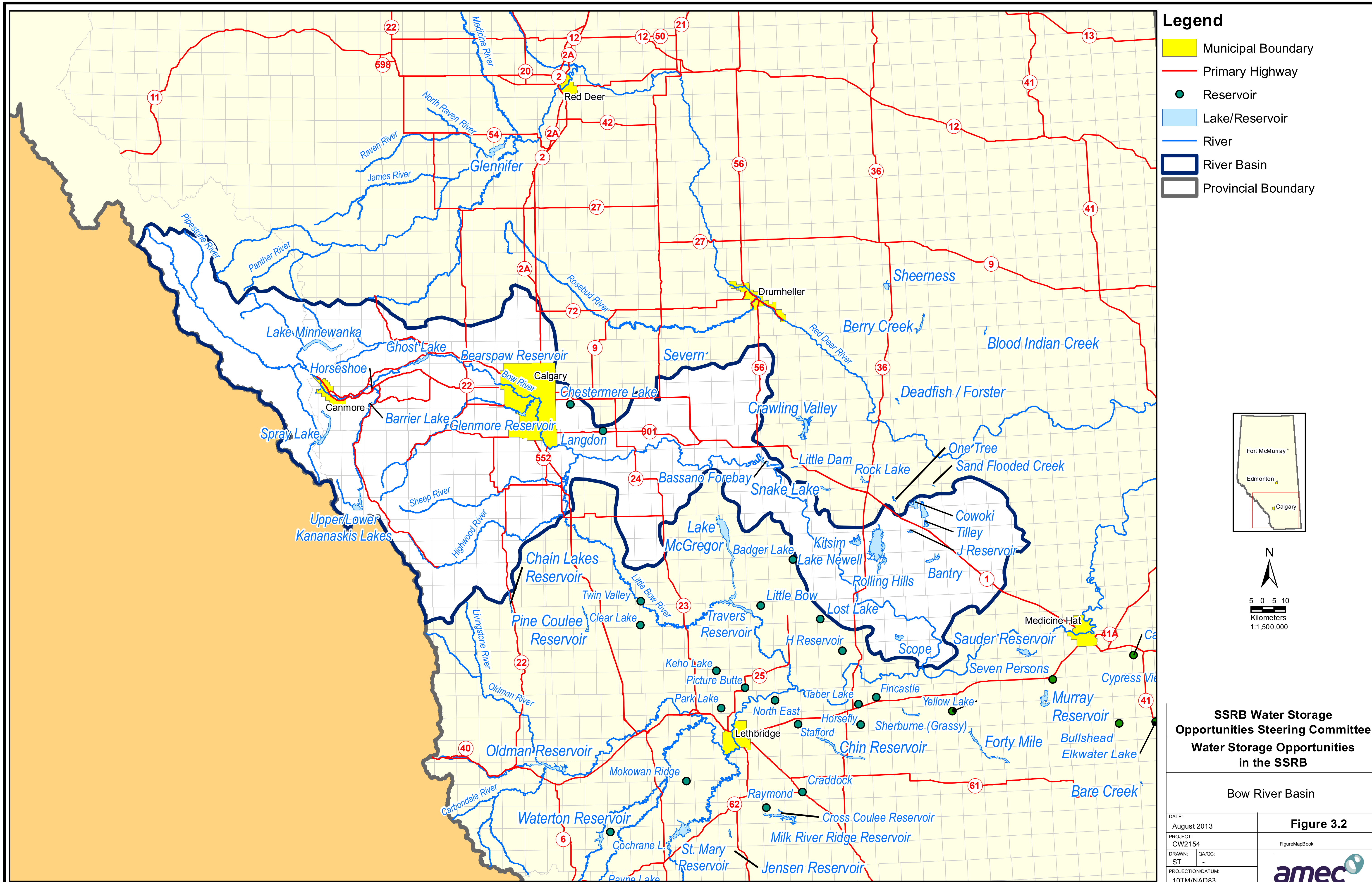
RESERVOIR	BASIN LOCATION	STORAGE (Dam^3)	ON / OFF STREAM	LICENSEE	LICENSED PURPOSE
Lake Minnewanka	Bow	219,000	On	TA	Power
Spray	Bow	165,000	On	TA	Power
Upper Kananaskis	Bow	107,700	On	TA	Power
Lower Kananaskis	Bow	62,800	On	TA	Power
Barrier	Bow	24,800	On	TA	Power
Ghost	Bow	69,800	On	TA	Power
Bearspaw	Bow	n/a	On	TA	Power
Glenmore	Bow	23,400	On	Calgary	Municipal
Chestermere	Bow	5,180	Off	WID	Irrigation
Langdon	Bow	7,895	Off	WID	Irrigation
Lake McGregor	Oldman	351,059	Off	GoA	Irrigation, Domestic
Travers	Oldman	104,638	Off	GoA	Irrigation, Domestic
Little Bow	Oldman	21,078	Off	GoA	Irrigation, Domestic
Bassano Forebay	Bow	n/a	On	EID	Irrigation
Badger	Oldman	53,650	Off	BRID	Irrigation, Domestic
Little Dam	Red Deer	n/a	Off	EID	Irrigation
Crawling Valley	Red Deer	130,500	Off	EID	Irrigation
Lost Lake	Oldman	5,050	Off	BRID	Irrigation, Domestic
Snake Lake	Red Deer	18,230	Off	EID	Irrigation

Table 3.2 - Continued

RESERVOIR	BASIN LOCATION	STORAGE (Dam^3)	ON / OFF STREAM	LICENSEE	LICENSED PURPOSE
H Reservoir	Oldman	2,220	Off	BRID	Irrigation, Domestic
Kitsim	Bow	26,520	Off	EID	Irrigation
Rock Lake	Red Deer	9,250	Off	EID	Irrigation
Lake Newell	Bow	320,215	Off	EID	Irrigation
Rolling Hills	Bow	31,130	Off	EID	Irrigation
One Tree	Red Deer	2,345	Off	EID	Irrigation
Scope	Bow	19,740	Off	BRID	Irrigation, Domestic
Cowoki Lake	Bow	19,735	Off	EID	Irrigation
Tilley A	Bow	33,300	Off	EID	Irrigation
Tilley B	Bow	38,235	Off	EID	Irrigation
Bantry #1	Bow	1,090	Off	EID	Irrigation
Bantry #2	Bow	4,150	Off	EID	Irrigation
Sand Flooded Creek	Red Deer	n/a	Off	EID	Irrigation

Legend:

BRID – Bow River Irrigation District
EID – Eastern Irrigation District
GoA – Government of Alberta
TA – TransAlta
WID – Western Irrigation District



Legend
Municipal Boundary
Primary Highway
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Lake/Reservoir
River
River Basin
Provincial Boundary
Fort McMurray
Edmonton
Calgary
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Red Deer
Calgary
Canmore
Drumheller
Medicine Hat
Lethbridge
Glennifer
Lake Minnewanka
Ghost Lake
Bearspaw Reservoir
Horseshoe
Barrier Lake
Glenmore Reservoir
Spray Lake
Chestermere Lake
Langdon
Severn
Crawling Valley
Sheerness
Berry Creek
Blood Indian Creek
Deadfish / Forster
Little Dam
Rock Lake
One Tree
Sand Flooded Creek
Bassano Forebay
Snake Lake
Cowoki
Tilley
J Reservoir
Upper/Lower Kananaskis Lakes
Lake McGregor
Badger Lake
Kitsim
Lake Newell
Rolling Hills
Bantry
Chain Lakes Reservoir
Twin Valley
Little Bow
Lost Lake
Pine Coulee Reservoir
Clear Lake
Travers Reservoir
H Reservoir
Scope
Sauder Reservoir
Seven Persons
Keho Lake
Picture Butte
Taber Lake
Fincastle
Park Lake
North East
Yellow Lake
Murray Reservoir
Cypress Vie
Horsefly
Stafford
Sherburne (Grassy)
Chin Reservoir
Forty Mile
Bullshead
Elkwater Lake
Oldman Reservoir
Mokowan Ridge
Craddock
Raymond
Bare Creek
Cross Coulee Reservoir
Milk River Ridge Reservoir
Waterton Reservoir
Cochrane L.
St. Mary Reservoir
Jensen Reservoir
Payne Lake
Medicine River
North Raven River
Raven River
James River
Pipestone River
Panther River
Rosebud River
Red Deer River
Bow River
Sheep River
Highwood River
Little Bow River
Livingstone River
Oldman River
Carbondale River
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Water Storage Opportunities in the SSRB
Bow River Basin
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3.3 Oldman River Sub-basin

The significant existing Oldman River Sub-basin reservoirs are listed in **Table 3.3** and shown on **Figure 3.3.**

Table 3.3
Existing Reservoirs – Oldman River Sub-basin

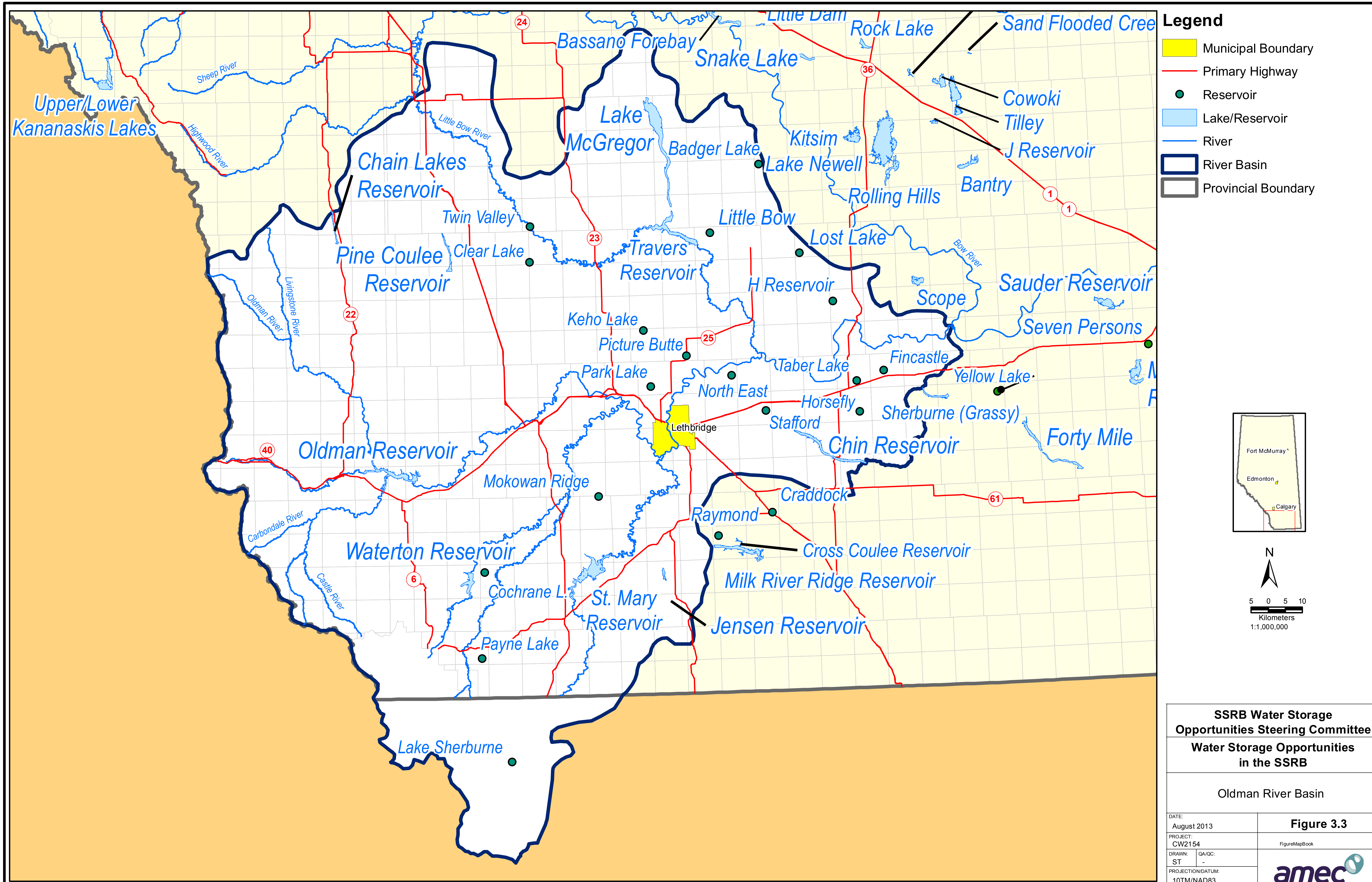
RESERVOIR	BASIN LOCATION	STORAGE (Dam^3)	ON / OFF STREAM	LICENSEE	LICENSED PURPOSE
Chain Lakes	Oldman	14,400	On	GoA	Flow Control
Oldman	Oldman	490,180	On	GoA	Water Management, Flood Control, Erosion Control, Flow Regulation, Conservation and Recreation
Pine Coulee	Oldman	50,400	Off	GoA	
Waterton	Oldman	111,196	On	GoA	Water Management, Flood Control, Erosion Control, Flow Regulation, Recreation
Payne Lake	Oldman	8,690	Off	GoA	Irrigation, Domestic
Cochrane Lake	Oldman	3,100	Off	UID	Irrigation
Twin Valley	Oldman	61,500	On	GoA	Water Management, Conservation, Recreation, Propagation of Fish and Wildlife, Irrigation, Other Uses
Clear Lake	Oldman	12,300	Off	GoA	Water Management, Conservation, Recreation, Fish & Wildlife, Irrigation & Agriculture
Mokowan Ridge	Oldman	6,000	Off	Blood First Nation	Irrigation
St. Mary	Oldman	369,310	On	GoA	Water Management, Flood Control, Erosion Control, Flow Regulation, Recreation
Keho	Oldman	95,635	Off	GoA	Water Management, Flow Regulation, Conservation, Recreation
Park Lake	Oldman	740	Off	LNID	Irrigation, Domestic

Table 3.3 - Continued

RESERVOIR	BASIN LOCATION	STORAGE (Dam^3)	ON / OFF STREAM	LICENSEE	LICENSED PURPOSE
Jensen	Oldman	19,000	On	GoA	Water Management, Flood Control, Erosion Control, Flow Regulation, Recreation
Picture Butte	Oldman	1,600	Off	LNID	Irrigation, Domestic
North East	Oldman	2,095	Off	SMRID	Irrigation
Stafford	Oldman	23,315	Off	SMRID	Irrigation
Chin	Oldman	190,330	Off	SMRID	Irrigation District Purposes
Taber Lake	Oldman	6,415	Off	TID	Irrigation District Purposes
Horsefly	Oldman	9,250	Off	SMRID	Irrigation District Purposes
Fincastle	Oldman	3,085	Off	TID	Irrigation District Purposes
Milk River Ridge	Milk	127,297	Off	GoA	Water Management, Flood Control, Erosion Control, Flow Regulation, Recreation
Raymond	Milk	1,600	Off	SMRID	Irrigation District Purposes
Cross Coulee	Milk	2,590	Off	SMRID	Irrigation District Purposes
Sherburne (Grassy)	SSRSB	10,625	Off	SMRID	Irrigation District Purposes
Yellow Lake	SSRSB	n/a	Off	SMRID	Irrigation District Purposes
Forty Mile	SSRSB	86,345	Off	SMRID	Irrigation District Purposes
Murray	SSRSB	30,590	On	SMRID	Irrigation District Purposes
Seven Persons	SSRSB	1,355	On	SMRID	Irrigation District Purposes
Sauder (Rattlesnake)	SSRSB	37,745	Off	SMRID	Irrigation District Purposes

Legend:

GoA – Government of Alberta
LNID – Lethbridge Northern Irrigation District
SMRID – St. Mary River Irrigation District
TID – Taber Irrigation District
UID – United Irrigation District



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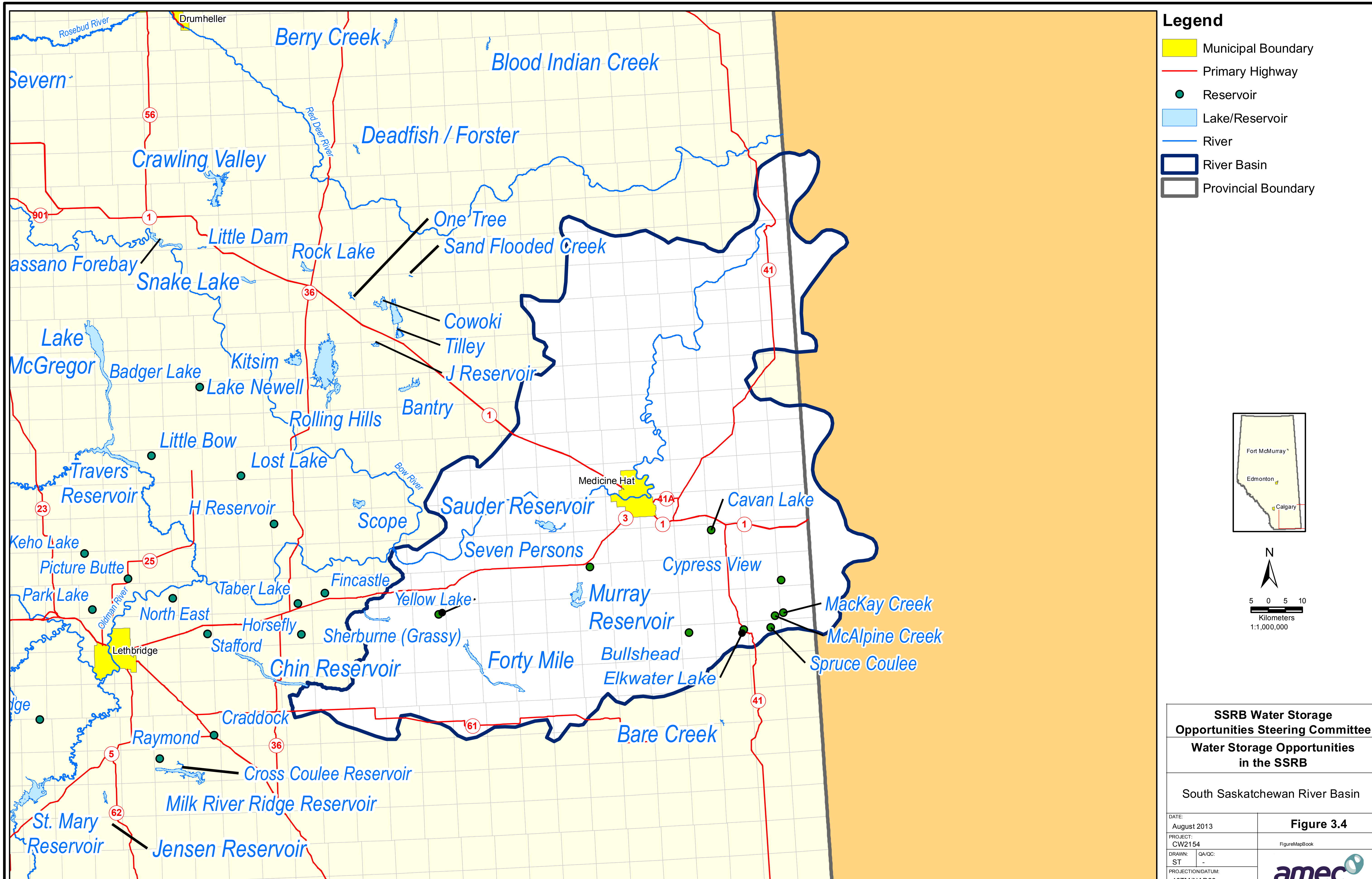
3.4 South Saskatchewan River Sub-basin

The significant existing South Saskatchewan River Sub-Basin reservoirs are listed in **Table 3.4** and shown on **Figure 3.4**.

Table 3.4
Existing Reservoirs – South Saskatchewan River Sub-basin

RESERVOIR	BASIN LOCATION	STORAGE (Dam^3)	ON / OFF STREAM	LICENSEE	LICENSED PURPOSE
Bullshead	SSRSB	1,846	On	GoA	Storage, Stock water
Cavan Lake	SSRSB	4,625	Off	GoA	Irrigation, Domestic
Elkwater Lake	SSRSB	6,579	On	GoA	Storage, Stock water
Spruce Coulee	SSRSB	570	On	GoA	
McAlpine Creek	SSRSB	630	Off	GoA	Storage
Cypress View	SSRSB	410	On	GoA	Storage
MacKay Creek	SSRSB	714	Off	GoA	

Legend:
GoA – Government of Alberta



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Water Storage Opportunities in the SSRB

South Saskatchewan River Basin

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4.0 RESERVOIR OPERATIONS

Water storage reservoirs are operated according to the physical limitations of the dams' infrastructure and their licensed purpose. Within those parameters, their operation can be adjusted or refined to achieve other purposes.

The concept of prior appropriation was reaffirmed by the *Water Act* (Alberta, 1999). In Alberta, prior appropriation applies only to the use of the natural flow of a stream. Use of water that has been legally captured in a reservoir is thereafter not bound by the priority system of the *Water Act*. The reservoir's owner has discretionary use of the stored water provided that its use is in keeping with the licensed purpose of the storage project. Stored water could be used to meet minimum environmental flows even if they had a lower priority than consumptive users on the same stream.

The *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009) identified operational modifications of existing reservoirs as a potentially effective method of reducing deficits to in-stream requirements and junior licences. This is an attractive strategy as the capital cost of constructing new storage to mitigate those deficits could be avoided.

The reservoir location and storage capacity have an impact on the effectiveness of operational modifications. Downstream delivery points are less valuable than those upstream as they cannot address upstream deficits unless the downstream storage is operated as a reserve or "water bank." Under this concept, the downstream storage would be released to senior priority use allowing upstream storage or diversions to be used for junior license priorities or WCOs.

4.1 Red Deer River Sub-basin Reservoir Operations

Gleniffer Reservoir is the only significant main-stream reservoir in the Red Deer River Sub-basin. The licensed purpose for Dickson Dam is "storage, flow control." The dam was constructed to:

- Assure present and future water supply;
- Improve water quality in the river; and
- Provide additional benefits such as; flood control, decrease erosion, improve fish habitat below the dam, provide lake-based recreational opportunities, and hydro-electric energy generation.

Following construction of the dam and reservoir (1983), 16.0 m^3/s was adopted as its minimum outflow. Downstream winter water withdrawals along the river frequently reduce the flow to less than 16.0 m^3/s and sometimes to less than the recommended minimum flow of 15.3 m^3/s (AMEC, 2009).

