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Alberta Irrigation Districts Association

# Adaptation Roadmap for the SSRB: Assessment of Strategic Water Management Projects to Support Economic Development in the South Saskatchewan River Basin (SSROM Phase 3)

## Final Report

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## Acronyms

**AEPA** – Alberta Environment and Protected Areas
**AGI** – Alberta Agriculture and Irrigation
**AIDA** – Alberta Irrigation District Association
**AIM** – Alberta Irrigation Modernization
**BRID** – Bow River Irrigation District
**BROM** – Bow River Operational Model
**BTAP** – Blood Tribe Agricultural Project
**CMRB** – Calgary Metropolitan Regional Board
**CWA** – Canada Water Agency
**EIA** – Environmental Impact Assessment
**EID** – Eastern Irrigation District
**FRC** – Fish Rule Curve
**FSL** – Full Supply Level
**GDP** – Gross Domestic Product
**GoA** – Government of Alberta
**IDM –** Irrigation Demand Model
**IJC –** International Joint Commission
**I-O** – Input-output Model
**IO –** Instream Objective
**LNID** – Lethbridge Northern Irrigation District
**MID** – Magrath Irrigation District
**MVID** – Mountain View Irrigation District
**OASIS** – Operational Analysis and Simulation of Integrated Systems
**OSSROM** – Oldman and South Saskatchewan River Operational Model
**PFRA** – Prairie Farm Rehabilitation Administration
**PM** – Performance Measure
**RDRMUG –** Red Deer River Municipal Users Group
**WPAC** – Watershed Planning and Advisory Council
**RDROM** – Red Deer River Operational Model
**RID** – Raymond Irrigation District
**SID** – Southwest Irrigation District
**SMRID** – St. Mary River Irrigation District
**SSRB** – South Saskatchewan River Basin
**SSROM** – South Saskatchewan River Operational Model
**UID** – United Irrigation District
**WCO** – Water Conservation Objective
**WG –** Working Group
**WID** – Western Irrigation District

## Executive Summary

Alberta is experiencing drought conditions; as of December 2023, there were 51 Water Shortage Advisories active across central and southern Alberta. The current drought status is a critical reminder of the importance of both short and long-term planning for water management and adaptation strategies. Alberta is also experiencing strong municipal and economic growth, which depends on access to a reliable supply of water. Water resources are the key to balancing provincial growth with maintaining a sustainable and clean water supply for safe, secure drinking water for all and preserving a healthy aquatic ecosystem. It is imperative that water managers continue to have up-to-date operational tools available to meet the needs of the basin, especially in the context of a changing climate.

Watershed management and climate adaptation are complex and require a collaborative approach to ensure that the resultant options are considered on both a local and regional scale. Since 2010, a series of initiatives has brought together water managers and knowledgeable water users in the South Saskatchewan River Basin (SSRB) on both a sub-basin and basin-wide level. Previous work resulted in the development of the South Saskatchewan River Operational Model (SSROM), a comprehensive daily mass-balance model which enables the comparison of adaptation strategies and evaluation of impacts across the SSRB.

In 2016, the SSRB Adaptation Roadmap for the SSRB (2016 Adaptation Roadmap for the SSRB) was published, outlining over 30 adaptation strategies that were either already being implemented or categorized based on their adaptive capacity. These strategies included operational changes, water sharing agreements, irrigation expansion and optimization projects, and new on-stream and off-stream reservoirs. The 2016 Adaptation Roadmap for the SSRB linked several projects together, providing a clear strategic pathway to managing water in the SSRB. The 2016 Adaptation Roadmap for the SSRB provided a conceptual level assessment to demonstrate the potential of each project. Between 2016 and 2023, over two thirds of the strategies in the 2016 Adaptation Roadmap for the SSRB are either completed or in progress. This showcases the dedication of water managers and advocates in the SSRB to strategic water resource management, and it has improved the water management outlook of the SSRB.

In 2021/2022, the SSROM model was updated to accommodate substantial changes seen in the basin since the original project, and to extend the historical flow data to include records from 1928 through 2015. Given the 2022 Update and basin changes since the 2016 Adaptation Roadmap for the SSRB, an opportunity was recognized to develop a new Adaptation Roadmap for the SSRB, which would incorporate testing of potential adaptations against future climate scenarios.

For this work, the best available climate data was used to reflect worst-case scenarios in terms of seasonality shifts and temperate and precipitation changes, provided by Alberta Environment and Protected Areas (AEPA) and incorporated into the SSROM. The scenarios selected for use in the updated Adaptation Roadmap for the SSRB below were used to stress test the different options:

1. **IPSL-CM6A-LR (ssp126):** Driest annual hydrograph, showing the largest reductions in Mean Annual Flow.
2. **IPSL-CM6A-LR (ssp370):** Hottest and driest combination scenario, leading to large shifts in timing and more frequent low flow events in the late summer.
3. **BCC-CSM2-MR (ssp370):** A drier and hotter future scenario, with reductions in annual as well as late summer flows.

This report summarizes the results of the Assessment of Strategic Management Projects to Support Economic Growth. These results form the basis of the 2024 Adaptation Roadmap for the SSRB and have been classified into the following categories:

- Continuous Implementation: Strategies with no fixed timeframe to implement, but which should be implemented on an ongoing basis.
- Already in Progress: Projects that are funded or already being implemented.
- Level 1: Projects that are differentiated by their short lead time to implementation. These projects are estimated to plausibly realize benefit within two years.
- Level 2: Mostly infrastructure projects requiring some form of conceptual, engineering, and construction timeline up to 10 years.
- Level 3: Large infrastructure projects requiring some form of conceptual, engineering, and construction timeline up to 20 years, due to complexity and other issues.

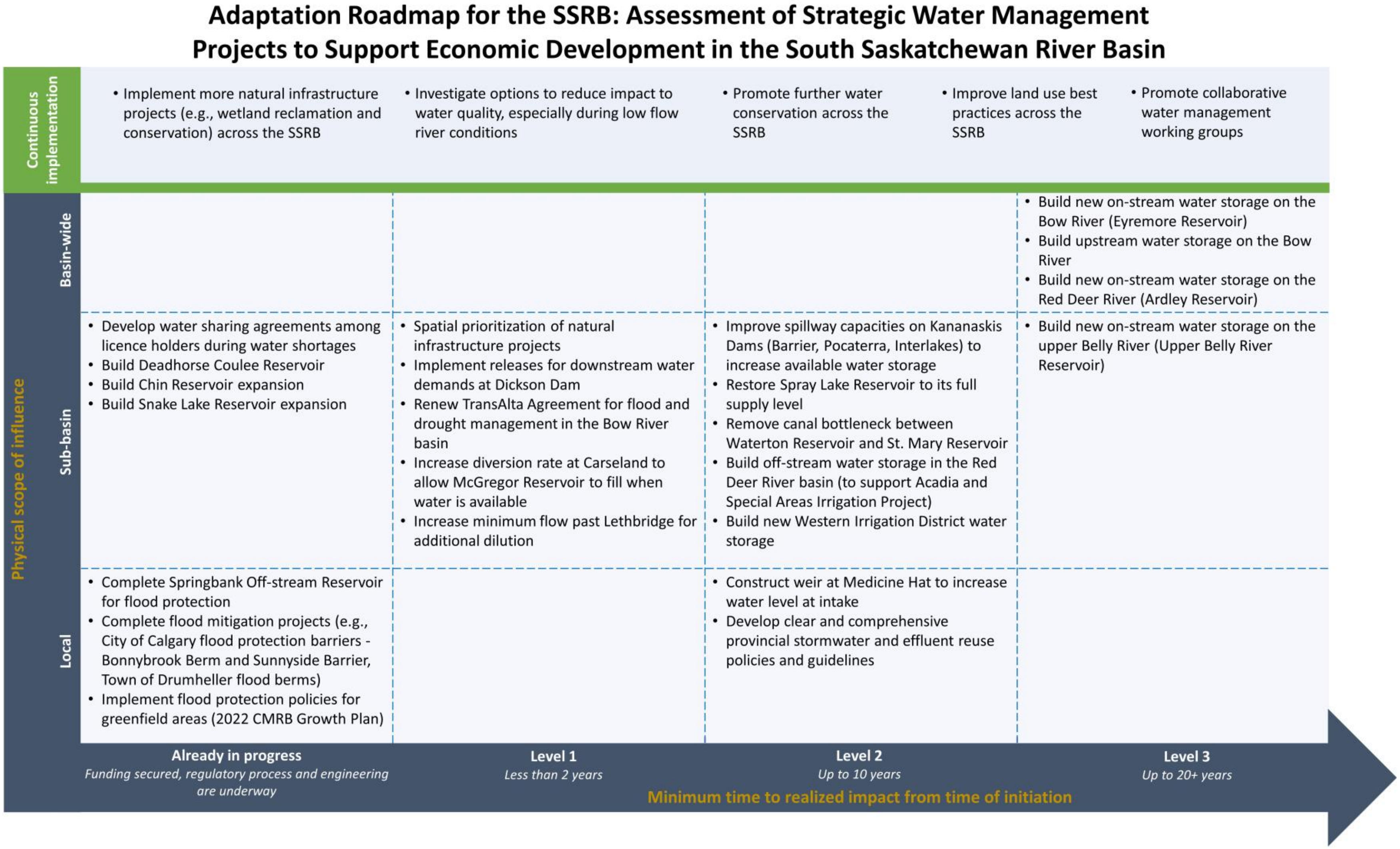
In addition to the levels, the strategies were also classified based on their physical scope of influence:

- Local: Projects which impact a local area specific to the location of the project.
- Sub-basin: Projects which benefit water users in the local area, but also generate positive impacts to other water users within the sub-basin.
- Basin-wide: Projects which benefit water users across the entire SSRB.

In the Adaptation Roadmap for the SSRB, the time to implement refers to the approximate length of time from project initiation to project realization. It does not refer to the publication date of this report. To realize the benefits of the Level 2 and Level 3 strategies, water managers should begin acting on these strategies imminently.

The Adaptation Roadmap for the SSRB was developed in collaboration with key participants formed via a Working Group across the basin. These recommendations, as part of the Adaptation Roadmap for the SSRB, provide several key strategies as recommended by the Working Group, which can be implemented throughout the SSRB. The collaborative sessions explored adaptation options, while acknowledging that the adaptation options do not necessarily reflect a consensus recommendation and are subject to further due diligence/analysis. In addition, the SSROM is built using conservative assumptions regarding water users and does not reflect water conservation efforts. Additional work is required to fully understand the impacts of water conservation in a changing climate and how those efforts, coupled with the adaptation options presented in the Adaptation Roadmap for the SSRB basin.

All of the options identified in the Adaptation Roadmap for the SSRB are promising and critical to ongoing sustainable water management in the SSRB. These strategies are not intended to be rated or ranked in importance through this work, but rather should all be advanced.



**Adaptation Roadmap for the SSRB: Assessment of Strategic Water Management Projects to Support Economic Development in the South Saskatchewan River Basin**