Flow augmentation for water quality improvements is considered the highest priority for reservoir operations, *Approved Water Management Plan for the South Saskatchewan River Basin* (AENV, 2006).

Reservoir operation rule curves define time period/water level zones required to match expected supply and demand. **Figure 4.1** shows the current operating rule curves for Gleniffer Reservoir.

When the reservoir level is above the lowest desirable drawdown line, it is probable that the reservoir will fill by the end of summer. The level is held below the highest desirable fill line to provide storage for flood attenuation. Ideally, the level should be maintained between those two lines to ensure favourable recreation levels and adequate supply for winter releases. If the reservoir is below the lowest desirable drawdown line, releases are limited to16.0 m^3/s with no increase for meeting downstream consumptive and in-stream demands.

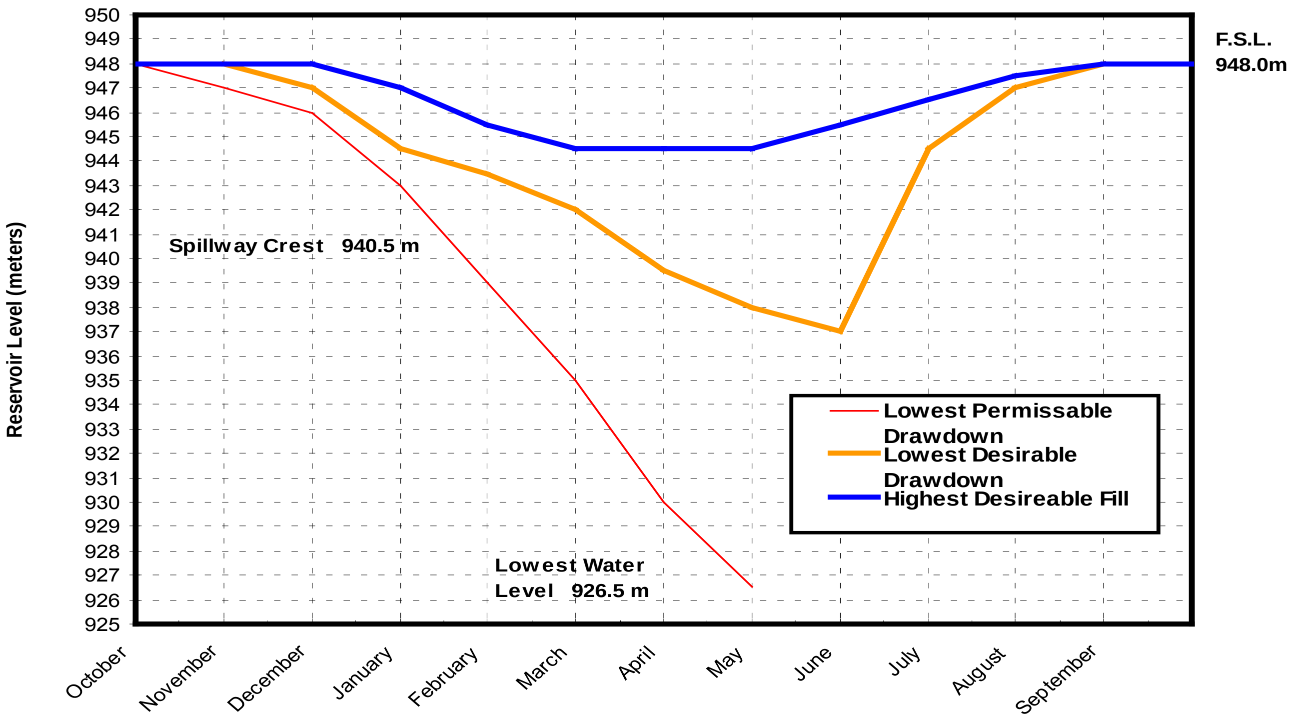


Figure 4.1 Gleniffer Reservoir Operating Rule Curves

In 2007, Alberta Environment (AENV; now ESRD) established 16.0 m^3/s as the November to March WCO from Dickson Dam to the Saskatchewan boundary, *Establishment of Red Deer River Sub-Basin Water Conservation Objective* (AENV, 2007c). The WCO applies to *"… any applications received or licences issued after May 1, 2005*." This means that when flow drops below 16.0 m^3/s, water users with licences issued after 1 May 2005 are required to cease withdrawing water. This would apply to several regional municipal and rural domestic projects that have been licensed since 2005.

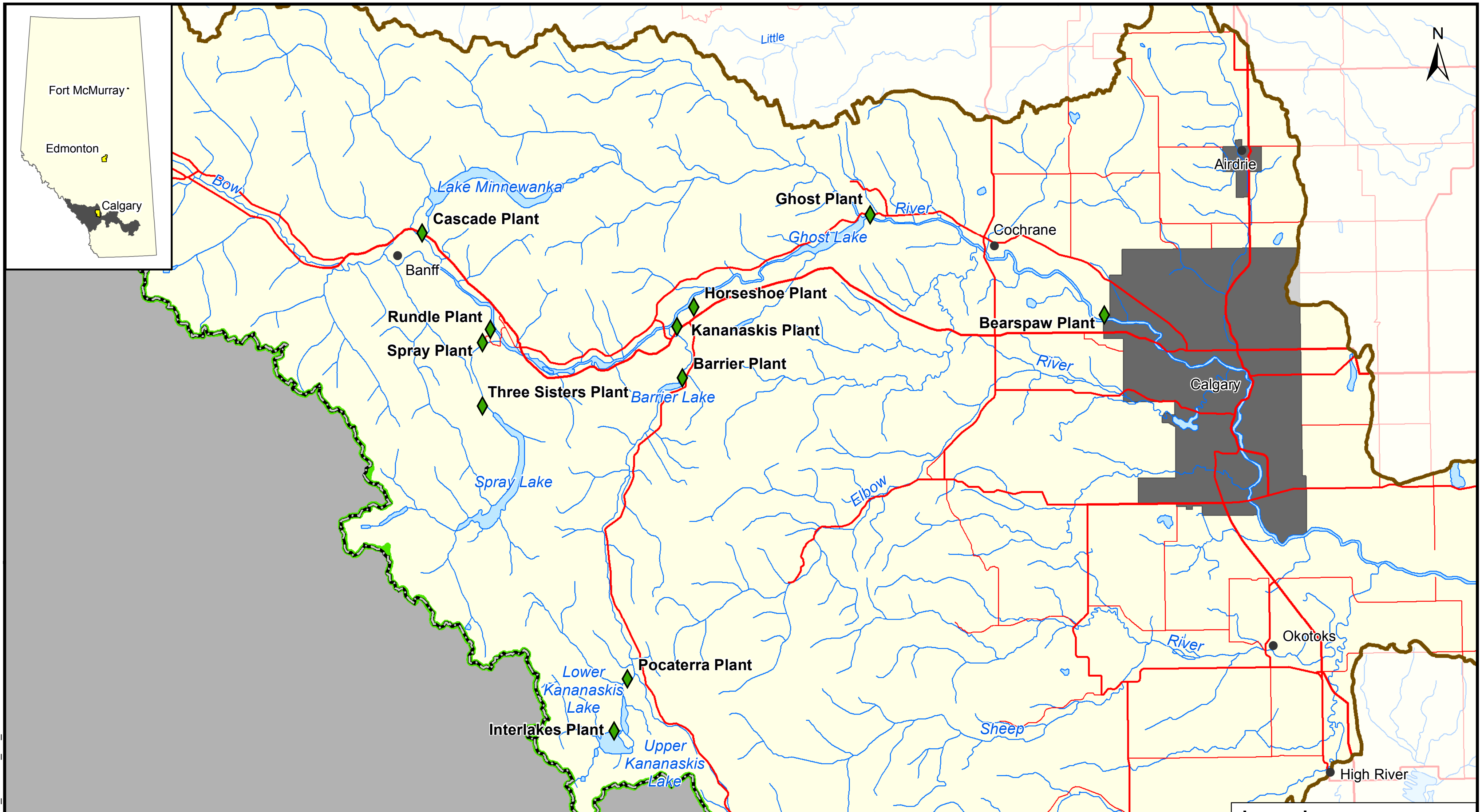
Scenario 3 from the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009) indicates that junior non-irrigation demands downstream of Dickson Dam during the five winter months are estimated to be about 34,000 dam^3 and the average annual deficit would be about 9,000 dam^3.

A solution to this issue could lie in refining the operation policy for Dickson Dam. A review for Gleniffer should include the following:

- A water quality study to determine if 16.0 m^3/s is needed for the entire length of the river and for the entire winter to maintain favourable water quality.
- A review of impacts of increasing releases to meet both the water quality and consumptive users along the river when the reservoir level is above the desirable drawdown line.
- Lowering the lowest desirable drawdown rule curve would increase available storage for meeting needs but increases the risk. Sharing the risk among all users to minimize impacts of deficits may be possible if recreation users and in-stream requirements could tolerate less than ideal conditions in some years.
- Consider adjusting rule curves for annual operations based on runoff forecasts and probability of filling.

4.2 Bow River Sub-basin Reservoir Operations

TransAlta owns and operates six large reservoirs in the Bow River Sub-basin upstream of Calgary to regulate flows for their 11 hydro-electric power generating stations (**Figure 4.2**).



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Location of TransAlta Facilities in the Bow River Basin

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In general, these reservoirs are operated to store water in spring and summer and release water to supplement the natural river flow for power generation during the remainder of the year. The difference between natural flow and recorded flow in the Bow River at Calgary is primarily due to operation of the hydro power facilities **(Figure 4.3)**.

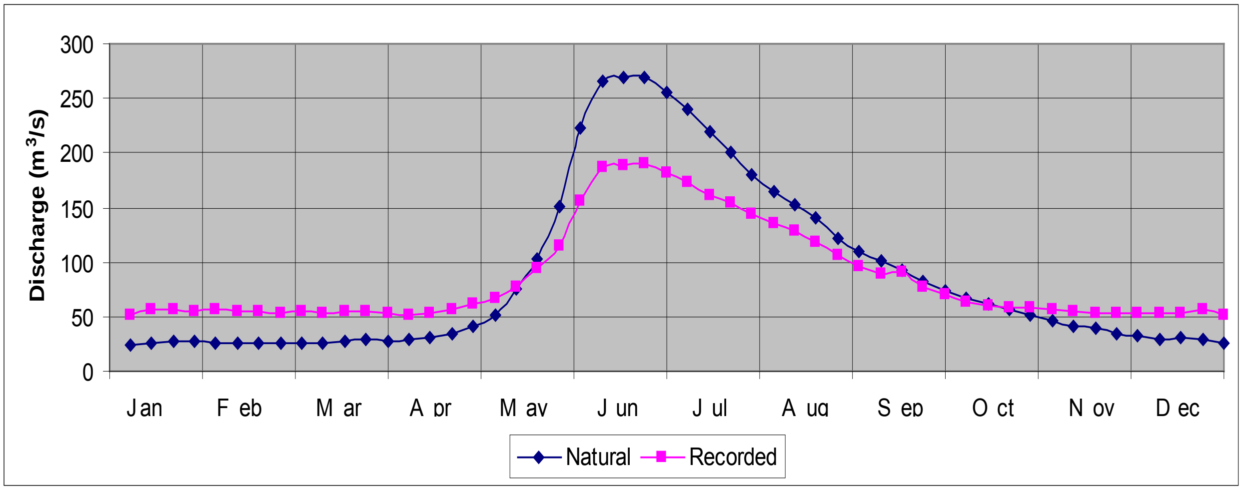


Figure 4.3 Discharge of the Bow River at Calgary

TransAlta is bound under the legislative authority of the *Alberta Energy Act* to a power purchase arrangement (PPA) which obligates TransAlta to supply pre-determined amounts of energy and reserves to the Alberta Electrical System Operator. The PPA obligations have a direct influence on reservoir operations and resulting power generation.

While the reservoirs are operated primarily to provide timely power production, other uses of water are also considered. Releases are made in summer months to accommodate river recreation, fish and riparian habitat, and water quality. Higher winter flows enhance municipal and industrial wastewater assimilation. Some reservoirs are licensed with minimum downstream flow and reservoir water level constraints.

Simulation modelling conducted in the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009) with existing TransAlta operating guidelines indicated that increased demands in Scenario 3 (2030) would significantly increase deficits to the WCO, junior private irrigation projects and non-irrigation projects in the SSRB.

The study also investigated re-management of TransAlta reservoirs, giving a higher priority to consumptive and in-stream needs than to hydro-electric energy production. The result of the re-managed operations (Scenario TA) compared to the current (Scenario 1) and future (Scenario 3) is shown on **Figure 4.4**. The 2009 study modelled the 69-year period of 1928 to 1996. **Figure 4.4** shows the percentage of weeks of deficits >10% of the WCO in the 3536 weeks of study period. The modelling results have the following caveats:

- As there are few projects subject to WCOs, modelling assumed the IO as the in-stream target. Scenarios 1 and 3 had occasional IO deficits while under Scenario TA the Bow River IO is always met. As Scenario TA releases water to reduce consumptive use deficits, there is less water in the system to contribute to WCOs.
- No detailed studies have been done to determine appropriate winter in-stream flow requirements. The modelled IOs are higher than natural during low flow years and are difficult to meet under Scenario TA.

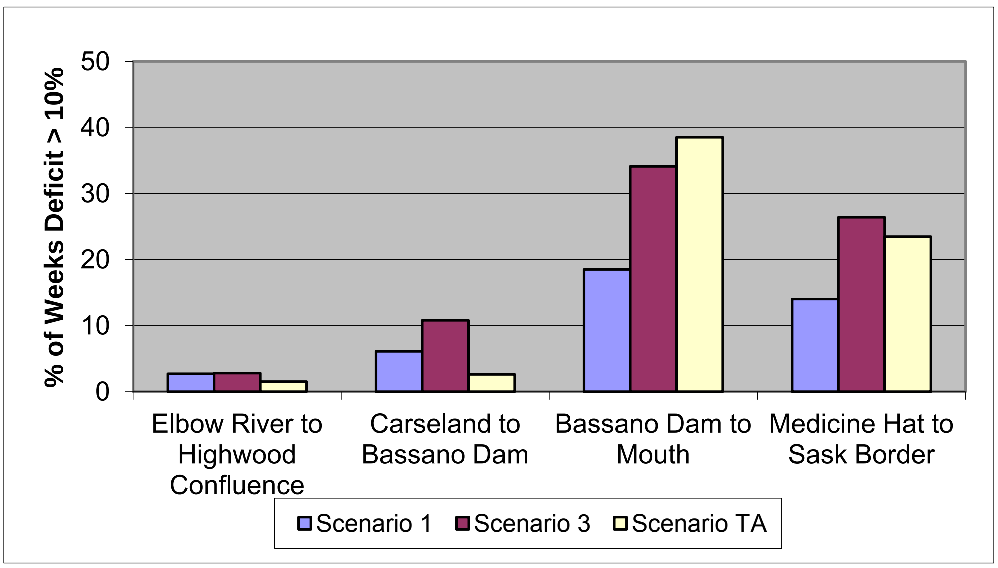


Figure 4.4 Frequencies of WCO Deficits Greater than 10% along the Bow and South Saskatchewan Rivers from the 2009 AMEC Study
(1971 – 2001 Source: Bow River Council 2005)

There are no significant deficits to irrigation district water demands in Scenario TA. With respect to junior private irrigation demands, performance is much improved for Scenario TA (**Figure 4.5**). Scenario TA has very few deficits, and significantly improves on Scenario 1 performance. There are no junior private irrigation projects between Carseland and Bassano Dam.

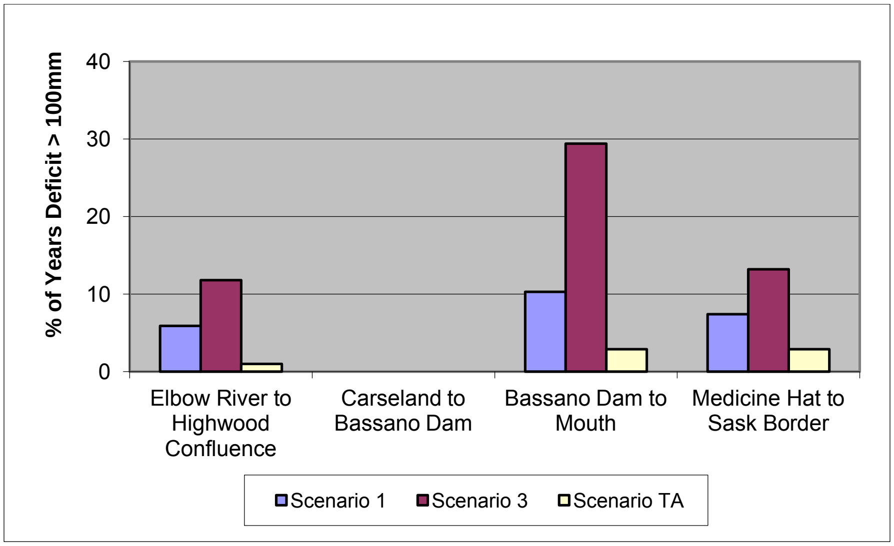


Figure 4.5 Frequencies of Deficits Greater than 100 mm for Junior Private Irrigation Projects along the Bow and South Saskatchewan Rivers

In regard to junior non-irrigation projects, simulation modelling indicated a very high frequency of deficits in Scenario 1 and Scenario 3. Scenario TA would decrease the deficits substantially (**Figure 4.6**).

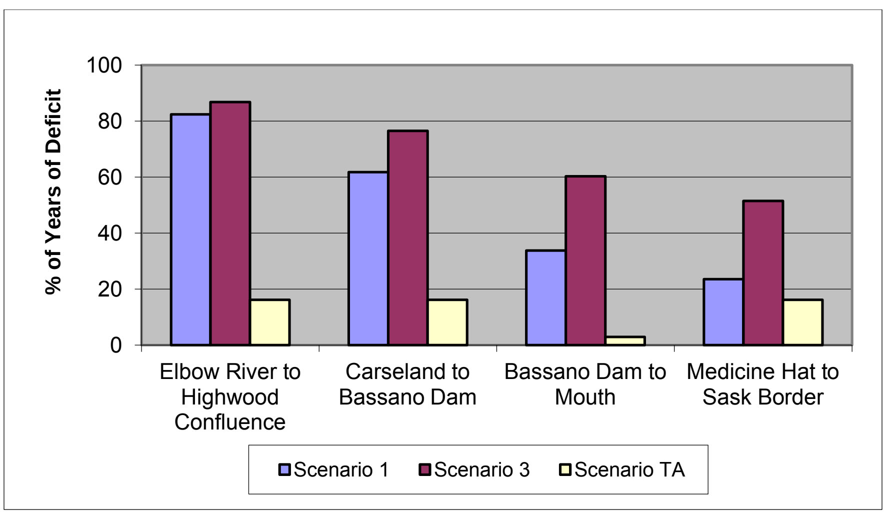


Figure 4.6 Frequencies of Deficits to Junior Non-irrigation Projects along the Bow and South Saskatchewan Rivers

In summary, results of simulation modelling in the 2009 AMEC study indicate that operation of the TransAlta reservoirs to meet in-stream and junior consumptive needs in the Bow River Sub-basin would eliminate deficits to the IOs and substantially improve performance in meeting consumptive demands. Performance in meeting the WCO would be about the same as Scenario 3.

Re-management as per Scenario TA would reduce winter flow and increase spring and summer flow at Calgary. Average winter flows would be slightly higher than natural. Spring flows would be higher than natural and summer flows lower than natural. The simulations done in the 2009 AMEC study indicate that changes to the operating patterns of the TransAlta storage reservoirs have potential for reducing deficits to in-stream demands, and existing and future consumptive demands in the sub-basin. Further study on Bow River Sub-basin operations has been conducted since the 2009 AMEC study and key findings are described in Section 7.3.

The *Bow River Project Final Report* (The Bow River Project Research Consortium, 2010) concluded that if the Bow River and its controlled tributaries are managed as an integrated system from headwaters to confluence there would be significant benefits to all users.
Key components of their preferred scenario include restoring Spray Reservoir to its original design specifications and dedicating the increased 74,000 dam^3 storage for use as a “water bank” and doubling the storage capacity of the WID Langdon Reservoir.

In *Adaptation Strategies for Current and Future Climates in the Bow Basin* (Alberta Innovates and WaterSMART, 2013) beneficial watershed management strategies were identified both for current conditions and a future more severe climate. The most promising strategies for adapting to severe drought conditions included those with new off-stream storage of 51,000 dam^3 at Bruce Lake (WID) and new on-stream storage of 308,000 dam^3 at Eyremore Reservoir downstream of Bassano.

4.3 Oldman River Sub-basin Reservoir Operations

As outlined earlier in the report, there are a substantial number of reservoirs with large storage volumes in the Oldman River Sub-basin, primarily owned by the province and the irrigation districts. The IOs downstream of the Oldman River Dam are currently met. If irrigation districts’ demands increase (within their allocations) it is expected that occasional IO deficits will occur and there will be more frequent and increased deficits to junior consumptive users. Reservoir operating procedures are reviewed periodically and are believed to be near optimum, leaving little opportunity to alleviate deficits through changes in operational procedures.

4.4 South Saskatchewan River Sub-basin Reservoir Operations

The small storage volumes and downstream locations of existing reservoirs within this sub-basin do not provide any significant opportunity or benefit for operational adjustments on a regional scale.

5.0 RATIONALE FOR ADDITIONAL STORAGE

The SSRB is prosperous in part because of the investment that has been made in dams, reservoirs, diversions and other infrastructure that has allowed the province to manage effectively the limited water supply. However expanding population, accelerating economic growth and the impacts from climate change will add additional challenges to managing our limited water supply. An increased number of water deficits could reduce or even halt the economic growth as all sectors (agriculture, industrial, municipal, etc.) depend on water in some way or another. Thus, the strongest argument for additional storage is that it can improve water security and thus allow the province to continue to reap the benefits from a strong economy.

The following sections provide an overview of the issues and provide additional justification for additional water storage.

5.1 Frequency and Magnitude of Deficits

In the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009). Scenario 3 simulation modelling indicated that there would be shortages or deficits to certain uses or priorities as indicated in **Table 5.1**.

The irrigation deficits are the percent of years when deficits exceed 100 mm whereas the WCO and non-irrigation deficits represent the percent of weeks that deficits exceed 10% of the objective or demand.