| Physical scope of influence | Already in progress<br>*Funding secured, regulatory process and engineering are underway* | Level 1<br>*Less than 2 years* | Level 2<br>*Up to 10 years* | Level 3<br>*Up to 20+ years* |
|---|---|---|---|---|
| Continuous implementation | • Implement more natural infrastructure projects (e.g., wetland reclamation and conservation) across the SSRB<br>• Investigate options to reduce impact to water quality, especially during low flow river conditions<br>• Promote further water conservation across the SSRB<br>• Improve land use best practices across the SSRB<br>• Promote collaborative water management working groups | | | |
| Basin-wide | | | | • Build new on-stream water storage on the Bow River (Eyremore Reservoir)<br>• Build upstream water storage on the Bow River<br>• Build new on-stream water storage on the Red Deer River (Ardley Reservoir) |
| Sub-basin | • Develop water sharing agreements among licence holders during water shortages<br>• Build Deadhorse Coulee Reservoir<br>• Build Chin Reservoir expansion<br>• Build Snake Lake Reservoir expansion | • Spatial prioritization of natural infrastructure projects<br>• Implement releases for downstream water demands at Dickson Dam<br>• Renew TransAlta Agreement for flood and drought management in the Bow River basin<br>• Increase diversion rate at Carseland to allow McGregor Reservoir to fill when water is available<br>• Increase minimum flow past Lethbridge for additional dilution | • Improve spillway capacities on Kananaskis Dams (Barrier, Pocaterra, Interlakes) to increase available water storage<br>• Restore Spray Lake Reservoir to its full supply level<br>• Remove canal bottleneck between Waterton Reservoir and St. Mary Reservoir<br>• Build off-stream water storage in the Red Deer River basin (to support Acadia and Special Areas Irrigation Project)<br>• Build new Western Irrigation District water storage | • Build new on-stream water storage on the upper Belly River (Upper Belly River Reservoir) |
| Local | • Complete Springbank Off-stream Reservoir for flood protection<br>• Complete flood mitigation projects (e.g., City of Calgary flood protection barriers - Bonnybrook Berm and Sunnyside Barrier, Town of Drumheller flood berms)<br>• Implement flood protection policies for greenfield areas (2022 CMRB Growth Plan) | | • Construct weir at Medicine Hat to increase water level at intake<br>• Develop clear and comprehensive provincial stormwater and effluent reuse policies and guidelines | |

Minimum time to realized impact from time of initiation

**Figure 1. SSRB Adaptation Roadmap showing projects with high potential to improve basin waters security.**

### SSRB Adaptation Roadmap for the SSRB Continuous Implementation

This section summarizes the strategies and what can be implemented across the SSRB.

**Implement more natural infrastructure projects (e.g., wetland reclamation and conservation) across the SSRB** to restore and conserve wetlands and other natural infrastructure with the ability to retain and slowly release water into local water bodies.

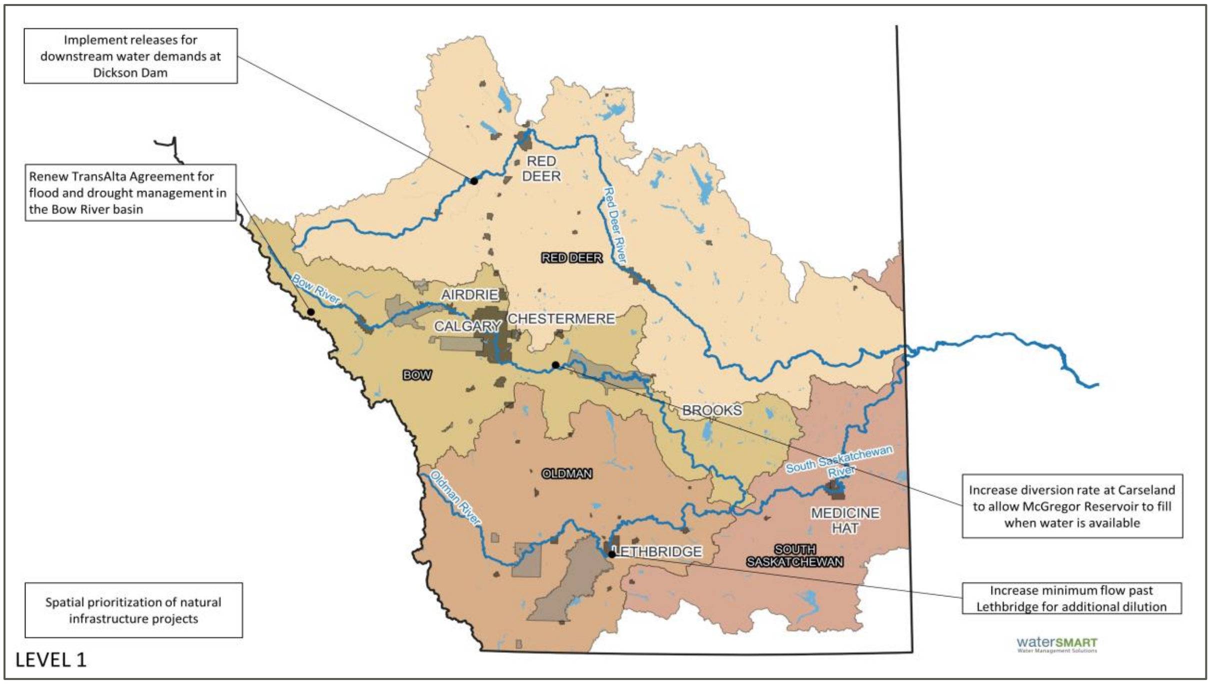
**Investigate options to reduce impact to water quality, especially during low flow river conditions.** Population is predicted to continue growing, which will put more strain on the current infrastructure to maintain effluent quality. It is essential to enhance wastewater treatment facilities to preserve the quality of surface waters to reduce the environmental impact of human activity. We need to continue exploring impacts to reducing water quality, which may include source water protection initiatives, reducing diversions from the river, or upgrading wastewater treatment plants.

**Promote further water conservation across the SSRB** by developing and implementing new technologies to reduce overall water consumption and provide education strategies to conserve water. There are numerous examples of past, current and ongoing work across the SSRB to reduce water consumption.

**Improve land use best practices across the SSRB** to protect critical resources like agricultural lands, wetlands, grasslands, forests, and unique natural features and landscapes. Effective land-use planning makes sure that lands, which are limited resources, are used and developed with landowner input to meet the needs of communities and the people who live in them now and in the future, while preserving the ecological goods and services these lands provide.

**Promote collaborative water management working groups** to continue to collaborate on key issues and resolve conflicts as they arise. Collaboration among a diverse group of water users from a diverse set of expertise and knowledge can be used to identify options and opportunities for better water management within the SSRB, including environmental protection.

## SSRB Adaptation Roadmap for the SSRB Level 1


Implement releases for downstream water demands at Dickson Dam

Renew TransAlta Agreement for flood and drought management in the Bow River basin

Increase diversion rate at Carseland to allow McGregor Reservoir to fill when water is available

Increase minimum flow past Lethbridge for additional dilution

Spatial prioritization of natural infrastructure projects

LEVEL 1

**Figure 2. Identified options in Roadmap Level 1 shown across the SSRB.**

**Spatial prioritization of natural infrastructure projects** to implement natural infrastructure projects within the SSRB to conserve and restore natural areas and processes.

**Implement releases for downstream water demands at Dickson Dam** to release downstream needs, including meeting the Water Conservation Objective and irrigation, as well as protection of environmental flows during extreme multi-year droughts.

**Renew TransAlta Agreement for flood and drought management in the Bow River basin** for TransAlta owned reservoirs to continue to operate for flood and drought conditions to conserve and protect downstream water users and the environment.

**Increase diversion rate at Carseland to allow McGregor Reservoir to fill when water is available.** By filling storage earlier in the season, the Bow River Irrigation District (BRID) could relax pressure on river flows outside the freshet period. It is anticipated that this would provide a direct water security benefit to BRID, as it would allow off-stream reservoirs to be filled earlier, leaving potentially higher water levels. It would also benefit others by reducing competition for water downstream.

**Increase minimum flow past Lethbridge for additional dilution** to explore effluent discharges from the City of Lethbridge's Wastewater Treatment Plant. Increased population in the City of Lethbridge may result in increasing discharge from the wastewater treatment plant, effecting the flow of water downstream of Lethbridge.