The WCO have the greatest impact on the St. Mary River, primarily due to large withdrawals by senior licenses for irrigation. The IDs themselves are not significantly impacted partly because of their senior license and the storage provided by provincial and district owned reservoirs. Deficits to private irrigators, particularly in the Oldman sub-basin and non-irrigation generally throughout the SSRB are significant. Piikani and Oldman reservoir areas under Scenario 3 would have significant deficit without additional storage.

Table 5.1
Scenario 3 (Year 2030) Deficits for Irrigation Districts and for Evaluated Reaches for WCO, Private Junior Irrigation and Junior Non-irrigation Demands

Purpose	Sub-Basin				
	Red Deer River	**Bow River**	**Oldman River**	**St. Mary River**	**SS River**
Water Conservation Objective					
Deficit[1]	8%	16%	12%	65%	26%
District Irrigation					
Irrigated Area (ha)	0	287,000	330,300		0
Deficit	N/A	0	4%		N/A
Private Irrigation					
Irrigated Area (ha)[2]	1,420	840	11,000	21	3,210
Deficit[3]	17%	25%	42%	19%	13%
Non-Irrigation					
Demand (dam^3)[4]	30,900	25,400	9,140	6,580	4,800
Deficit[3]	60%	51%	86%	53%	19%
Committed New Projects					
Special Areas Water Supply					
Irrigated Area (ha)	3,237				
Deficit	2%				
Acadia Irrigation					
Irrigated Area (ha)	10,900				
Deficit	7%				
Siksika Irrigation					
Irrigated Area (ha)		9,440			
Deficit		0%			
Piikani Irrigation					
Irrigated Area (ha)			6,190		
Deficit			47%		
Oldman Res Area Irrigation					
Irrigated Area (ha)			4396		
Deficit			82%		
BTAP Expansion					
Irrigated Area (ha)				10,121	
Deficit				0	

Note:

[1] Deficits are average of deficits in reaches evaluated in AMEC 2009.
[2] Areas are sum of private irrigated areas in reaches evaluated.
[3] Deficits are weighted averages of deficits in reaches evaluated.
[4] Demands are sum of non-irrigation demand in reaches evaluated.
Source: AMEC, 2009

5.2 Economics

One of the goals of the *Water for Life, Alberta's Strategy for Sustainability* (AENV, 2003) strategy is "reliable, quality supplies for a sustainable economy." Public and private investment in water management infrastructure is heavily concentrated in the Oldman and Bow river sub-basins. Industries, municipalities, and citizens rely on availability of water for their livelihood and contribution to the provincial economy.

The total economic footprint of Alberta's rural economy has been estimated at $79 billion annually. The province's Irrigation Rehabilitation Program province/irrigation district cost share ratio started at 86% to 14% based on economic studies that determined the ratio of economic benefits to society versus farmers and currently sits at 75% to 25% since 1995.

In light of the projections of 2030 deficits, investigation of new storage opportunities for protecting the economy, water security and the environment is prudent.

5.3 Operations

Studies have identified opportunities to improve conditions by revised operation of reservoirs in the Red Deer and Bow river sub-basins. The deficits in the Red Deer River Sub-basin are low in volume, relatively infrequent, and may be alleviated by modifying Dickson Dam operations.

In the Bow River Sub-basin, re-management of the TransAlta reservoirs and other options can be used to reduce deficits. Improvement scenarios for the Bow River Sub-basin include development of additional new storage at TransAlta reservoirs, Langdon Reservoir, Bruce Lake, and Eyremore.

The operation of provincially owned projects in the Oldman River Sub-basin have been periodically reviewed and modified in keeping with changing policies, safety requirements and the collective needs of water users (AMEC, 2009). The *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009) identified and discussed several options for alleviating water supply deficits in the Oldman River Sub-basin. None of the options or combinations thereof would have a substantial impact on reducing the deficits. It appears that there is little opportunity for improvement in Oldman Sub-basin through operational modifications.

Additional new storage in the Oldman River Sub-basin is a good option to investigate for its ability to improve water security to users and reduce deficits to in-stream objectives and junior priority uses.

5.4 Regulatory and Policy Background

The *Water Act* (Alberta, 1999) gives the minister the power to construct, own and operate water management projects. The Alberta Government has long been involved in the development and management of water management projects in support of the province's economic, social, and environmental goals. *Regulation 171* (Alberta, 2007) allows licensing of reserved water for storage provided that it is for the protection of the aquatic environment or improves availability of water to existing licensees.

The *Water Management Plan for the South Saskatchewan River Basin* (AENV, 2006) is based on existing infrastructure in the basin. It recognizes that the existing storage capacity is being fully utilized and its ability to provide additional benefits is limited. The plan referred to the possibility of new storage and recommended in-stream flow requirements for the operation of any new storage.

The *Water for Life* strategy developed a framework for effective and efficient management and protection of Alberta's water resources. The framework consists of a set of principles, goals and actions including:

- Principles:
  - Shared responsibility for water management in local watersheds.
- Goals:
  - A safe, secure drinking water supply.
  - Healthy aquatic ecosystems.
  - Reliable, quality supplies for a sustainable economy.
- Actions:
  - Evaluate water management infrastructure needs.

The legislation, regulations and policies are in place to enable the province to make decisions on water management and related infrastructure, including new storage, required to meet the future needs.

5.5 Inter-provincial Apportionment

In order to determine if there is water surplus to apportionment commitments *Master Agreement on Apportionment* (Canada, 1969) which could be stored, historical weekly flow data was analyzed using the following assumptions:

- Recorded flow represents residual flow after all historical water uses, diversions, and changes in storage have taken place. Historically, there have been few shortages in meeting consumptive water demands, with exception of 2001. In that year shortages were experienced in the southern tributaries of the Oldman River.
- Recorded flow minus apportionment and in-stream commitments were considered to be surplus flow in the furthest downstream reach of each river.
- Each of the rivers was assumed to contribute at least 50% of their own natural flow to inter-provincial apportionment. At present, there is no specific policy on the contribution from each sub-basin toward meeting the 50% of natural flow commitment to Saskatchewan; however, a principle of the Water for Life strategy is shared responsibility for water management in local watersheds which implies such a policy.

- The in-stream flow commitments were taken as the current operating WCO in the Red Deer River, and the current operating IOs in the Bow and Oldman rivers.
- Apportionment is administered on a calendar year basis for volume. Alberta's volume commitment can be in deficit at any time during the year providing that the full 50% is delivered by 31 December each year.
- Apportionment requires an instantaneous minimum flow in the South Saskatchewan River (downstream of the Red Deer River confluence) of 42.5 m^3/s. In-stream flow commitments are administered on a weekly basis. Surplus deliveries in any week do not offset subsequent weekly minimum flow requirements.
- The analysis was conducted for 1983 to 2009, a period of common databases for all three rivers. There have been some changes in demands and infrastructure during that period, so the database is not entirely homogeneous. In particular, the Oldman River Dam did not become operational until 1992. Nevertheless, it is desirable to include as much as possible of the 1980s drought period.

The results of the analysis are shown in **Table 5.2** and are discussed below.

The Red Deer River has deficits in meeting the WCO. In most years, the deficit was small and occurred during the winter months. It could possibly have been eliminated by additional releases from storage.

The Red Deer River had no deficits and very large surpluses in supplying its 50% contribution to apportionment, averaging 900,000 dam^3 per year, the highest of the three basins despite having an average natural flow volume less than 50% of the Bow River and Oldman River. The Red Deer surplus includes about 100,000 dam^3 of return flow of Bow River water from the WID and EID.

The Bow River met its IO in the Bassano to the mouth reach in all but 5 of the 27 years. Its 50% apportionment contribution was met in all but 1 year. In only 2 of the 27 years the Bow River would have no surplus flow to contribute to storage. The surplus flow that could contribute to additional storage averages about 730,000 dam^3 per year and would require storage constructed near the mouth on or all tributaries.

Table 5.2
Estimates of Surplus Water Potentially Available for New Storage

Year	Red Deer River Sub-Basin			Bow River Sub-Basin			Oldman River Sub-Basin		
	In-stream WCO Deficit (dam^3)	50% Apportionment Surplus (dam^3)	Surplus (dam^3)	In-stream WCO Deficit (dam^3)	50% Apportionment Surplus (dam^3)	Surplus (dam^3)	In-stream WCO Deficit (dam^3)	50% Apportionment Surplus (dam^3)	Surplus (dam^3)
1983	-40,874	623,921	583,047	-20,145	315,236	295,091	-24,292	34,721	10,429
1984	-21,079	525,394	504,316	-19,712	12,351	-7,361	-71,048	-240,914	-311,962
1985	-17,329	727,628	710,299	-2,913	109,854	106,941	-83,072	-66,744	-149,815
1986	-3,881	1,260,340	1,256,459	0	716,938	716,938	-50,873	571,530	520,657
1987	-6,411	743,693	737,282	0	355,212	355,212	-14,433	144,523	130,090
1988	-28,222	580,916	552,694	0	24,502	24,502	-67,674	-258,972	-326,646
1989	-14,094	807,180	793,086	0	324,739	324,739	-20,858	-26,494	-47,352
1990	-3,006	1,456,715	1,453,709	0	1,049,279	1,049,279	-272	708,877	708,605
1991	-1,835	1,031,025	1,029,190	0	1,119,936	1,119,936	0	939,227	939,227
1992	-1,339	851,289	849,950	0	565,620	565,620	-1,642	-154,737	-156,378
1993	-5,479	1,150,281	1,144,803	0	1,605,198	1,605,198	0	1,616,101	1,616,101
1994	-4,305	837,027	832,721	-16,628	539,886	523,257	0	549,874	549,874
1995	-6,963	1,048,258	1,041,295	0	1,171,364	1,171,364	0	1,151,568	1,151,568
1996	-295	1,056,585	1,056,291	0	943,218	943,218	0	766,916	766,916
1997	-8,688	1,327,955	1,319,267	0	847,886	847,886	0	530,031	530,031
1998	-3,667	1,011,571	1,007,904	0	943,771	943,771	-5,227	491,662	486,435

Table 5.2 - Continued

Year	Red Deer River Sub-Basin			Bow River Sub-Basin			Oldman River Sub-Basin		
	In-stream WCO Deficit (dam^3)	50% Apportionment Surplus (dam^3)	Surplus (dam^3)	In-stream WCO Deficit (dam^3)	50% Apportionment Surplus (dam^3)	Surplus (dam^3)	In-stream WCO Deficit (dam^3)	50% Apportionment Surplus (dam^3)	Surplus (dam^3)
1999	-4,706	1,182,711	1,178,006	0	1,056,061	1,056,061	0	123,005	123,005
2000	-6,379	651,893	645,514	0	47,593	47,593	-2,301	-80,387	-82,688
2001	-33,297	485,898	452,602	-77,309	-152,093	-229,402	-1,904	-199,019	-200,923
2002	-27,669	448,324	420,655	0	723,010	723,010	0	492,683	492,683
2003	-9,627	862,385	852,758	0	556,084	556,084	0	329,053	329,053
2004	-22,999	637,250	614,251	0	807,823	807,823	0	-270,919	-270,919
2005	-6,236	1,558,005	1,551,769	0	2,130,643	2,130,643	0	1,098,687	1,098,687
2006	0	821,736	821,736	0	1,018,231	1,018,231	0	509,031	509,031
2007	-4,199	1,471,557	1,467,358	0	1,062,534	1,062,534	0	273,562	273,562
2008	-5,704	1,070,362	1,064,659	0	1,312,177	1,312,177	0	86,621	86,621
2009	-17,639	562,942	545,303	0	598,465	598,465	0	-24,688	-24,688
Averages	-11,330	918,253	906,923	-5,063	733,538	728,474	-12,726	336,844	324,119

The Oldman River failed to meet the IO flows until the Oldman River Dam became operational in 1992. Since that time there were only four deficit years. This demonstrates the benefit of storage. Its apportionment contribution was less than 50% of its natural flow in 9 of the 27 years. The Oldman River had the lowest average annual surplus flow of the three rivers (324,000 dam^3) and there would be no surplus flow in one third of the 27 years.

The above analysis suggests that water delivered in excess of the apportionment commitment could be available for Alberta's use if additional storage was built. The Red Deer and Bow river sub-basins have the greatest surplus volumes but, if each sub-basin must contribute 50% of its annual natural flow, the Oldman River Sub-basin exhibits the greatest need for additional storage as it has the most deficits.

5.6 Conclusion

The *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009) identified deficits to water conservation objectives, junior private irrigation and non-irrigation uses by the year 2030. Cursory analysis of apportionment deliveries indicates additional water could be available to reduce the deficits.

Nine irrigation districts are sourced from streams in the Oldman River Sub-basin. As in the Bow River Sub-basin, districts have withdrawn much less than their full licence allocations in recent years. The 2009 AMEC study observed that with their existing allocations and continued improvements in efficiencies and if the Oldman River Sub-basin irrigation districts expanded their current irrigated area by about 20% there would be little impact on district water shortages. Such increased usage by the districts could adversely impact WCOs and junior licensees. Furthermore, changes in natural stream flow patterns due to climate change would increase the deficits to the irrigation districts, WCOs, and junior licensees. As Oldman River Sub-basin water operations are considered near optimum, additional new storage would be required to eliminate these future deficits or reduce them to an acceptable level.

Although analyses indicated that availability of surplus flows in the Oldman Sub-basin may be a limiting factor, new storage in the Oldman River Sub-basin should be investigated to determine if it could improve water security to users (junior irrigation and non-irrigation) and reduce deficits to in-stream objectives and First Nations developments.

6.0 STORAGE OPPORTUNITIES ANALYSIS

The previous section suggest that significant more surplus water is available for storage in both the Red Deer and Bow river sub-basins. However, the majority of the reliability of supply issues are situated with the Oldman River Sub-basin and the southern tributaries.

If the Oldman Sub-basin irrigation districts expanded their current actual irrigated area by about 20% there would be little impact on water shortages to the districts. But such increased usage by the districts could adversely impact WCOs and junior licensees. Furthermore, changes in natural stream flow patterns due to climate change could increase the deficits to the irrigation districts, WCOs, and junior licensees. As Oldman Sub-basin water operations are considered near optimum, additional new storage may be the best option to eliminate these future deficits or reduce them to an acceptable level.

Previous analyses indicated that availability of surplus flows in the Oldman River Sub-basin may be a limiting factor. This section focuses on potential new storage sites in the Oldman River Sub-basin and identification of those sites, if any, that could improve water security to users (junior irrigation and non-irrigation) and reduce deficits to in-stream objectives and First Nations developments.

6.1 Potential Storage Sites within the Oldman Sub-basin

6.1.1 Inventory of Potential Projects

A total of 48 potential storage sites were identified from existing records such as the *Provincial Inventory of Potential Water Storage Sites and Diversion Scenarios* (MPE, 2005b). The sites are listed in **Table 6.1**.

Table 6.1
Potential Storage Sites in the Oldman Sub-basin

Site #	Site Name	Volume (dam^3)	Area (ha)	Type
16	Belly River Reservoir	19,119	202	On-stream
48	Castle River (Canyon Site)	49,339	*	On-stream
49	Chin Reservoir Expansion	74,000	*	Off-stream
49	Chin Reservoir (East Chin Coulee)	18,500	283	Off-stream
58	Dead Horse Coulee	30,837	*	Off-stream
77	Glenn Lakes Reservoir	28,370	*	*
96	Jensen Reservoir Extension	11,101	111	On-stream
102	Kenex-Rocky Coulee Reservoir	86,344	2,428	Off-stream
104	Lee Creek – Site 5A	15,419	162	On-stream
105	Lee Creek – Site 6	4,000	142	Off-stream
106	Lee Creek Reservoir	9,868	*	On-stream
107	Lee Creek – Site 3	20,352	146	On-stream

Table 6.1 - Continued

Site #	Site Name	Volume (dam^3)	Area (ha)	Type
114	Little Bow River Project Dam and Reservoir	60,710	856	On-stream
115	Little Bow Site 2	33,427	698	On-stream
116	Little Bow Site 3	32,687	635	On-stream
117	Little Bow Site 7A (50,000 ac-ft)	60,700	800	On-stream
118	Little Bow Site 7A (70,000 ac-ft)	86,300	1,000	On-stream
119	Little Bow Site 7B	50,000	700	On-stream
120	Little Bow Site LB1	21,278	328	On-stream
123	Lumpy Butte Reservoir	15,295	466	Off-stream
125	Mary Lakes Reservoir	26,643	395	Off-stream
131	Middle Coulee	8,634	121	Off-stream
139	Mosquito Creek Site 3	7,253	188	On-stream
140	Mosquito Creek Site MC4	25,903	486	On-stream
141	Mud Lake	55,507	*	Off-stream
145	Oldman River Gap Dam Site	283,701	971	On-stream
146	Oldman River Site 1-1A	140,617	1,720	On-stream
147	Oldman River Site 1-2A	302,203	2,287	On-stream
148	Oldman River Site 1-3A	305,904	1,679	On-stream
149	Oldman River Site 1-4	182,555	862	On-stream
150	Oldman River Site 2-1A	240,529	1,121	On-stream
151	Oldman River Site 3-1	493,393	3,743	On-stream
152	Oldman River Site 5-1A	155,419	809	On-stream
153	Parkland Reservoir	87,577	1,093	On-stream
169	Rolph Creek Reservoir	17,269	293	On-stream
200	St. Mary – Kimball Reservoir	125,815	688	On-stream
201	St. Mary Border Reservoir	74,009	607	On-stream
205	Taylorville reservoir	52,842	1,506	Off-stream
211	Travers Reservoir Outlet Lowering – Concept 1	*	*	On-stream
212	Travers Reservoir Outlet Lowering – Concept 2	*	*	On-stream
230	West Raymond Reservoir	19,736	304	Off-stream
232	Willow Creek – Site 1	*	*	On-stream
233	Willow Creek – Site 3	*	*	On-stream
234	Willow Creek – Site 4 (below Chain Lakes)	*	*	On-stream
235	Willow Creek – Site 5 (South Willow Creek)	*	*	On-stream
236	Willow Creek – Site 6 (Trout Creek)	*	*	On-stream
237	Women’s (Squaw) Coulee Project	*	*	Off-stream
238	Women’s (Squaw) Coulee Site SC2	*	*	On-stream

Note: * indicates data not available

6.1.2 Initial Screening of Sites

Simulation modeling is the definitive method for evaluating the benefits of a potential storage project. However, modeling all identified potential storage sites in the Oldman River Sub-basin would be expensive and likely unnecessary. Many of the potential sites can be eliminated from consideration using coarser screening criteria. The initial screening process should result in identifying the sites with the best potential to meet project goals within the established criteria while reducing the number of sites for further investigation by simulation modeling.

6.1.3 Initial Screening Criteria

The criteria used for initial project screening should facilitate a high level, defensible evaluation for elimination of a potential storage site from further detailed investigation. The main criteria applied in the initial screening process are as follows.

1. **No longer relevant** - Some sites were alternatives for a storage project that has been developed. Unless otherwise indicated in the records, it is presumed that the best site was developed and the others are no longer candidates for development.
2. **Unsuitable location** - Potential sites may be physically located in the USA, other sub-basins, locations detrimental to urban and other infrastructure, or at locations which cannot provide benefits within the Oldman River Sub-basin.
3. **No apparent or only minor benefit** - The project must be of benefit to First Nations, WCOs, aquatic environment, and junior licensees or have substantial water management benefits within the Oldman River Sub-basin. Projects which support new development unrelated to the above beneficiaries are not considered in this study.
4. **Negative impact on existing infrastructure** - The project would affect the operation or utility of an existing development.
5. **Other** - An obviously better site on the same stream, unacceptable environmental consequences, expected high cost, inadequate inflow, and water sourced from or delivered to another sub-basin.

6.1.4 Eliminated Projects

The 42 projects listed in **Table 6.2** were deemed to be unlikely candidates for development or of little benefit according to the established project criteria. The evaluation considers 26 projects as no longer relevant, 11 projects have little or no apparent benefit, 3 projects are in unsuitable locations and 2 projects were eliminated for other reasons.

Table 6.2
Eliminated Storage Sites in the Oldman Sub-basin

Site #	Project Name	Elimination Rationale
16	Belly River Reservoir	(4) Negative impact on existing infrastructure – Payne Lake, UID Diversion (5) Requires large capacity spillways (5) High estimated cost (5) Potentially better site (151) downstream
48	Castle River (Canyon Site)	(1) No longer relevant – Oldman River Dam developed (4) High recreational use area (5) Poor borrow sources
58	Dead Horse Coulee	(3) Benefit very limited and primary beneficiary is BRID (5) Water source in Bow Sub-basin
77	Glenn Lakes Reservoir	(2) Unsuitable location – in USA, Glacier National Park
96	Jensen Reservoir Extension	(5) Pump storage scheme, costly operation (5) Potentially better site (West Raymond) downstream (5) Very small reservoir
102	Kenex-Rocky Coulee Reservoir	(3) No benefit – irrigation district (LNID) benefit only (5) Modelling done as part of OSSK showed minimal benefit
104	Lee Creek – Site 5A	(3) No benefit – suited only for water supply and flood control for Town of Cardston
105	Lee Creek – Site 6	(3) No benefit – suited only for water supply and flood control for Town of Cardston
106	Lee Creek Reservoir	(3) No benefit – suited only for water supply and flood control for Town of Cardston
107	Lee Creek – Site 3	(3) No benefit – suited only for water supply and flood control for Town of Cardston
114	Little Bow River Project Dam and Reservoir	(1) No longer relevant – project was built and re-named Twin Valley Reservoir
115	Little Bow Site 2	(1) No longer relevant – alternate site developed; Twin Valley Reservoir
116	Little Bow Site 3	(1) No longer relevant – alternate site developed; Twin Valley Reservoir
117	Little Bow Site 7A (50,000 ac-ft)	(1) No longer relevant – alternate site developed; Twin Valley Reservoir
118	Little Bow Site 7A (70,000 ac-ft)	(1) No longer relevant – alternate site developed; Twin Valley Reservoir

Table 6.2 – Continued

Site #	Project Name	Elimination Rationale
119	Little Bow Site 7B	(1) No longer relevant – alternate site developed; Twin Valley Reservoir
120	Little Bow Site LB1	(1) No longer relevant – alternate site developed; Twin Valley Reservoir
123	Lumpy Butte Reservoir	(3) No benefit – irrigation expansion only (5) Very small capacity – limited value
125	Mary Lakes Reservoir	(3) No benefit – irrigation expansion only (5) Very small capacity – limited value
131	Middle Coulee	(2, 3) No benefit - project is in Milk River Sub-Basin (5) Very small capacity – limited value
139	Mosquito Creek Site 3	(1) No longer relevant – alternate site developed; Clear Lake
140	Mosquito Creek Site MC4	(1) No longer relevant – alternate site developed; Clear Lake
141	Mud Lake	(1) No longer relevant – alternate site developed; Oldman River Dam (5) Poor economics
145	Oldman River Gap Site	(1) No longer relevant – alternate site developed downstream; Oldman River Dam (5) Environmental – 1993 Oldman River Dam mitigation report stated it would be an unacceptable development
146	Oldman River Site 1-1A	(2) Unsuitable location – reservoir impacts City of Lethbridge
147	Oldman River Site 1-2A	(1) No longer relevant – alternate site developed upstream; Oldman River Dam (2) Unsuitable location – reservoir could impact Town of Fort MacLeod
148	Oldman River Site 1-3A	(1) No longer relevant – alternate site developed upstream; Oldman River Dam
149	Oldman River Site 1-4	(1) No longer relevant – alternate site developed; Oldman River Dam
152	Oldman River Site 5-1A	(1) No longer relevant – alternate site developed; Oldman River Dam (2) Unsuitable location – Castle River, high recreational use area
153	Parkland Reservoir	(1) No longer relevant – site was developed and renamed Twin Valley Reservoir

Table 6.2 - Continued

Site #	Project Name	Elimination Rationale
169	Rolph Creek Reservoir	(3) No benefit – irrigation expansion only (5) Very small capacity – limited value
201	St. Mary Border Reservoir	(2) Unsuitable location – reservoir would extend into USA (5) Very small capacity – limited value
205	Taylorville reservoir	(3) No benefit – irrigation expansion only (5) Very small capacity – limited value
211	Travers Reservoir Outlet Lowering – Concept 1	(1) No longer relevant – alternate developed
212	Travers Reservoir Outlet Lowering – Concept 2	(1) No longer relevant – alternate developed
232	Willow Creek – Site 1	(1) No longer relevant – alternate site developed; Pine Coulee
233	Willow Creek – Site 3	(1) No longer relevant – alternate site developed; Pine Coulee
234	Willow Creek – Site 4 (below Chain Lakes)	(1) No longer relevant – alternate site developed; Pine Coulee
235	Willow Creek – Site 5 (South Willow Creek)	(1) No longer relevant – alternate site developed; Pine Coulee
236	Willow Creek – Site 6 (Trout Creek)	(1) No longer relevant – alternate site developed; Pine Coulee
237	Women's (Squaw) Coulee Project	(1) No longer relevant – alternate site developed (5) Source – Bow Sub-basin
238	Women's (Squaw) Coulee Site SC2	(1) No longer relevant – alternate site developed (5) Source – Bow Sub-basin

6.1.5 Sites for Further Evaluation

Sites selected for further investigation by simulation modelling are listed in **Table 6.3**.

Table 6.3
Oldman Sub-basin Storage Sites for Evaluation

Site #	Project Name	Volume (dam^3)	Comments and Rationale for Evaluation
49	Chin Reservoir Expansion[1]	74,000	• Off-stream • Use as a "water bank" allowing upstream releases for other purposes • Existing dam, minimal environmental impact, easier permitting
151	Oldman River Site 3-1 (Belly River Site)	493,393	• Located on lower Belly River just upstream of confluence with Oldman River • Partially located on Blood Indian Reserve
200	St. Mary – Kimball Reservoir	125,815	• Located on upper St. Mary River between USA Boundary and St. Mary Reservoir

Note:

1. Chin has two expansion options: raising existing FSL or construction of new East Dam. The raised FSL option was modelled.

Beneficial impact of the Lower St. Mary (Site # 150) and West Raymond (Site # 230) sites listed in **Table 6.4** would be similar to or less than those of the Chin and Kimball sites; therefore, modelling of those sites was deferred pending evaluation of the results for Chin and Kimball.

Table 6.4
Oldman Sub-basin Storage Sites for Evaluation

Site #	Project Name	Volume (dam^3)	Comments and Rationale for Evaluation
150	Oldman River Site 2-1A (Lower St. Mary River)	240,529	• Located on-stream, lower St. Mary River between St. Mary Reservoir and confluence with Oldman River • Partially located on Blood Indian Reserve • Would inundate the Ammolite mine
230	West Raymond	19,736	• Off-stream • Use as a "water bank" allowing upstream releases for other purposes • Less environmental impact, easier permitting

6.2 Modelling

The *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009) described the current in-stream flow requirements (WCO and IO), and the current and potential future (year 2030) water use levels that provided the demand database for simulation modelling. The study focused on surface-water uses that impact the main river systems in the basin, particularly in low-runoff years when there are likely to be issues related to water deficits. Modelling identified the frequency, magnitude, and locations of issues related to water supply and demand that set the stage for identification and assessment of adjustments or adaptation strategies that will improve water supply security. This is of major importance in the SSRB in Alberta because of the historical dependence on water management and use in the semi-arid climate, and because of concern about impacts on environmental resources.

Demand data from the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009) Scenario 3 was used as a base case for assessing the benefits of additional storage. Scenario 3 reflects development that could take place by the year 2030. Modelling showed that projected demands to 2030 stressed the system adequately to provide a good scenario for assessing the value of new storage development or operational refinements for existing storage.

In this study, the intent is to improve simulation modelling and interpretation of its output by providing greater detail. In particular, the updated model:

- Used an updated demand database in the SSRB model. This is particularly important in the Red Deer River Sub-basin, the only sub-basin that is accepting applications for new licences.
- Provided a breakdown of demands on regulated or mainstem streams and unregulated tributary streams within the SSRB. Water use on both regulated mainstems and unregulated tributaries deplete natural flow in the mainstem streams. Therefore all streams that contribute to mainstem flows must be included in the model. However, operational changes for existing storage or new storage developments can only improve performance on the regulated streams or areas. Deficits on the unregulated tributaries to the mainstem streams remain unchanged.

> **Licensed Use** – Water use based on information provided in the license. Licensed use is equal to Consumption plus Losses, or Allocation minus Return Flow (which will give the same value). Licensed use is usually larger than actual use because the full allocation is not required in most years. However, licensed use can be less than actual use if actual return flows are less than the estimated licensed amounts, or actual losses are larger than the licensed amounts.

- Provided a breakdown of junior and senior licences within each modelled reach of the SSRB. Junior licences are those that are subject to WCOs or relatively large IOs that have been established in various areas throughout the SSRB since the mid-1980s. Senior licences are generally those with priorities that predate the junior licences. Senior licences may not be subject to an in-stream requirement or would have only a nominal such requirement by today's standards. Some licences have a retrofit provision whereby an in-stream flow constraint can be added if and when such a constraint is established. Deficits to consumptive water users in the SSRB generally affect junior water users and, less frequently, users with both junior and senior licences.

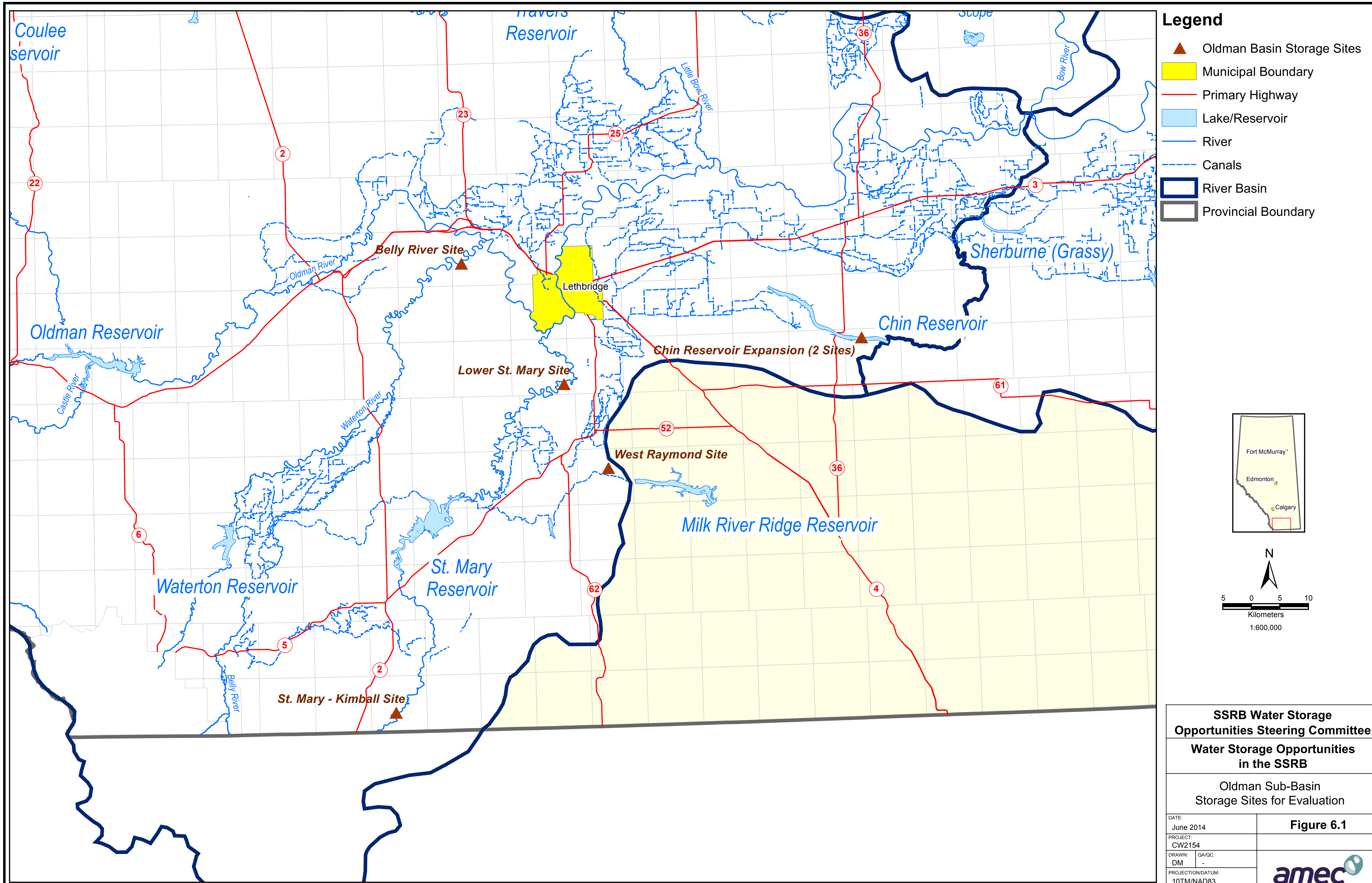
- Distinguished between district irrigation, private irrigation, urban municipal use and "other" uses within the modelling reaches. Irrigation use is by far the largest category of use within the SSRB. It is also one that can tolerate occasional deficits. Irrigation district withdrawals and most return flows are recorded. For modelling purposes, irrigation uses are based upon Alberta Agriculture and Rural Development (AARD) estimates of weekly irrigation demands. Irrigation district water use commonly crosses sub-basin boundaries. For instance, large areas of land in the Red Deer River Sub-basin are within the WID and EID which are sourced from the Bow River. Throughout this report, areas of land where water is being used are identified with the sub-basin that is the source of supply.
- Used licenses for municipal recreational wildlife habitat, industries, stockwater, and other minor uses. Household use for human consumption, cooking, and sanitation is a relatively small use, but is arguably the most important consumptive use in the SSRB. Water supply deficits to municipal users would have high impacts on urban centers (cities, towns, villages). There are good recent records of actual community uses within ESRD's Water Use Reporting System (WRS). Household users in rural areas are usually supplied by individual groundwater systems or water co-ops. Like urban users on municipal systems, these users would be equally highly impacted by deficits. Water requirements and performance on meeting demands in rural areas is limited. The quantities of "other" uses are highly variable and poorly defined. There are limited recorded data available on uses for projects associated with recreation, wildlife habitat, most industries, stockwater, and commerce. Their tolerances for deficits are highly variable. In this study, demands for these sectors are based on licensed use. They are modelled as a group within each reach.

6.2.1 Modelling of Potential Storage Sites

Simulation modelling assists in identifying and developing an understanding of issues, and provides a basis for a rational discussion of alternative remedial measures. In this study, WRMM is used as the analytical tool. It is the same model that was used by ESRD for SSRB water management planning (AENV, 2006) and by AMEC for the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009).

Modelling mathematically determines the performance of a simulated physical system over a sequence of years and time steps. Inputs to the model include the physical system, which is the configuration of streams, diversions, canals, and water management infrastructure, the natural water supply, current and future consumptive uses, in-stream flow requirements, licence priorities, and current water management policies and operation procedures. **Figure 6.1** shows the location of the three dams. Simulation modelling was conducted for the following scenarios:

- SSRB Base Case (Scenario 3);
- Chin Reservoir Expansion Project (Site # 49);
- Belly Reservoir Project (Site # 151, Oldman River Site 3-1); and
- Kimball Reservoir Project (Site # 200).



P:\Water Resources\PROJECTS\CW2154_SSRB\2 WIP\02 Survey Data\GIS Data from the R drive\Figure 6.1.mxd

The primary purpose of modelling was to determine the extent to which the new storage options would reduce deficits to WCOs and junior consumptive users in the Oldman and South Saskatchewan river sub-basins.

Key assumptions and databases used for modelling in this study are noted below.

- Modelling was conducted for the 74-year historical period of reconstructed natural flows (1928 to 2001) using a weekly time step (AEP, 1998; Updated in October 2004).
- Projected actual demands to year 2030 were used as demand data for irrigation and urban municipal demands. These are the largest users in the SSRB for which demands have been recorded or can be reliably estimated. Little recorded information is available for other uses. "Licensed demands" (licensed allocations minus return flows) were used for all other purposes. Actual uses and demands are usually lower than licensed demands.
- For most private irrigation projects, crop water demands estimated by AARD exceed licence allocations in some years. Modelling assumed that irrigation diversions would cease when the full licensed allocation has been withdrawn from the source of supply. Model output of annual irrigation deficits for junior projects is computed as the lesser of crop water requirements or licence allocation. This issue was analyzed and discussed in detail for irrigation water users in the Little Bow Basin in the report, *Highwood Water Management Plan, Phase 1: Report and Recommendations for Highwood Diversion Plan* (Highwood Diversion Plan Public Advisory Committee, 2006).
- Demands on regulated streams (referred to mainstem demands) are considered separate from those on unregulated tributary streams to better define the impacts of deficits and the demands that could benefit from changes in infrastructure operations of new storage developments. In previous studies using the WRMM (AENV, 2006; AMEC, 2009), no distinction was made between mainstem and tributary demands.
- The IOs and WCOs, as specified in the approved SSRB Plan and decisions of *Water Act* Directors (ESRD 16 January 2011), are used for all scenarios modelled. Licences issued since about the mid-1980s usually include in-stream flow constraints on withdrawals. These limitations may be a constant minimum flow or variable minimum flows indexed to natural flows. Older licences may not have any in-stream flow conditions or very low nominal conditions attached to their licences.
- In this study, the licence priorities are respected, although simulation modelling does not address the priority of each individual licence. Water demands of similar priority in relation to in-stream needs (IOs or WCOs) are accumulated, assigned to a node, and treated as a single-demand block.
- "Junior priority licences" are those that are subject to WCOs or high IOs that have been developed since the 1980s. "Senior priority licences" may be subject to low, nominal in-stream flows or no in-stream flows at all. Senior licences on mainstem streams are unlikely to experience water supply deficits.

Retrofit provision: Water licences issued since about February 1997 usually contain a condition that indicates that the licence may be amended to include a WCO once one has been established. Individual licences should be checked to determine if they contain the retrofit provision.

On amended licences, the licensee would not be permitted to divert when the river flow is less than the WCO.

The model computes water deliveries to meet consumptive and in-stream demands in accordance with priorities and considering physical constraints within the system, such as reservoir storage capacities, canal, and reservoir outlet flow capacities. Output from the model includes stream and canal flows, reservoir levels, and performance in meeting in-stream demands and consumptive uses. Subject to assumptions and the limitations of the database and model physical representations, the model output represents the conditions that would have existed if the management scenario had been in place during the 1928 to 2001 historical period of natural stream flow and climatic conditions that are simulated.

6.2.2 Legislative and Regulatory Requirements

A recommendation in the *Approved Water Management Plan for the South Saskatchewan River Basin* (AENV, 2006), Section 2.3.2 states that for the Bow, Oldman and South Saskatchewan river sub-basins WCOs:

> "The recommended WCOs are either 45% of the natural rate of flow, or the existing in-stream objective increased by 10%, whichever is the greater at any point in time."

The plan also recommends that the "WCO for all storage licences under the Crown Reservation should be the existing in-stream objective (IO) plus 10% at any point in time."

The statements in the SSRB water management plan (AENV, 2006) are recommendations. ESRD formalized guidelines for implementation of WCOs for the SSRB in a policy dated 16 January 2007. Irrespective of the recommendations in the plan, the implementation policy does not distinguish between storage reservoirs and other types of use. Therefore, the WCO that will be applied to a new license for new storage projects under the Crown Reservation will be:

$$WCO = MAX\ (0.45{*}Q_{nat},\ 1.1{*}IO)$$

where Q_{nat} is the weekly natural flow of the river and IO is the In-stream Objective.

The issue was discussed with ESRD. ESRD indicated that when the director established WCOs for the Oldman River Sub-basin on 16 January 2007 there was no reference to the SSRB management plan recommendation. Therefore the WCO is as defined above for all new developments (Murphy, pers. comm.). A copy of the policy is included in **Appendix F.**

The existing IO is 0.93 m^3/s for the Belly River downstream of the Waterton Reservoir to the confluence with the Oldman River. The existing IO is 2.75 m^3/s for the St. Mary River downstream of the St. Mary Reservoir to the confluence with the Oldman River. WCOs will be established as stated in the policy for river reaches where there is no existing IO. On streams where there are other factors affecting the "natural flow" such as the international agreement on the Milk and St. Mary rivers, establishing the WCO requires a specific review.

Under the current policy only flows in excess of the WCO and downstream priority licensed uses would be available for storage in any new reservoir developed whereas if the recommendation in the SSRB plan was implemented, new storage would be subject to a minimum downstream flow of 1.02 m^3/s for the lower Belly River, and 3.00 m^3/s for the lower St. Mary River. The *In-stream Flow Needs Determinations* (Clipperton, 2003) report developed integrated in-stream flow needs based on the natural flow paradigm for protection of the aquatic ecosystem. Modelling new storage using both the WCO policy and the 1.1×IO criteria would provide insight on the relative benefits to the ecosystem of each approach.

6.2.3 The Scenarios

6.2.3.1 South Saskatchewan River Basin Base Case

Scenarios are compared against the Base Case to determine their effectiveness. The Base Case is an update of Scenario 3 from the *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009).

The update reflects changes in the demand database, operational practices, and a more detailed reach by reach analysis of performance in meeting demands. Scenario 3 represents expansion of development within irrigation districts to full use of their current allocations. Other demands are projected to 2030 based largely on population growth projections, licence applications on hand, and other committed projects through measures such as reservations and agreements.

Details of the updated base case are included in **Appendix C.**

6.2.3.2 Chin Reservoir Expansion Project

The Chin scenario assumes expansion of Chin Reservoir. Chin Reservoir is a component of the SMRID's infrastructure with a capacity of 190,000 dam^3. The licensed purpose is for irrigation demands within the SMRID and TID. The additional off-stream storage would allow increased releases from St. Mary Reservoir to meet in-stream flow needs and existing consumptive uses, including junior priority uses, downstream of St. Mary Reservoir without jeopardizing performance in meeting irrigation districts needs.

Apart from the Chin Reservoir expansion, all infrastructure and demands remain the same as in the Base Case scenario. The Chin Reservoir expansion can be created either by raising the two existing Chin dams (NW Dam 1 and SE Dam 2) or by developing a new dam further eastward along Chin Coulee. More detailed field investigations and analyses would be required to determine the most cost effective and social and environmentally acceptable option to pursue. Either of the two options gives the same performance for modelling purposes.

Modelled assuming raising of the two existing dams. Modelled characteristics of the Chin expansion are:

- Increased Storage - 74,000 dam^3;
- FSL - 867.25 m;
- Dam Height - Dam 1 is 26.3 m, Dam 2 is 18.7 m; and

- Increased storage managed by the province.

6.2.3.3 Kimball Reservoir Project

The Kimball scenario assumes construction of a new dam on the St. Mary River upstream of the existing St. Mary Reservoir to improve performance in meeting in-stream needs and existing consumptive uses, including junior priority uses. Modelling investigated two in-stream release scenarios, a 1.1×IO release and ESRD's current WCO policy.

Apart from the Kimball Reservoir Project, all infrastructure and demands remain the same as in the Base Case scenario. The Kimball Reservoir site would extend southward close to the International Boundary. Characteristics of the new Kimball Reservoir Project are:

- Storage - 125,800 dam^3;
- FSL - 1,260 m;
- Flooded Area - 688 ha; and
- Dam Height - 55 m.

6.2.3.4 Belly Reservoir Project

The Belly scenario assumes construction of a new dam on the Belly River near its confluence with the Oldman River. The storage is intended to improve performance in meeting in-stream needs and existing consumptive uses, including junior priority uses along the downstream Oldman River and aid in meeting Alberta's apportionment commitments. This would enable operational changes at the Oldman River Dam to benefit in-stream flows and consumptive uses between the Oldman Dam and the Belly River confluence.

Modelling assumed that the USA used their full entitlement and investigated two in-stream release scenarios, a 1.1×IO release and ESRD's current WCO policy. Apart from the Belly Reservoir Project, all infrastructure and demands remain the same as in the Base Case scenario.

A portion of the reservoir would be located on the Blood First Nation Reserve. Modelled characteristics of the new Belly Reservoir Project are:

- Storage - 493,000 dam^3;
- FSL - 927 m;
- Flooded Area - 3,725 ha; and
- Dam Height - 41 m.

6.3 Evaluation of Modelling Results

Performance in meeting demands is assessed by analyzing output data to determine how well objectives are met. The magnitude and frequency of failure to meet objectives are the most common measures of performance. Evaluations of model results assess performance in meeting both consumptive and in-stream needs. Simplified tables or graphics are prepared to assist in evaluating the performance of one management scenario against others.

Scenario evaluation is primarily comparative rather than absolute. The "Base Case" most often represents the current situation or a "do-nothing" option and is a key scenario for comparisons. In this study, the Base Case is an updated Scenario 3 from the *South Saskatchewan River Basin in Alberta Water Supply Study (*AMEC, 2009). Scenario 3 represents expansion of development within irrigation districts to full use of their current allocations. Other demands are projected to 2030 based largely on population growth projections, licence applications on hand, and other committed projects through measures such as reservations and agreements.

Absolute performance criteria vary among water-use sectors. For instance, it is generally considered that municipalities and industries require more assured water supplies than recreation or wildlife projects. Irrigators can withstand occasional deficits. No definitive local studies have been done to determine the tolerances of various water use sectors to deficits. For irrigation use, several previous studies have used the criteria that gross diversion deficits greater than 100 mm in more that 10% of the years or in any back-to-back years would cause financial hardship and perhaps insolvency to some irrigation farmers. However, even in this case, the criteria have not been universally accepted by irrigation farmers. Because irrigation is such a dominant water use in the SSRB, reference to these criteria are made in the evaluations. Apart from irrigation, evaluations are comparative among the scenarios.

Tables are presented to show the frequency and magnitude of deficits for various river reaches and for the WCO, irrigation districts, private irrigation and other purposes.

Graphics are prepared for convenient comparison among reaches and among scenarios.

The WCOs are an indicator of the health of the downstream aquatic environment. The graphics for WCOs compare the frequency of weekly deficits greater than 10% during the 3,848-week study period (74 years times 52 weeks). The WCOs are administered on a weekly basis. Deficits greater than 10% are shown to allow for possible streamflow monitoring error, particularly during the winter months. Simulated weekly flows that are less than the weekly WCO are considered to be in deficit regardless of whether not previous or subsequent weekly flows exceed the WCO.

Graphics for district and private irrigation show the frequency of annual deficits greater than 100 mm, that being the primary criteria for judging the acceptability of irrigation performance.

The graphics for non-irrigation uses show the frequency of annual deficits greater than 10% of the demand. Tolerance for deficits would vary widely for this group of users. Probably the most sensitive group would be the urban municipal users, but even this group could tolerate some deficits by use of constructed storage or short-term rationing.

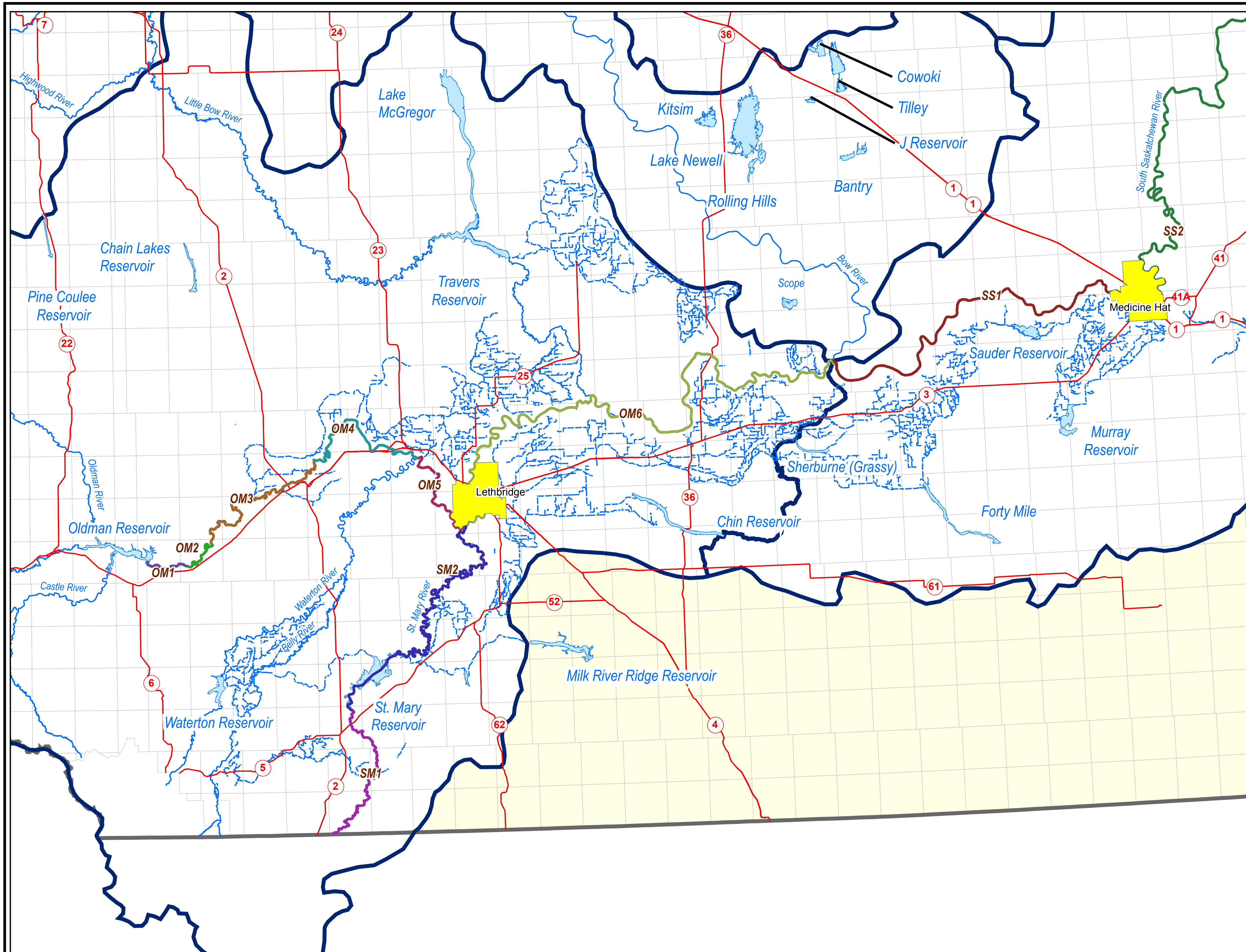
6.3.1 Base Case (2030 Demands) for Oldman and South Saskatchewan Sub-basins

There are six in-stream flow reaches along the Oldman River from the Oldman Reservoir to the Oldman River mouth (Bow River confluence), two reaches along the St. Mary River and two reaches along the South Saskatchewan River (**Figure 6.2**).

The magnitude and frequency of the deficits are noted in the tables in **Appendix D** whereas the graphs provide a visual index of performance. Pertinent results and figures are shown below for the Oldman River Sub-basin.

Oldman River Evaluation Reaches

OM1: Oldman Reservoir to Pincher Creek
OM2: Pincher Cr to LNID Diversion
OM3: LNID Diversion to Willow Creek
OM4: Willow Creek to Belly River
OM5: Belly River to St Mary River
OM6: St. Mary River to Oldman Mouth
SM1: St Mary River U/S St Mary Reservoir
SM2: St Mary River D/S St Mary Reservoir
SS1: South Sask River U/S Medicine Hat
SS2: South Sask River D/S Medicine Hat



SSRB Water Storage Opportunities Steering Committee

Water Storage Opportunities in the SSRB

Oldman River Evaluation Reaches

DATE: June 2014	Figure 6.2
PROJECT: CW2154	
DRAWN: DM / QA/QC: -	
PROJECTION/DATUM: 10TM/NAD83	amec

6.3.1.1 Water Conservation Objective Results

Modelling indicates that the frequencies of WCO deficits upstream of Willow Creek are minor (<10% of weeks). The frequencies increase downstream of Willow Creek. St. Mary River WCO deficits downstream of the St. Mary Dam are very high (>50% of weeks; **Figure 6.3**).

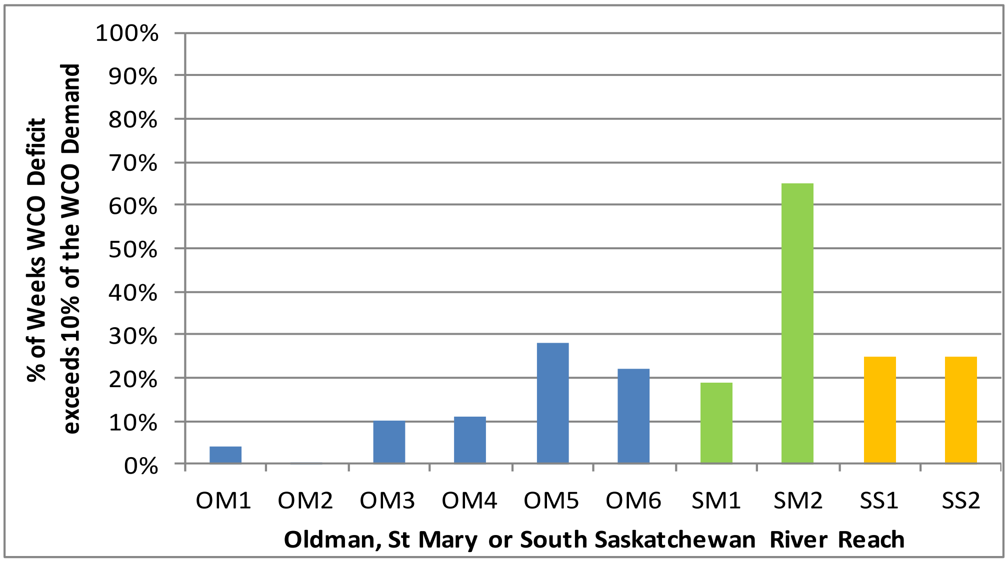


Figure 6.3 Base Case (2030 Demands): Oldman, St. Mary & S. Saskatchewan Rivers Frequency of Water Conservation Objective Deficits >10%

6.3.1.2 Irrigation District Results

Base Case modelling indicates acceptable performance (annual deficits >100 mm in <10% of years) within the Oldman River irrigation districts (**Appendix D, Table D.5**). This conclusion is predicated on improvements in on-farm and district operating efficiencies, reduced return flows, a shift toward higher value crops and increased water applications to generate higher revenues and improve farm financial performance.

6.3.1.3 Junior Private Irrigation Results

There are no junior private irrigation projects in reach SM1. Junior private irrigation projects in reaches OM1 to OM5 do not meet acceptable performance criteria (**Figure 6.4**). This includes the potential Oldman River Reservoir Area (Summerview) project (OM1) and the Piikani project (OM2), which are both supplied from the Oldman Reservoir. Projects in the lowest reach (OM6) benefit from irrigation return flows. Private irrigation along the lower St. Mary River and the South Saskatchewan River meet the irrigation performance criteria.

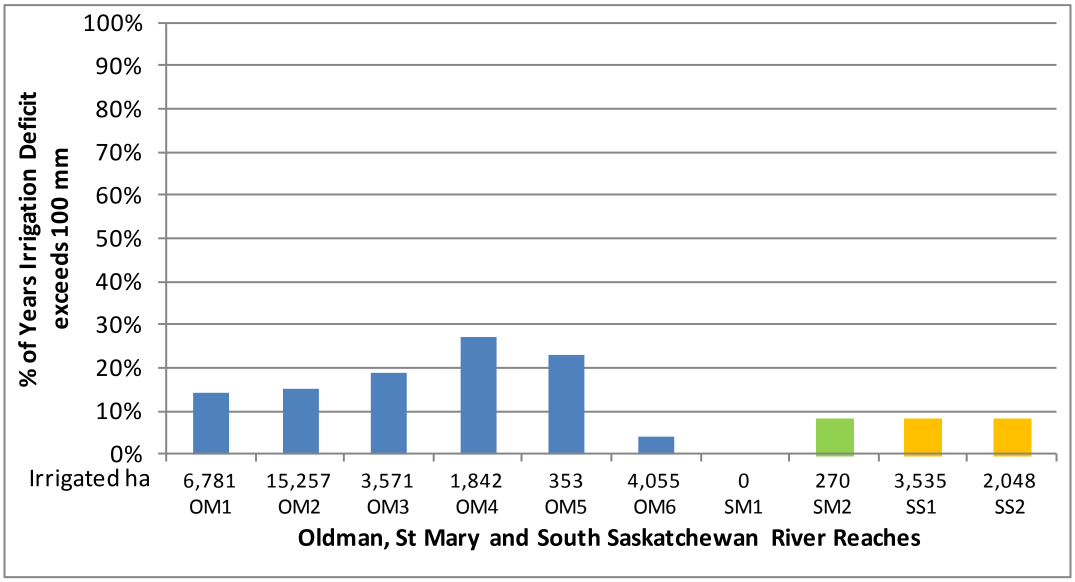


Figure 6.4 **Base Case (2030 Demands): Oldman, St. Mary & S. Saskatchewan Rivers Junior Private Irrigation Frequency of Deficits > 100 mm**

6.3.1.4 Junior Non-irrigation Results

There are no junior non-irrigation projects in OM1 and OM5. Junior non-irrigation projects perform poorly in all reaches modelled in the Oldman River Sub-basin (**Figure 6.5**).
The frequency of deficits is very high (over 50%) in reaches OM2, OM3, OM4, SM1, and SM2. Deficits are moderately high (between 10% and 50%) in Reaches OM6, SS1, and SS2.

The 10,720 m^3 of junior non-irrigation demand in OM3 (LNID Diversion to Willow Creek) is almost all licensed for diversions from the Oldman River through the Lethbridge Northern Headworks. The licensees may have made arrangements for use of internal storage within the LNID to meet their needs during the non-irrigation season when Headworks are shut down or when the WCO and higher priority demands preclude diversions. This anomaly is not reflected in the WRMM model, and hence the deficits in model output for OM3 are probably overstated.

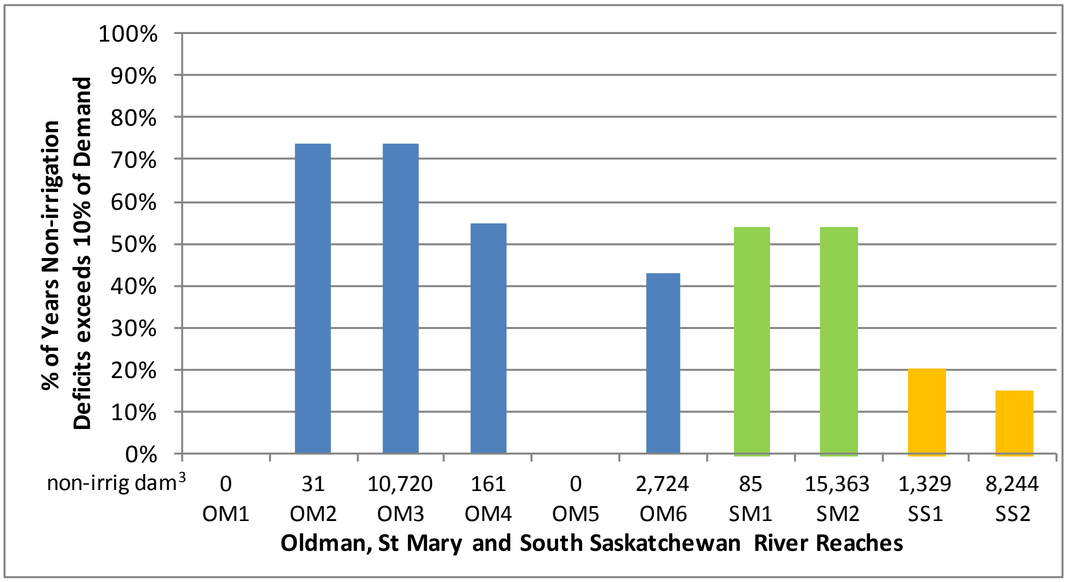


Figure 6.5 Base Case (2030 Demands): Oldman, St. Mary & S. Saskatchewan Rivers Junior Non-irrigation Projects Frequency of Deficits >10%

6.3.2 Chin Reservoir Expansion and Kimball Projects

Off-stream storage in an expanded Chin Reservoir could be used to enable changes in the operation of the St. Mary Reservoir without affecting the Base Case performance of the irrigation districts and other users of the St. Mary River system. The primary objective is to improve performance for in-stream flows and junior consumptive users along the St. Mary River downstream of the St. Mary Reservoir, and possibly in the lower reach of the Oldman River.
In the operation of the new Chin and Kimball storage projects, priority was given to reducing deficits to WCOs and junior consumptive users rather than reducing deficits to irrigation districts. The Base Case scenario considered a 24% expansion of the irrigated areas of the Oldman irrigation districts from the average area irrigated during the past 4 years. In the Base Case, district demands were met well within the performance criteria for irrigation projects. Rather than further reduce irrigation district deficits, the new storage was dedicated to meeting the needs of in-stream flows and junior consumptive users, most of which have a high magnitude and frequency of deficits in the Base Case.

Model calibration required several iterations to ensure that:

- Adjustments to St. Mary Reservoir operations made effective use of the Chin Reservoir Expansion storage; and
- There was no adverse impact on irrigation district use.

The impact on downstream demand was then evaluated.

A storage project (Kimball) on the St. Mary River upstream of the existing St. Mary River Reservoir could supplement regulation of St. Mary River flow and improve performance for in-stream flows and junior consumptive users along the St. Mary River upstream and downstream of the St. Mary Reservoir. If sufficient water is available the project may improve in-stream and consumptive use along the Oldman River downstream of the confluence with the St. Mary River.

The Kimball Project was evaluated considering two alternative downstream flow requirements:

- MAX(WCO or 3.0 m^3/s), where WCO = 45% of the natural flow; and
- 3.0 m^3/s.

The value 3.0 m^3/s is based on the IO downstream of the St. Mary Reservoir increased by 10%.

The performance of the Chin and Kimball sites are evaluated against the Base Case and against each other in the following sections. The frequency and magnitude of deficits for the Chin and Kimball projects are provided in **Appendix E, Tables E.1 to E.4**.

6.3.2.1 Water Conservation Objective Results

Model output for the Chin and Kimball scenarios indicated no significant change (<5%) from the Base Case in the frequency of WCO deficits along the Oldman or the South Saskatchewan River reaches (**Figure 6.6**). Reaches upstream of OM4 are not shown in the graphic since there was no change from the Base Case. The Kimball 3.0 m^3/s scenario showed an increase in deficits of about 5% upstream of the St. Mary Reservoir and a decrease of about 5% downstream of the reservoir. The other scenarios showed no significant change along the St. Mary River.

Deficits are very frequent and large in St. Mary River reach SM2 for all scenarios.

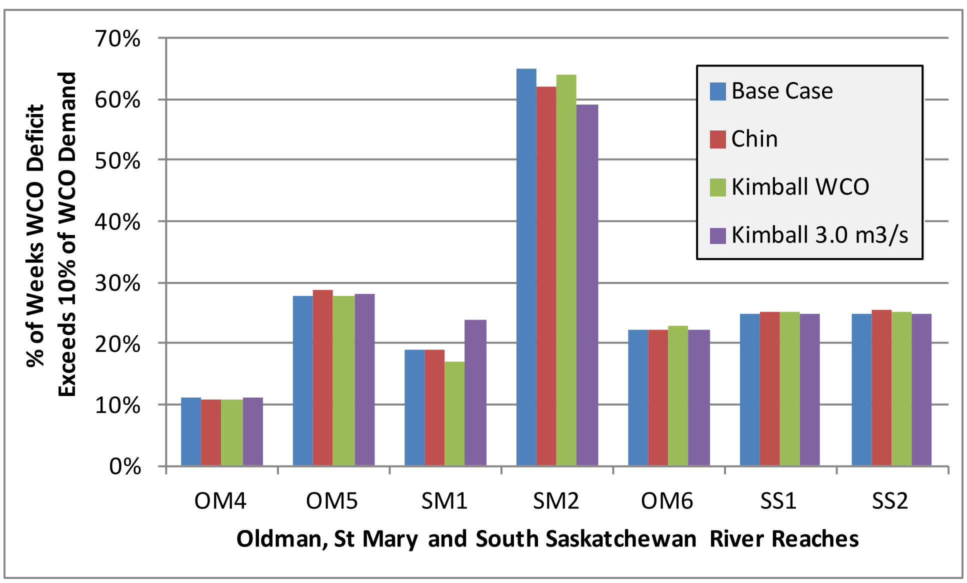


Figure 6.6 Chin and Kimball Projects (2030 Demands): Frequency of Oldman, St. Mary & S. Saskatchewan River WCO Deficits >10%

6.3.2.2 *Irrigation District Results*

The irrigation district performance for the Chin and Kimball scenarios indicated no significant change from the Base Case (**Table D.5**).

6.3.2.3 *Junior Private Irrigation Results*

The frequency of deficits for private irrigation improved by a small amount over the Base Case in reach OM5 for the Chin and Kimball Projects, and in reach SM2 for the Chin Project (**Figure 6.7**). In reaches SM2, SS1 and SS2, the Base Case, Chin and Kimball scenarios indicated that the irrigation performance was within the guidelines used for determining the adequacy of water supply for irrigation projects. Changes from the Base Case were not significant.

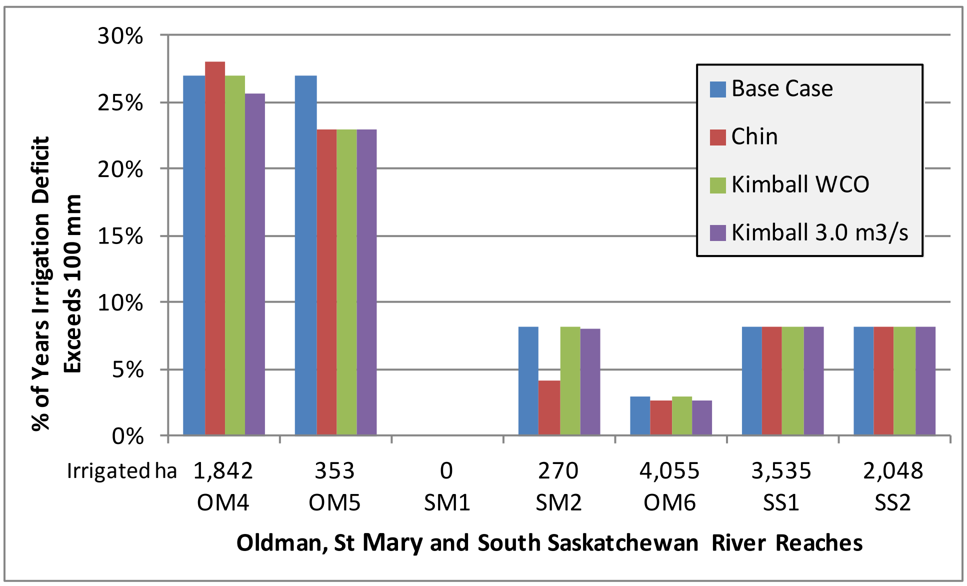


Figure 6.7 Chin and Kimball Projects (2030 Demands): Oldman, St. Mary & S. Saskatchewan Junior Private Irrigation Frequency of Deficits >100 mm

6.3.2.4 *Junior Non-irrigation Results*

Junior non-irrigation demands from the St. Mary River in SM2 total 15,363 dam^3, which includes urban municipal demands of 4,141 dam^3. All of the urban municipal demands and 7,275 dam^3 of other demands (stock water, industrial, waterfowl, recreation, etc.) are diverted from the St. Mary Reservoir through the works of ESRD and the four irrigation districts served from that reservoir. Model output indicated that the frequencies of deficits greater than 10% to the non-irrigation demands were reduced from 54% of the years in the Base Case to less than 10% of years with the expanded Chin Reservoir or Kimball projects. This apparent major benefit may be overstated since the junior licensees with year-round demands delivered through the works of the districts would have arrangements for use of off stream storage to satisfy their needs during the non-irrigation period and at other times when licence priorities and conditions restrict diversions from the St. Mary River.[1] As such, up to 75% of the non-irrigation users from SM2 are located within or near the irrigation infrastructure and may have more water supply security than indicated in the Base Case.

Model output indicates no reductions in the frequency of non-irrigation deficits greater than 10% along the Oldman River upstream or downstream of the St. Mary confluence or along the South Saskatchewan River (**Figure 6.8**).

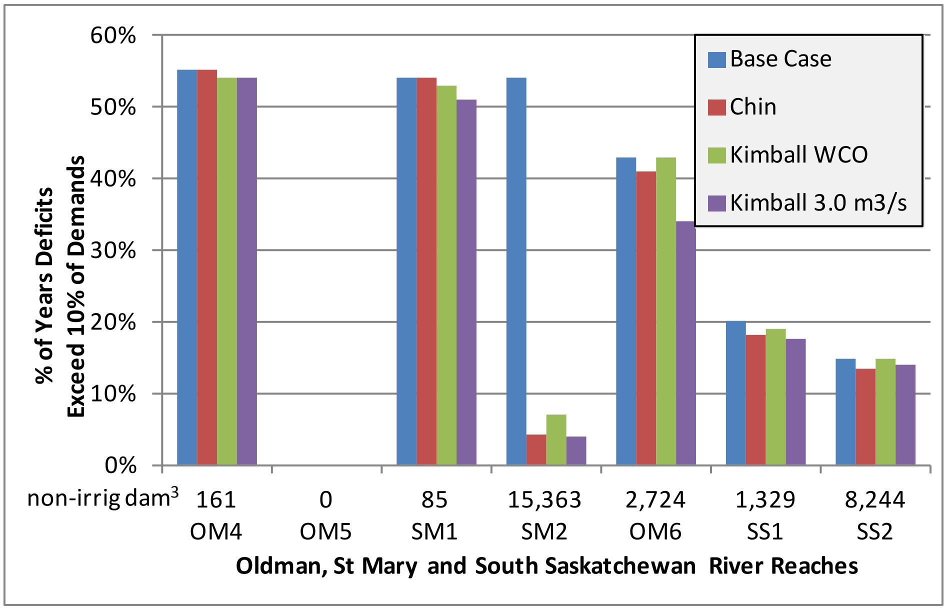


Figure 6.8 Chin and Kimball Projects (2030 Demands): Oldman, St. Mary & S. Saskatchewan Junior Non-irrigation Projects Frequency of Deficits >10%

6.3.3 Belly Reservoir Project

A new storage reservoir near the mouth of the Belly River could be used to reduce deficits to junior consumptive users along the Oldman River downstream of the confluence (in OM5 and OM6). Relieving the Oldman Reservoir of this demand would allow its operation to be modified to improve performance in meeting needs upstream of the Belly confluence (in OM1 to OM4).

In addition to modelling two in-stream release criteria, it was decided to model three storage capacities to determine if the reservoir could be used for both water supply and flood mitigation. The four options considered were as follows.

- Scenario Belly 490K:
  - WCO Capacity = 490,000 dam^3.
  - Downstream release = MAX (0.45*Q_{nat}, 1.1*IO).

[1] Personal communication with SMRID, TID and BRID engineering staff.

- Scenario Belly 490K:
  - 1.1*IO Capacity = 490,000 dam^3.
  - Downstream release = 1.1*IO.
- Scenario Belly 324K:
  - 1.1*IO Capacity = 324,000 dam^3.
  - Downstream release = 1.1*IO.
- Scenario Belly 160K:
  - 1.1*IO Capacity = 160,000 dam^3.
  - Downstream release = 1.1*IO.

6.3.3.1 Water Conservation Objective Results

Modelling of the Belly scenarios indicates no significant reduction in WCO deficits in any of the reaches along the Oldman or South Saskatchewan rivers (**Figure 6.9**). In fact, deficits increased slightly in reaches OM5 (Belly to St. Mary River) and OM6 (St. Mary River to the Mouth) for the Belly 1.1*IO scenarios.

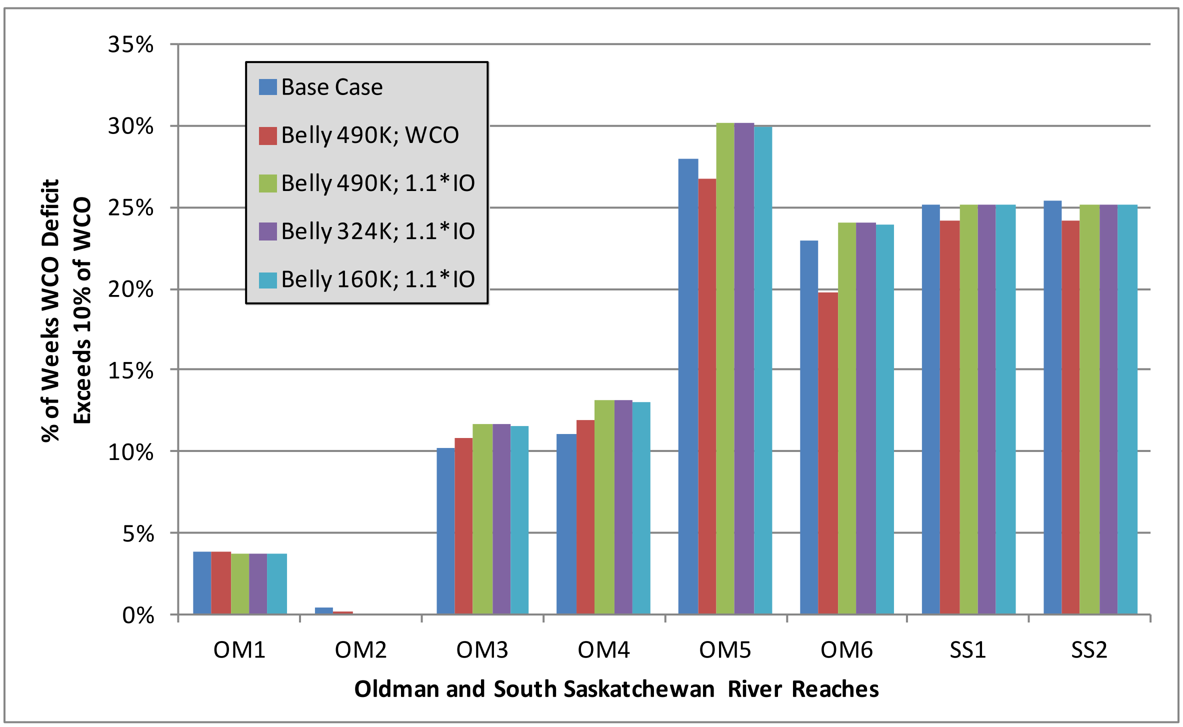


Figure 6.9 Belly Project (2030 Demands): Oldman & S. Saskatchewan Rivers WCO Deficits >10%

In all scenarios, the existing reservoirs in the Oldman River Sub-basin are regulated to meet the downstream IOs; the targeted IOs are met along the rivers with few, if any, deficits. However, with additional storage on the Belly River and operational changes for the Oldman Reservoir, flows can be regulated to better match the needs of consumptive users. Also, in the Base Case operational spills from the Belly River would contribute to meeting the WCO. With the Belly Reservoir in place, the high flows can be stored and regulated to coincide with consumptive demands during periods that do not contribute to WCOs. This results in increased use and lower in-stream flows that are surplus to the IOs. Hence, in some reaches there are higher WCO deficits than in the Base Case.

WCO deficits in Oldman Reaches OM3 to OM6 are slightly higher for the three 1.1×IO scenarios compared to the WCO scenario.

6.3.3.2 Irrigation District Results

The irrigation district performance in the Belly Project scenarios is the same as the Base Case (**Table D.5**).

6.3.3.3 Junior Private Irrigation Results

Downstream of the Belly River project, junior demands in Oldman River reaches OM5 and OM6 include 4,408 ha of private irrigation with an allocation of 14,207 dam^3 (**Figure 6.10; Appendix A, Table A.3**). Performance in meeting the irrigation demand in OM5 improved somewhat over the Base Case for scenario Belly 490; WCO, but the frequency of deficits was still well above what is considered acceptable for irrigation. Performance is much improved in OM5 and within acceptable frequencies of deficits for the three Belly 1.1*IO scenarios. In OM6, performance is within acceptable limits for all scenarios including the Base Case, but deficits are less frequent for the Belly 1.1×IO scenarios.

There are 5,583 ha of junior private irrigation in South Saskatchewan River reaches SS1 and SS2 with a total allocation of 22,509 dam^3 (**Figure 6.11**; **Appendix A, Table A.4**). Model output showed no significant improvement from the Base Case for scenario Belly 490K; WCO but considerable improvement for the three Belly 1.1×IO scenarios. In reaches SS1 and SS2, the Base Case and all four Belly scenarios are within the performance criteria for irrigation.

Considering the three Belly 1.1×IO scenarios, the frequencies of deficits increase significantly for the 160,000 dam^3 storage project but they are still within the acceptable criteria.

Upstream of the Belly Project, there are 22,037 ha of private irrigation in reaches OM1 and OM2, including the future Summerview and Piikani First Nation projects (**Figure 6.10**). Modelling output showed little improvement in performance for Scenario Belly 490K; WCO over the Base Case. Performance remains outside acceptable criteria for both scenarios. For the three Belly 1.1×IO scenarios, performance is within the acceptable criteria in reaches OM1 and OM2. In reach OM3, with 3.571 ha of private irrigation, there is considerable reduction in deficits with any of the four Belly scenarios, but none of the scenarios already perform within the acceptable irrigation criteria. In reach OM4 (1,842 ha), there is modest improvement in performance for scenario Belly 490K; WCO but not within the acceptable criteria. For the three Belly 1.1×IO scenarios, there is considerable improvement in performance, but scenario Belly 160K; 1.1×IO performance is not within the acceptable criteria.

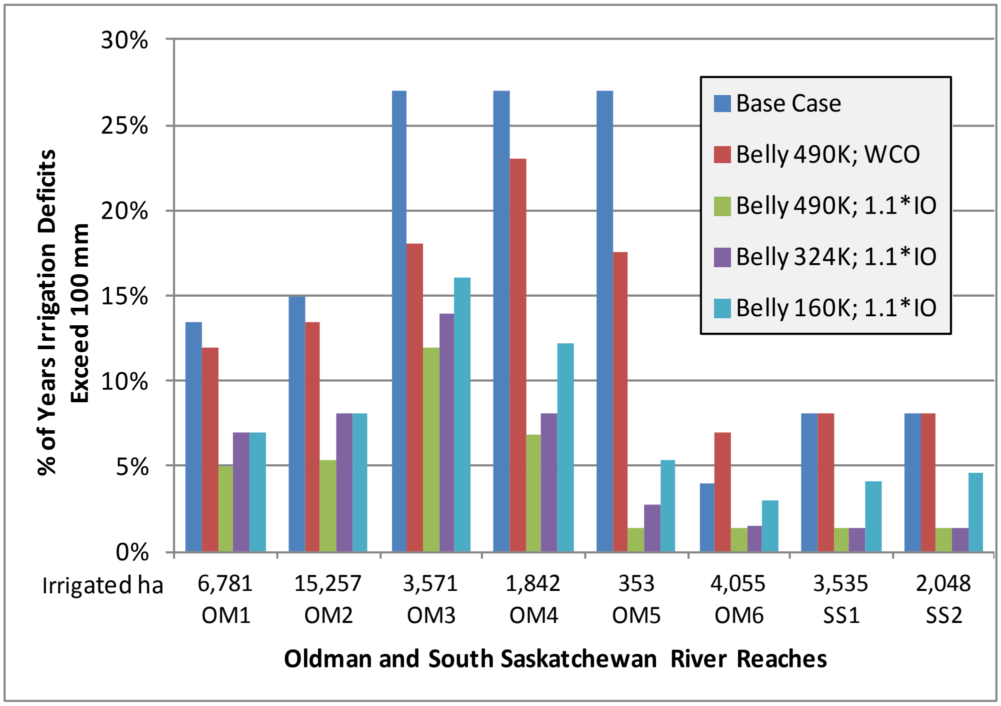


Figure 6.10 Belly Project (2030 Demands): Oldman & S. Saskatchewan Rivers Junior Private Irrigation Frequency of Deficits >100 mm

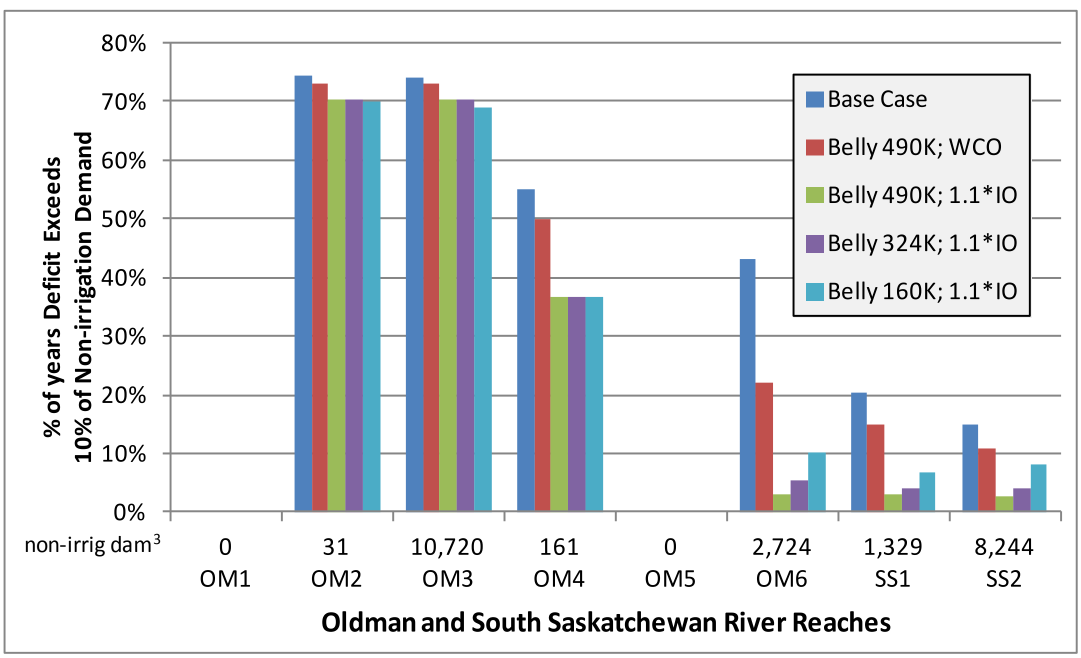


Figure 6.11 Belly Project (2030 Demands): Oldman & S. Saskatchewan Rivers Junior Non-Irrigation Projects Frequency of Deficits >10%

6.3.3.4 Junior Non-irrigation Results

Downstream from the Belly Project, there are no junior non-irrigation projects in reach OM5; in reach OM6 there are 2,724 dam^3 total junior allocation of which 1,106 dam^3 are for urban municipal use. Performance in meeting demands in reach OM6 is poor for the Base Case, considerably better for the Belly 490K; WCO scenario, and excellent for the three Belly 1.1×IO scenarios.

Further downstream in South Saskatchewan River reaches SS1 and SS2 there are allocations for 9,572 dam^3 for junior non-irrigation projects. The Belly 490K WCO scenario showed moderate improvement over the Base Case scenario. The three Belly 1.1×IO scenarios had excellent performance in both SS1 and SS2 differing little among the scenarios (**Figure 6.9**).

7.0 INTEGRATION AND ANALYSIS

This section discusses the updated base case performance, analysis of the modelling results for potential new storage in the Oldman River Sub-basin, and the performance of the reservoirs. It also reviews the BROM and Oldman-South Saskatchewan (OSSK) study results and possible linkages to this study.

7.1 Base Case

Base Case modelling considered:

- 2030 projected demands, including full irrigation district expansion within their existing licensed allocations;
- Meeting commitments for projects on First Nation Reserves;
- Meeting commitments for other large private projects with water licence applications; and
- Meeting municipal needs for population projections to year 2030.

The modelling was based on updated water licence data. The demand database made a distinction between demands on regulated streams and those on unregulated streams.

7.1.1 Red Deer River Sub-basin

Performance in meeting the WCO is significantly improved over the previous study (AMEC, 2009) due to the increased minimum flow release from Gleniffer Reservoir (**Appendix D, Table D.1**).

All existing junior private irrigation projects perform within acceptable limits. The irrigation component of the proposed SAWSP and the Acadia Irrigation Project perform well due to their associated off stream storage developments. New irrigation developments subject to the WCO will experience frequent and large deficits unless new storage is developed to support the projects (**Appendix D, Table D.6**).

Junior non-irrigation projects will experience high deficits in all Red Deer River reaches upstream of the Berry Creek confluence (**Appendix D, Table D.9**).

7.1.2 Bow River Sub-basin

There are only minor deficits to the Bow River WCO and junior private irrigation upstream of the Bassano Dam. Deficits are much higher downstream of Bassano Dam (**Appendix D, Tables D.2 and D.7**). Performance in meeting water needs for the irrigation districts and for Siksika expansion would be acceptable (**Appendix D, Tables D.6 and D.7**). Modelling indicates high deficits for junior non-irrigation projects along the entire length of the Bow River (**Appendix D, Table D.10**).

7.1.3 Oldman River Sub-basin

Modelling indicates that WCO deficits in the Oldman River upstream of Willow Creek are minor. Deficits increase downstream of Willow Creek (**Appendix D, Table D.3**).

St. Mary River WCO deficits downstream of the St. Mary Dam are very high (**Table D.3**).

Junior private irrigation projects, including the Summerview and Piikani projects, perform less than adequately along all reaches of the Oldman River except the lowest reach. Projects in the lowest reach benefit from irrigation return flows (**Appendix D, Table D.8**).

Junior non-irrigation projects perform poorly in all reaches modelled in the Oldman River Sub-basin (**Appendix D, Table D.11**).

7.2 Impact of New Storage Development in the Oldman Sub-basin on Water Deficits

In the St. Mary River Sub-basin, the Chin and Kimball projects would benefit the 270 ha of junior private irrigation along the lower St. Mary River; however, an acceptable performance criterion for an irrigation project is being met already in the Base Case. The Chin storage project would reduce the frequency of deficits.

Junior non-irrigation projects (4,000 dam^3) sourced from the lower St. Mary River would benefit substantially from the Chin and Kimball projects. Deficits would essentially be eliminated. An additional 11,400 dam^3 of non-irrigation demand is supplied through the works of ESRD and the irrigation districts. These projects may have secure water supplies through arrangements with the irrigation districts for the use of stored water during periods when they cannot divert from the St. Mary River. It is difficult to definitively state the extent to which these non-irrigation projects may benefit from the Chin and Kimball projects. Direct contact with the users would be required to verify their water supply arrangements.

With full utilization of the US commitment in Montana, the committed downstream supply from the St. Mary Reservoir to meet licensed uses for irrigation and other purposes, and the in-stream flow commitment for the Kimball WCO Scenario, there is little surplus water available for storage in a Kimball Reservoir.

Modelling indicates that there would be no water available for eight consecutive years in the droughts of the 1930s and 1980s when additional supplies are most needed (**Figure 7.1**). The 125,800 dam^3 project would never fill when operated to the current WCO policy (making the full size project unnecessary). The reservoir would be drawn down to its minimum elevation almost every year and be essentially dry during the drought periods of the 1930s and 1980s.

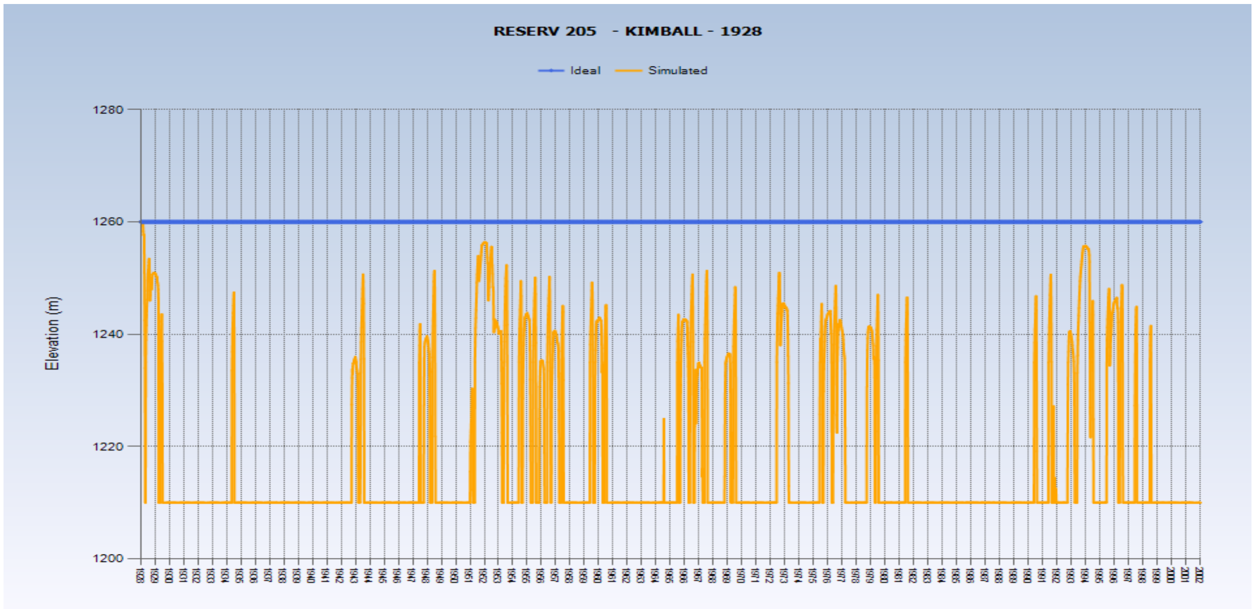


Figure 7.1 Kimball Project; scenario WCO: Simulated Reservoir Water Levels, 1928 to 2001

If the in-stream flow requirement downstream of the Kimball Reservoir was reduced from the WCO required under the current ESRD policy to 1.1×IO, the reservoir performance would be somewhat better but it would still be virtually empty for eight consecutive years in the 1930s and 1980s. The reservoir would fill in about 40% of the years (**Figure 7.2**).

Modelling indicated that neither of the two options for the Kimball Project would improve performance for the private irrigation projects in reach SM2.

Scenario Kimball 1.1×IO would be about the same as Kimball WCO and Chin for reducing the frequency of deficits to junior non-irrigation projects. There would be a slight deterioration in performance in meeting the WCO downstream of the Kimball Reservoir. Other impacts on meeting the WCO are insignificant.

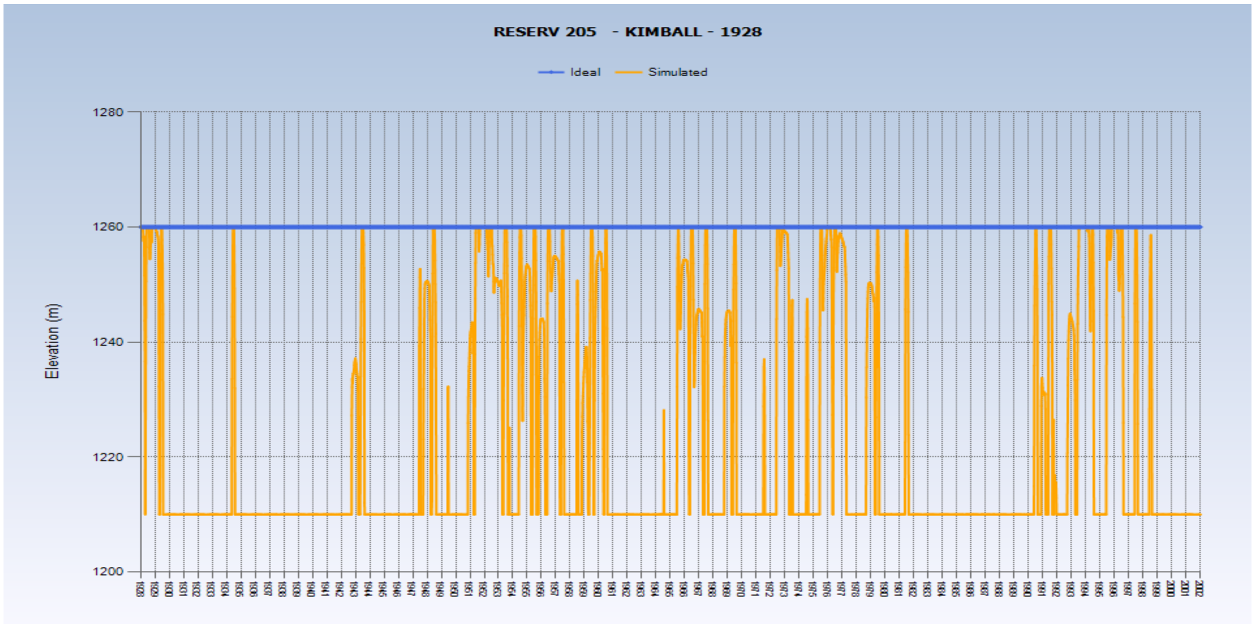


Figure 7.2 Kimball Project; Scenario 1.1×IO: Simulated Reservoir Water Levels, 1928 to 2001

With respect to the Belly Project, Scenario Belly 490 WCO has similar characteristics to the Kimball WCO Project. With the existing Waterton Reservoir, major diversions to the St. Mary Reservoir from both the Waterton and Belly rivers and WCO passing flows through the new storage, there is little surplus water to contribute to new storage in low runoff years when it is most critically needed. **Figure 7.3** shows that the Belly Reservoir would be ineffective in the 1930s and 1980s. It would rarely fill and would be at a very low level all too frequently.

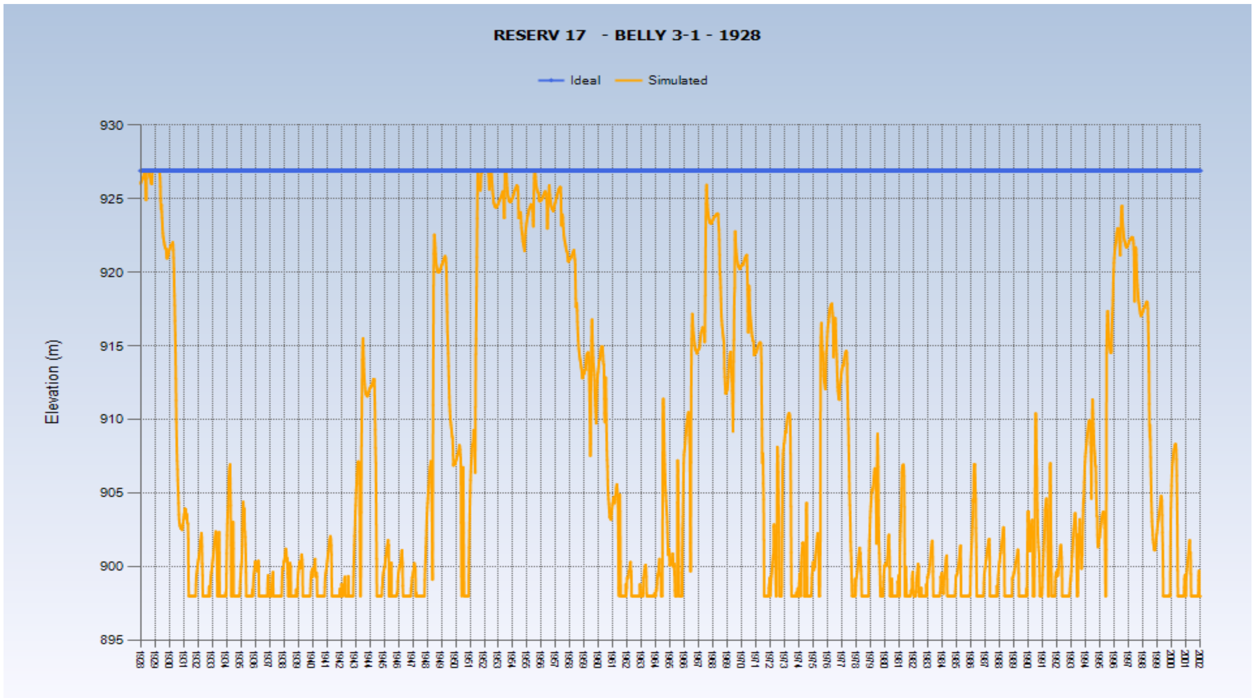


Figure 7.3 Scenario Belly 490 WCO: Simulated Reservoir Water Levels, 1928 to 2001

If the required in-stream flow release were modified to be 1.1×IO the reservoir performs in a more acceptable manner for water supply purposes (**Figure 7.4**). The project would fill in most years and contribute to meeting needs in the critical drought years. The performance in meeting consumptive needs along the Oldman River confirms the benefits of the project (**Figures 6.8 and 6.9**). By relieving the Oldman Reservoir of having to meet in-stream and consumptive needs along the Oldman and South Saskatchewan rivers, the Oldman Reservoir can do a better job of meeting needs upstream of the confluence of the Belly River, including the committed future Piikani and Summerview projects. Operation modelling of the Oldman Reservoir could be carried out in an attempt to improve performance in meeting needs of non-irrigation users between the dam and the Belly River confluence.

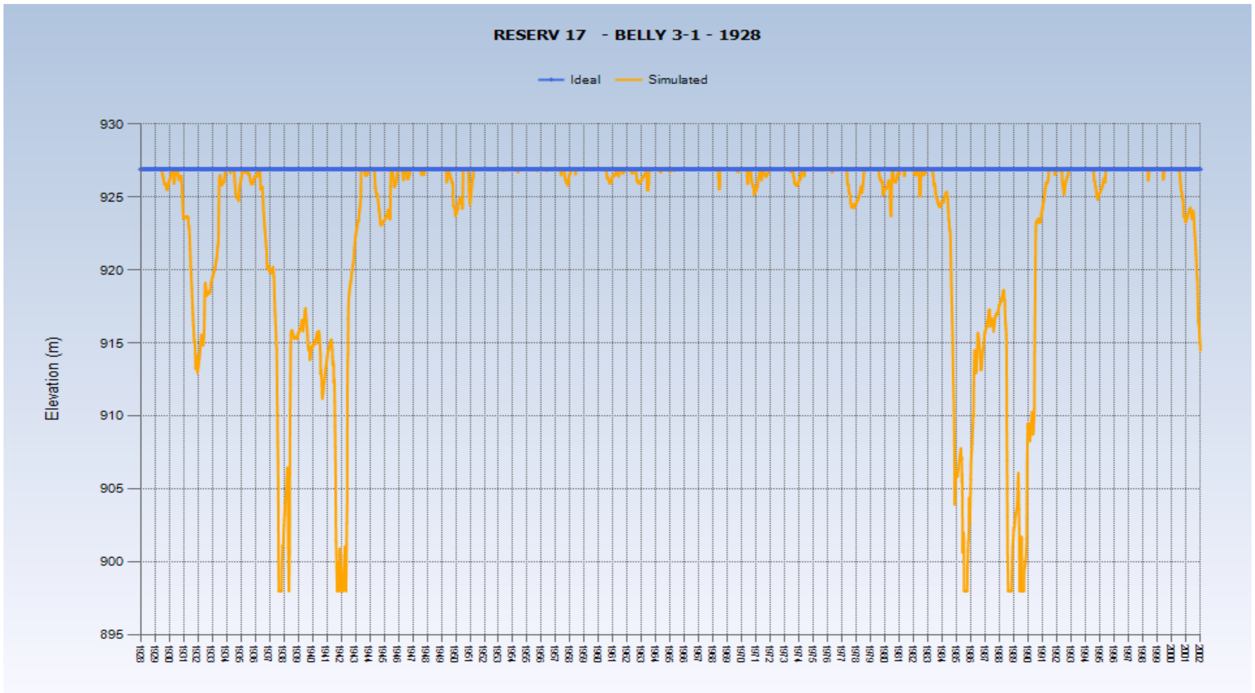


Figure 7.4 Scenario Belly 490 1.1×IO: Simulated Reservoir Water Levels, 1928 to 2001

The modelling was extended to determine the impact that a smaller Belly storage project would have on reducing water supply deficits. The storage capacity was reduced from 490,000 to 324,000 dam^3, and 160,000 dam^3 (**Figures 7.5 and 7.6**). The following graphics show that the 324,000 dam^3 project does not significantly increase deficits compared with the performance of the larger project; the 160,000 dam^3 project has increased deficits compared to the 324,000 dam^3 project. Based on the assumptions and databases used in the modelling, it appears that the project could be reduced in size to between 160,000 and 324,000 dam^3 without seriously affecting water supply performance. If surplus storage capacity is available at the site, it could conceivably be utilized for flood mitigation purposes, pending further evaluation of the benefits for that purpose.

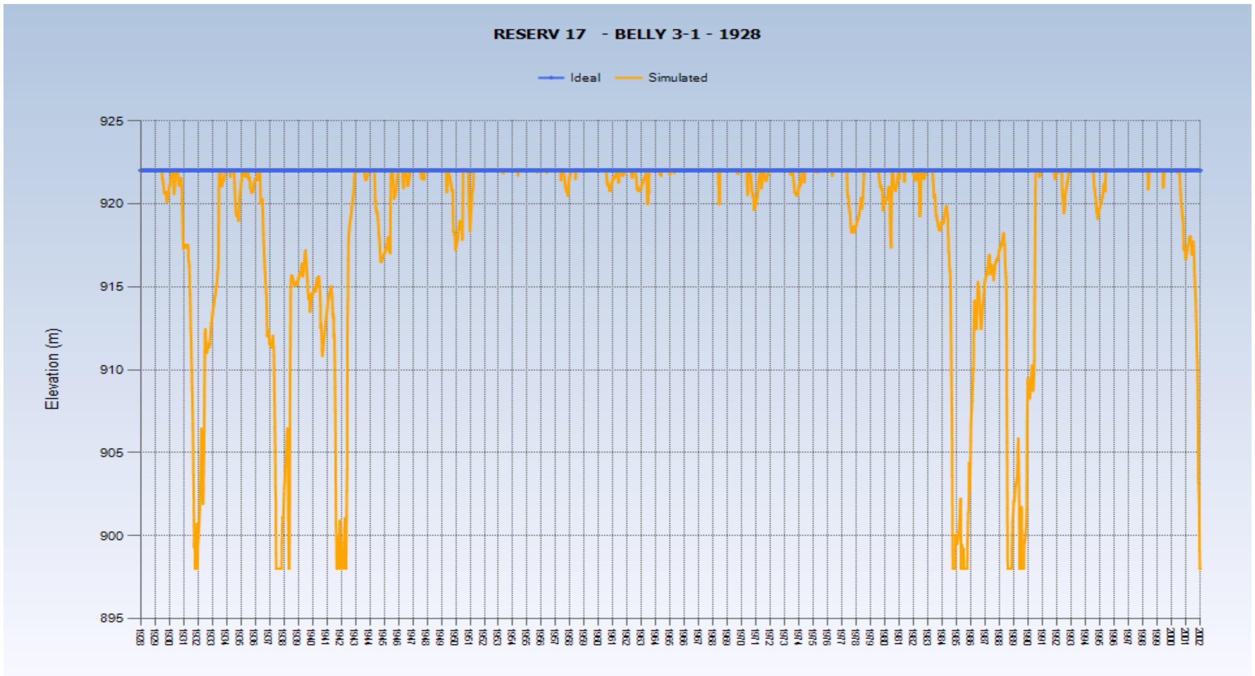


Figure 7.5 Scenario Belly 324 1.1×IO: Simulated Reservoir Water Levels, 1928 to 2001

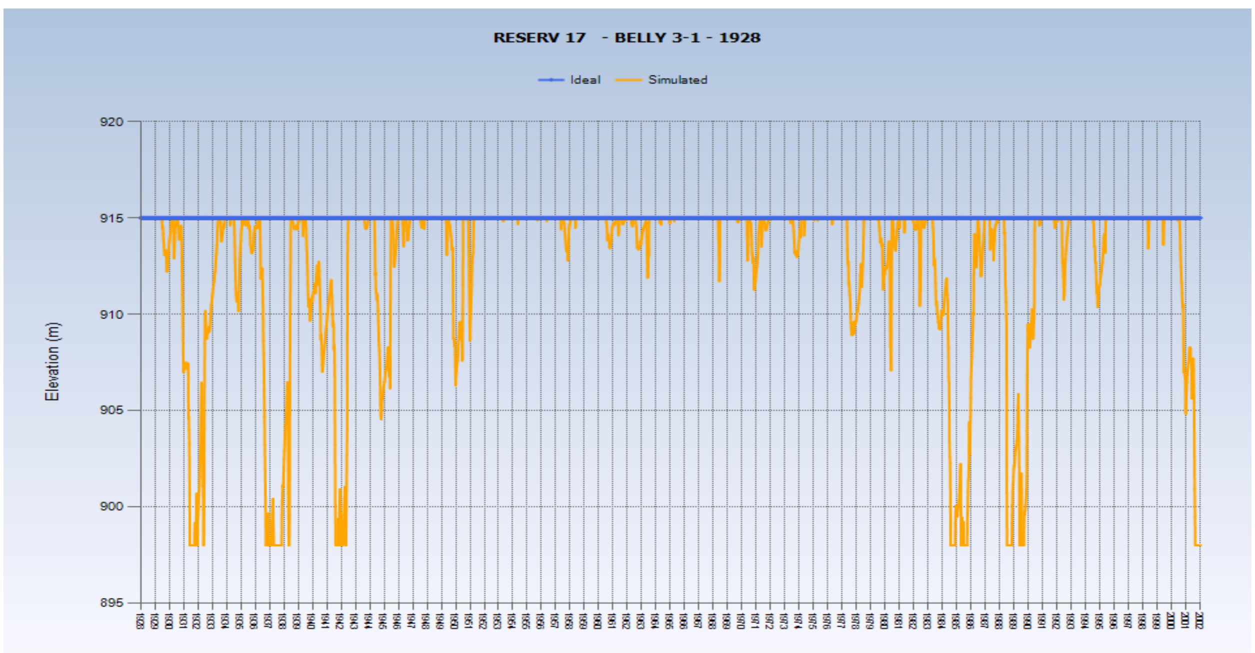


Figure 7.6 Scenario Belly 160 1.1×IO: Simulated Reservoir Water Levels, 1928 to 2001

7.3 Lower St. Mary Project and West Raymond Projects

Performance for the Lower St. Mary Project (Site #150) and the West Raymond Project (site #230) would be similar to or less than those of Chin and the Kimball Sites. Because minimal benefit is derived from either Chin or Kimball, Lower St. Mary and west Raymond were not modeled.

7.4 First Nation Development

With respect to supporting First Nation development, a water licence has been issued to the Blood Band Council for sufficient water to irrigate 25,000 acres (10,120 ha) on the Kainai First Nation Reserve. The commitment for a licence was made as partial compensation for land and access for constructing, operating and maintaining irrigation works on the Reserve by the provincial and federal governments from time to time beginning as early as 1922. On 1 December 2003, a licence was issued to ESRD for a project or projects on or near the Piikani First Nation Reserve in partial compensation for land and access for Lethbridge Northern Headworks located on the Reserve. The allocation is for 43,200 dam^3. Both projects were modelled assuming they would be administered in keeping with their respective licence priorities.

Kainai Licence
Issued to: Blood Band Council
Date Issued: Jan 31, 1994
Priority: 19911107001
Purpose: Irrigation
Allocation: 40,270 ac ft (49,650 dam^3)
Irrigation Area: 25,000 ac (10,120 ha)
Source: Waterton and Belly Rivers

Piikani Licence
Issued to: Alberta Environment
Date Issued: Dec 5, 2003
Priority: 20021206002
Other: Specified by Director
Allocation: 43,200 dam^3
Source: Oldman River
Conditions: Subject to Oldman R IOs

For the Kainai Reserve, about 7,700 ha has been developed, leaving about 2,400 ha remaining to fulfill the commitment. Simulation modelling indicated that the full Kainai commitment would be met in the Base Case and for all the storage scenarios modelled in this study.

For the Piikani commitment, modelling indicated unacceptable deficits for the Base Case, and for the Chin, Kimball, and Belly projects modelled with the ESRD policy for in-stream flows downstream of new storage development. For the Belly project modelled assuming in-stream requirements of the IOs plus 10%, the Piikani commitment could be met.

7.5 Economic Ramifications

Estimated project costs for the three modeled sites are shown in **Table 7.1**.

Table 7.1
Estimated Current Construction Costs Updated to Current Values

(Million $)*			
	Kimball	**Belly**	**Chin**
Initial Estimate	$98.2	$81.4	$56.1
Year of Estimate	2002	1978	2002
Index Adjustment**	1.51	3.11	1.51
Current (2013)	$148.3	$253.2	$84.7

*Update did not review design for modifications or improvement
**Based on average Consumer Price Index (CPI) and Commercial Construction Index. Earth Construction Index no longer available.

The economic ramifications of reducing potential water shortages through increased storage in the Oldman River basin was evaluated. The complete analysis is included as **Appendix G**. The WRMM results indicate very minor improvements in water shortage risks for junior water licensees associated with the three proposed storage sites. Risk improvement is so minor that risk changes may be neutralized by the stochastic nature of the WRMM simulation techniques. Crop budgets (2013) were derived from Alberta Agriculture's website and expected yield reductions in water short years were derived from a previous St. Mary Main Canal study. Mitigation of annual farm crop sales is expected to be $261,707, $80,286, and $107,854 per year for the Belly, Kimball, and Chin sites, respectively. Provincial mitigated GDP benefits derived as a multiple of total crop sales were discounted at a rate of 3% over 50 years. The ability of the provincial society to fund these projects based on mitigated total societal savings are $6.7 million, $2.1 million, and $2.8 million for the Belly, Kimball, and Chin projects, respectively. 2013 construction costs are estimated at $148 million, $253 million, and $85 million, respectively. Net present value (savings minus cost) is calculated at -$134.5 million, -$249.5 million, and -$78.4 million for the Belly, Kimball, and Chin projects, respectively. Based on the assumptions and analyses herein, the Alberta provincial society cannot justify the Belly, Kimball, and Chin investment from the anticipated savings of reducing water shortages to junior irrigation licenses in the Oldman River Sub-basin.

7.6 Review of Bow River Operational Model Results for New Storage

The Bow River Project Research Consortium, comprised of water users and managers holding 95% of the Bow River diversion license, was established in 2010. They explored options for re-managing the Bow River system from the headwaters to the confluence with the Oldman River. Participants worked collaboratively to develop scenarios for protecting the health of the river while meeting the needs of the water users. A key tool developed and used for the project is the BROM, an interactive hydrologic simulation model.

The Bow River Project investigated several alternatives for managing the river system. Their "preferred scenario" included two key components:

- Establishing a virtual water bank within existing TransAlta storage reservoirs. The 74,000 dam^3 of storage would be used during low flow periods on the Bow River.
- Stabilizing the Lower Kananaskis Lake and Kananaskis River for recreational and economic benefits.

The *Bow River Project Final Report* (The Bow River Project Research Consortium, 2010) concluded that if the Bow River and its controlled tributaries are managed as an integrated system from headwaters to confluence there would be significant benefits to all users. Key components of their preferred scenario include restoring Spray Reservoir to its original design specifications and dedicating the increased 74,000 dam^3 storage for use as a "water bank" and doubling the storage capacity of the WID's Langdon Reservoir.

A second phase of the SSRB adaptation project employed the Operational Analysis and Simulation of Integrated Systems (OASIS; by Hydrologics Inc.) model to focus on four main areas:

- Preparation of the Bow River Basin Integrated River Management business case;
- Enhancement of the BROM;
- Development of climate scenarios for the Bow River Sub-basin; and
- Development of adaptation strategies for present and future climate of the Bow River Sub-basin.

The *Adaptation Strategies for Present and Future Climates in the Bow Basin* (Alberta Innovates and WaterSMART, 2013) investigated 15 individual beneficial water management strategies for current conditions and a future more severe climate. Five (including the "preferred scenario") were viewed as having the most promising benefits under normal conditions for the chosen climate scenario.

An additional three strategies were identified as promising for the most severe drought conditions of the chosen climate scenario. Two of these adaptation strategies involved construction of new infrastructure to expand storage capacity. The identified new storage reservoirs are:

- Bruce Lake – off stream storage of 51,000 dam^3 in the WID; and
- Eyremore Reservoir – on stream storage of 308,000 dam^3 on the Bow River downstream of Bassano.

These projects would also benefit the region under normal as well as the severe drought climate conditions.

7.7 Linkages to Oldman-South Saskatchewan Adaptation Project

The OSSK adaption project expanded the OASIS model to include the Oldman River Sub-basin. The work aimed to improve understanding of climate variability in the OSSK basins and then to identify adaptation strategies to build the resiliency of the system.

The OSSK model is a daily mass balance model that reflects the streamflows and operations of the river system. It is a single model that includes the Oldman and South Saskatchewan river basins with all their major tributaries. It does not explicitly calculate and account for groundwater nor include water quality aspects, but groundwater contribution to base streamflow is inherently part of the naturalized flow data, which are used as inflows to the model. As it is currently configured, the model meets as many existing and future water needs defined by stakeholders in the basin as possible.

The OSSK model focuses primarily on what water users actually need to do rather than strictly replicating decision making mandated by the current regulatory scheme in Alberta. The model gives Fish Rule Curves (FRC) and IO senior priority to all demands. The lower South

Saskatchewan River was modelled for a flow of 28.3 m^3/s rather than the 42.5 m^3/s required by the Apportionment Agreement. When there is insufficient water to meet all demands, small municipal and industrial demands (6% of demands) have first priority, followed by private irrigators (13% of demands), then the remaining demands (78%) based on their licensed priority. This is different from the actual system where the senior licences in the last group are entitled to the water first.

Potential risk management strategies identified took a variety of approaches, including optimizing existing infrastructure, building new infrastructure, changing operations by supplementing environmental flows, reducing demand, and sharing supply. Some apply to specific geographic regions while others could be implemented across the basins.

While the results of the OSSK and WRMM modelling are noted below, the reader must be advised that the two modelling efforts are not directly comparable due to differences in modelling assumptions and databases, including the following:

- The OASIS model used the current level of demands, with irrigation demands at something less than the full AARD Irrigation Demand Model estimates for current conditions, irrigation district demands were given the lowest priority of all demands in the Oldman Basin, inter-provincial apportionment was not considered, and the in-stream flow requirement for the South Saskatchewan River was 1,000 cfs, which is 33% less than the full requirement.
- The WRMM modelling used an estimated 2030 level of demand which increased the Oldman Basin irrigation district consumptive use by almost 50%, increased private irrigation use (allocation) by about 50,000 dam^3, and increased urban municipal demand based on 2030 population projections. Future irrigation demands were estimated by AARD assuming higher value crops, higher applications and improved irrigation efficiencies. The full AARD demand estimates were used in the model runs. Irrigation district demands were given a high priority in keeping with their licences. The WRMM modelling always met inter-provincial apportionment commitments. The in-stream flow requirement for the South Saskatchewan River was 1,500 cfs, which is the regulatory requirement.

For the OSSK modelling, five strategies were identified as having the most promise and benefit in conditions of climate variability, drought in particular. The five strategies and their linkage to this study are discussed as follows:

- **Strategy 1**- Lower Belly Reservoir (Oldman Site 3-1): A storage volume of 493,000 dam^3 was modelled. Both the WCO and existing IO flow release scenarios were modelled. Results indicate that if the reservoir was included in the ESRD balancing system, all the reservoirs would drain to meet the WCO requirement. The modelling then removed the Belly Reservoir from the balancing system and WCO was met entirely with Belly storage. When the Belly Reservoir storage falls to 10%, flow release reverts to the IO to prevent access to the Waterton Reservoir storage. Comparing the performance to existing operations, Belly Reservoir operating to WCO results in a 149 day (4%) reduction in shortage days (82-year period) or a 716 day (20%) reduction when operated to IO. Irrespective of whether the WCO or IO release is applied, flows in the Oldman River at

Lethbridge decrease compared to current operations, often falling to minimum flow requirements.

  - Modelling results for this study with WCO indicate the Belly Reservoir would be ineffective in drought periods when it is most critically needed. It would rarely fill and would be at a very low level all too frequently. A smaller reservoir at the Belly site could provide benefits if operated under a 1.1×IO release.

- **Strategy 2 -** Minimum Flow Augmentation below Reservoirs: This strategy is intended to augment flow below a reservoir to provide environmental benefits, particularly for fish. It would optimize low flows when reservoir volumes are high during the summer and fall to achieve ecosystem benefits.
  - Flow augmentation was not directly modelled in this study.
- **Strategy 3 -** Kimball Reservoir: A reservoir of 125,800 dam^3 was investigated with WCO release to the river upstream of St. Mary Reservoir and operated as per ESRD reservoir balancing system. This results in 600 fewer shortage days compared to current operations, distributed evenly across the irrigation districts.
  - This study found that the reservoir would drain more than once during irrigation season and would empty repeatedly during drought cycles. Furthermore, improvements to irrigation district senior licenses are excluded from the study.
- **Strategy 4 -** Chin Expansion: Increase storage by 74,000 dam^3. Several strategies were considered including expanding storage to reduce the risk of downstream municipal and irrigation shortages, adding Chin Reservoir at its current capacity to the balancing system, balancing only the new storage, and fully balancing the entire amount of existing and new storage. Expanding Chin Reservoir and balancing it with ESRD managed reservoirs showed a large decrease in shortages and an extension of the irrigable period during a drought. These benefits occur due to expansion and balancing of all storage, and to the location of Chin Reservoir, which is upstream of most of this system's demand. As such, water in this reservoir can contribute to meeting a large proportion of water needs, allowing a large number of opportunities for rebalancing existing irrigation shortage days during the 82-year period. All strategies involving Chin Reservoir show a reduction in irrigation shortage days, but expanding and balancing the full reservoir capacity was the most effective. This strategy resulted in 879 fewer days of shortage during the 82 years (almost a 25% reduction). Adding Chin Reservoir to the balancing system means that irrigation districts in the St. Mary system may assume more risk since Chin Reservoir may be kept at lower levels. However, this might be mitigated by removing current operational considerations for hydropower generation and allowing Chin Reservoir to receive water more quickly than it does today. If a Chin-based storage option is pursued, the "balancing" aspect of this strategy must also be applied to ensure that benefits accrue to the rest of the system. Without balancing, water is preferentially stored in Chin Reservoir, ahead of ESRD reservoirs, where it has fewer potential applications. This worsens total system performance because water in Chin Reservoir can only be used by irrigators in the SMRID and TID. Chin Reservoir will thus pull additional water from the system that would otherwise remain in a more versatile upstream position.
  - Modelling in this study does not seek to improve deficits to the senior licensees, the irrigation districts. Maintaining deficits to the senior licensees indicated no improvement

to the WCO, the junior private irrigation is very small and improvements to the junior non-irrigation licensees are likely over stated. The cost of adding storage at Chin to benefit the WCO, junior private irrigation, non-irrigation and First Nations needs does not appear justified.

- **Strategy 5** – Forecast Based Rationing: This strategy emerged as one that could be applied across the OSSK basins when severe dry conditions warranted. Forecast-based rationing suspends licensing priorities. The water-sharing agreement implemented for the southern tributaries during the drought of 2001 sets a precedent for this strategy.
  - This strategy is out-of-scope for this study.

7.8 Impact on Climate Change

As discussed in Section 2.15, the 2009 AMEC study noted that climate change is likely to reduce streamflows in the SSRB. Modelling done by PARC conclude that spring runoff will occur on average 8.6 days earlier and more precipitation will fall as rain rather than snow, thus reduced snow packs. Studies done by Martz and Golder say median annual flow volumes in the Oldman sub-basin will decrease by 4% (Martz) and 14% (Golder). Both studies predict generally less water availability.

As can be seen in **Figure 7.1**, Kimball WCO would only fill about 40% of the years and would remain virtually empty for eight consecutive years in the 1930s and 1980s. It performs marginally better if the WCO was reduced to 1.1*IO (**Figure 7.2**). Belly (490K) WCO has similar characteristics to Kimball (**Figure 7.3**). It rarely fills and would be at a low reservoir level frequently. Both projects would be ineffective in the 1930s and 1980s. With a WCO reduced to 1.1×10 (**Figure 7.4**), the Belly Project would fill most years and could contribute to meeting the needs in the critical drought years.

A future drier climate would further decrease the water available to be captured and may increase the number of years the reservoirs would not fill and neither would be effective in the critical prolonged drought years (1930s and 1980s). Thus construction of either Kimball or Belly with the WCO downstream requirement would be expected to have little impact on mitigating climate change.

Climate change would be expected to impact demands in addition to water supply. Deficits to irrigators in the Oldman Basin could increase to unacceptable levels (AMEC, 2009). The full impacts of climate change and variability on water demands in the SSRB are not well understood and require further study.

8.0 SUMMARY AND CONCLUSIONS

The *South Saskatchewan River Basin in Alberta Water Supply Study* (AMEC, 2009) identified re-management of existing reservoirs and the development of additional water storage sites as potential solutions to reduce the risk of water shortages for junior license holders and the aquatic environment.

A major objective of this study was to identify and assess potential water storage opportunities in the Oldman Sub-basin for their capacity to:

- Improve security of water supply to existing licensees;
- Support the downstream aquatic environment;
- Support First Nations development; and
- Mitigate impacts of climate change and variability.

Potential new storage site were to adhere to existing legislative and regulatory requirements.

A total of 48 potential storage sites were identified from existing records. Of the sites, 42 were eliminated from further consideration for various reasons leaving 5 locations (chin site had 2 options) to be evaluated for their potential to mitigate future water shortages (updated year 2030 demand Scenario 3 of the 2009 AMEC study) in the Oldman River Sub-basin.

The five potential storage sites were Belly, Kimball, Chin, Lower St. Mary, and West Raymond. Three of the sites - Chin, Kimball and Belly - were modelled to determine if they would be of benefit, assuming future (2030) expanded water demands. Modelling focussed on improving deficits to WCOs, junior licensees and First Nations. Irrigation District deficits were acceptable in the Base Case Scenario, and therefore were fixed at Base Case levels in the reservoir modelling.

With respect to improving the water supply to existing users, the Chin and Kimball storage projects have insignificant improvement in the performance for junior private irrigators along the St. Mary River. There are no junior priority private irrigation projects upstream of the existing St. Mary River Reservoir, and only 270 ha under irrigation downstream of the reservoir. Under the Base Case scenario (the “do-nothing” option), performance for the junior irrigators meets the acceptability criteria. The Chin project would improve performance by a small amount by reducing deficits from 8% of years to 4% of years; the Kimball project would not improve performance of junior irrigation users.

There are 85 dam^3 of junior non-irrigation demand upstream of the St. Mary River Reservoir and 15,363 dam^3 downstream. Neither the Chin nor the Kimball projects have a significant impact on the performance for non-irrigation uses along the upper St. Mary River. Both the Chin and Kimball projects have a large impact on junior non-irrigation uses downstream of the St. Mary Dam, reducing the frequency of deficits greater than 10% from 54% of the years to 4% and 7%, respectively. This benefit may be somewhat overstated because about 70% of the 15,363 dam^3 demand is delivered to the users through the works of ESRD and the irrigation districts. These users would have access to storage to meet their needs during the non-irrigation season when diversions from the St. Mary Reservoir are unavailable (pers. Comm. with SMRID, TID and BRID engineering staff). In doing so, they may have more water supply security than indicated in the Base Case scenario.

Neither the Chin nor the Kimball projects have a significant impact on water supply deficits along the Oldman or South Saskatchewan rivers. With the international sharing agreement (Boundary Waters Treaty, 1909), ESRD's policy on in-stream requirements downstream of new storage (Max [WCO; 1.1×IO]), the existing St. Mary Reservoir and numerous offstream storage reservoirs, and priority commitments for water deliveries to the irrigation districts sourced from the Southern Tributaries, there is insufficient surplus water to fill new storage during drought years when water is most needed. This becomes evident from review of water levels for the Kimball project (**Figure 7.1**).

A new storage project on the Lower Belly River operated in accord with ESRD in-stream flow policy would have only a minor impact on the frequency of deficits to junior water uses along the Oldman and South Saskatchewan Rivers. In none of the reaches with unacceptable Base Case deficits for private irrigation, would performance be improved to the extent of acceptability. Neither the Summerview nor Piikani projects would have acceptable performance. There would be some improvement in reducing deficits to junior non-irrigation water users upstream and downstream of the Belly River confluence with the Oldman River. The largest improvement in performance would occur in the short Oldman River reach between the Belly and St. Mary River confluences where the junior non-irrigation demand is 353 dam^3. Modelling output indicated that the frequency of deficits greater than 10% of the demand would be reduced from 27% of years in the Base Case to 18% of years with the Belly project in place. With ESRD's policy on in-stream requirements, the existing Waterton Reservoir, diversions to the St. Mary Reservoir from both the Waterton and Belly Rivers, and priority commitments to the irrigation districts, there is insufficient water to consistently fill a large new reservoir on the Belly River. Reservoir water levels in **Figure 7.3** indicate that the Belly Reservoir would be near empty during prolonged droughts when water to reduce deficits is most needed.

To test the sensitivity of the findings to the ESRD in-stream policy, model simulations were conducted to assuming the in-stream requirement downstream of new storage was equal to the current IO increased by 10% (this change does not apply to offstream storage in an enlarged Chin Reservoir). This change in in-stream requirement did not result in a significant change in the findings with respect to the Kimball Project. There was still insufficient surplus flow in the St. Mary River to support the Kimball storage reservoir.

The change in the in-stream requirement greatly improved the value of the Belly project for future demands of existing users. It improved the performance of the junior private irrigation projects all along the Oldman and South Saskatchewan Rivers, including converting the Summerview and Piikani projects from unacceptable in the Base Case to acceptable with the Belly Reservoir in place. Improved performance for the junior non-irrigation projects was limited to reaches along the Oldman and South Saskatchewan Rivers downstream of the Belly River confluence. Most of the water supply benefits could be achieved with a smaller sized Belly reservoir, giving rise to a lower cost water supply reservoir or a large reservoir with a portion of the storage dedicated for flood mitigation. Since this project was not in keeping with ESRD policy on in-stream requirements, the economic, social and environmental aspects were not addressed pending discussions with ESRD and the duty to consult the Kainai First Nation whose land would be impacted.

With respect to the downstream aquatic environment, in this study the deficits to the WCO were used as an indicator of impacts on the aquatic requirements (Clipperton, 2003). None of the three storage projects investigated had a significant impact on the performance in meeting the WCO. The existing water management infrastructure and conditions on licences issued since the mid-1980s in the Oldman basin are geared toward maintaining the current IOs throughout the basin. Other than in river reaches immediately downstream from the Kimball and Belly projects, any improvement in performance in meeting the WCO would be incidental rather than a deliberate operation policy. Hence, improved water management made possible by the new storage was dedicated to reducing water supply deficits. The performance in meeting the WCOs remained essentially unchanged, including for the Belly storage options with the reduced downstream flow requirement.

For the Kainai Reserve, 6,900 ha of a license to support 10,120 ha has been developed. Modelling indicated that the full Kainai commitment would be met in the Base Case and for all storage scenarios modelled.

The Piikani have an allocation for 43,200 dam^3, with an agreement by the province to have the development supported from Oldman Reservoir storage. Without this agreement, the modelling indicated unacceptable deficits for the Base Case and for all Chin, Kimball, and Belly projects under current ESRD policy. The Belly project with the requirements to meet IOs plus 10% would meet the Piikani commitment.

With respect to mitigating impacts of climate change and variability, studies of climate change impacts on streamflow in the SSRB, based on Global Climate Model projections, indicate highly variable results for the Oldman River Basin. For instance, Martz et al. (2007) indicated a projected change (circa 2050) in mean annual natural streamflow for the Oldman River at Lethbridge to range between minus 14% and plus 7%, with an average change of minus 3%. For the same period, Acres (2010) indicated a change for the Oldman River near the mouth ranging between minus 28% and plus 3%, with a median change of minus 7%. Furthermore, both studies predict higher variability in Oldman River flows under climate change conditions; dryer droughts and higher floods. It is clear that various GCMs and scenarios for adaptive management produce a wide range of potential conditions. However, in spite of the uncertainty, on average the projections point to future reductions in flows in the Oldman Basin.

Unfortunately this does not bode well for this current study. Under current climate conditions, the three projects operating in accord with ESRD's current in-stream flow policy are constrained by lack of streamflow to restore reservoir storage. Under reduced streamflow conditions projected for climate change, these projects will be even more constrained and probably ineffective in mitigating any aspects of climate change. With the assumed alternate in-stream flow conditions (IO plus 10%), the Belly storage project would probably be valuable in mitigating the impacts of climate change.

The lower St. Mary and West Raymond sites were not modelled because they would essentially realize similar (or worse) results as the Kimball and Chin scenarios. Thus, there does not appear to be a storage site that would directly improve the aquatic environment or water security to junior licensees and First Nations on the southern tributaries.

Economically, the modelling indicated very minor improvements in water shortage risks for junior water licensees associated with the three proposed projects. Based on the anticipated savings (benefits) of reducing water shortages to the junior water licencees and the estimated construction costs, the Alberta provincial society cannot justify the Belly, Kimball, or Chin projects.

The conclusion derived from the modelling results is that there are no viable new storage sites that adhere to the current licensing priorities and legislative/regulatory regime in the Oldman River Sub-basin that can significantly improve water supply security, support the aquatic environment, support First Nations development, or mitigate the impact of climate change.
If the ESRD WCO policy was amended to require only 1.1×IO releases, then the Belly River site may be viable. Development of the Belly project would impact the Blood Indian Reserve.
The ramifications and required mitigation would need to be further explored if the WCO policy is amended and there is interest to develop the site. Modelling indicates that by contributing to consumptive needs along the Oldman and South Saskatchewan rivers, a Belly Reservoir allows the Oldman Reservoir to better meet consumptive needs upstream of the Belly River confluence, including the committed future Piikani and Summerview projects. Modelling indicates that a reservoir sized between 160,000 and 324,000 dam^3 would be adequate to achieve some benefit for water security and First Nations. Over sizing the storage capacity could possibly contribute to flood mitigation.

9.0 RECOMMENDATIONS FOR FURTHER WORK

Possible further investigative work arising from this study includes:

- Establishment of performance thresholds for non-irrigation use. The performance criteria used for irrigation in this and other similar studies has been a useful tool for use in conjunction with the WRMM for making water management decisions. Performance thresholds for other purposes, including IOs and WCOs, would significantly enhance decision making in the SSRB. Because of the variety of non-irrigation uses, developing thresholds for all uses would prove to be a difficult task. Municipal residential and rural domestic use is arguably the most important use in the SSRB. A significant first step in addressing non-irrigation thresholds would be to develop thresholds for this purpose.
- More definitive modelling of urban municipal supplies to examine the magnitude and frequency of deficits. Each community would have to be modelled. Many communities have a mixture of allocation priorities, and a variety of storage and return flow conditions which cannot be properly represented by combining them with other non-irrigation uses.

> A **threshold** is a value of an indicator that reflects a problem condition. In this study our indicator is the magnitude and frequency of deficits determined by simulation modelling. Most water users can tolerate occasional deficits. For non-irrigation users we do not know how often or how large the deficits can be without becoming an intolerable problem.

- Modelling to determine benefits of new storage on the lower Oldman, Bow (e.g., Eyremore) or South Saskatchewan rivers to meet apportionment while reducing upstream deficits. The objective would be to relieve the Oldman Reservoir of releases for apportionment purposes so that it could better used to meet in-stream and consumptive needs.
- Modelling to determine possibilities for maintaining or improving base case WCO performance. This study found that the storage projects evaluated did not significantly change in-stream flow conditions from that of the Base Case. The intent would be to explore the possibility of using stored water to improve the aquatic environment by moving closer to the flow requirements of the WCO.
- If the province is willing to reconsider their in-stream flow policy, the Belly River Site should be studied in more detail. This would include determination of the optimum reservoir site, evaluation the social and economic ramifications of the development, and reviewing the current design and updating the cost estimate for the project.

10.0 CLOSURE

This report has been prepared for the exclusive use of **South Saskatchewan River Basin Water Storage Opportunities Steering Committee**. This report is based on, and limited by, the interpretation of data, circumstances, and conditions available at the time of completion of the work as referenced throughout the report. It has been prepared in accordance with generally accepted engineering practices. No other warranty, express or implied, is made.

Yours truly,

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12.0 ACRONYMS AND DEFINITIONS

AARD	Alberta Agriculture and Rural Development
AID	Aetna Irrigation District
BRID	Bow River Irrigation District
BROM	Bow River Operational Model
CV	Coefficient of Variation
EDA	Effective Drainage Area
EID	Eastern Irrigation District
ESRD	Alberta Environment and Sustainable Resource Development
FRC	Fish Rule Curves
GDA	Gross Drainage Area
IO	In-stream Objective
LID	Leavitt Irrigation District
LNID	Lethbridge Northern Irrigation District
MID	Magrath Irrigation District
MVID	Mountain View Irrigation District
OASIS	Operational Analysis and Simulation of Integrated Systems
OSSK	Oldman-South Saskatchewan
PPA	Power Purchase Arrangement
RID	Raymond Irrigation District
RCID	Ross Creek Irrigation District
SAB	Special Areas Board
SAWSP	Special Areas Water Supply Project
SMRID	St. Mary River Irrigation District
SSRB	South Saskatchewan River Basin
TID	Taber Irrigation District
TransAlta	TransAlta Corporation
UID	United Irrigation District
WCO	Water Conservation Objective
WID	Western Irrigation District
WRMM	Water Resources Management Model
WRS	Water Use Reporting System