## SSRB Adaptation Roadmap for the SSRB Level 2

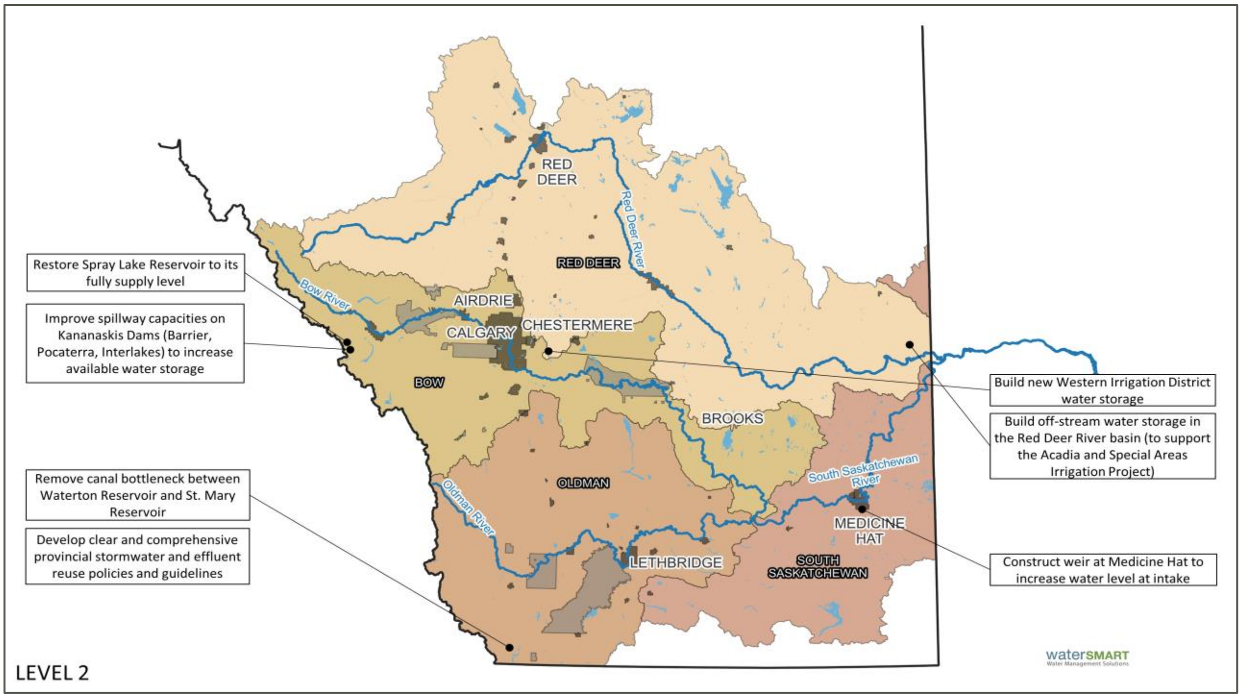


**Figure 3. Identified options in Roadmap Level 2 shown across the SSRB.**

**Improve spillway capacities on Kananaskis Dams (Barrier, Pocaterra, Interlakes) to increase available water storage** in the Kananaskis system in June/July. These restrictions could be removed with relatively modest capital investments in the spillways at the sites to provide limited incremental power generation. **This also allows TransAlta to fill their reservoirs faster when water is abundant and to pass more water downstream later in the season.**

**Restore Spray Lakes Reservoir to its full supply level.** This involves reconstructing part of the reservoir to prevent seepage underneath the reservoir, which will add an additional 74,000 dam$^3$ (60,000 acre-feet) of storage that could be released in low flow periods.

**Remove canal bottleneck between Waterton Reservoir and St. Mary Reservoir,** which limits the rate of flow through the canals. This option would modify the canal system to remove the bottleneck and increase canal flow rates.

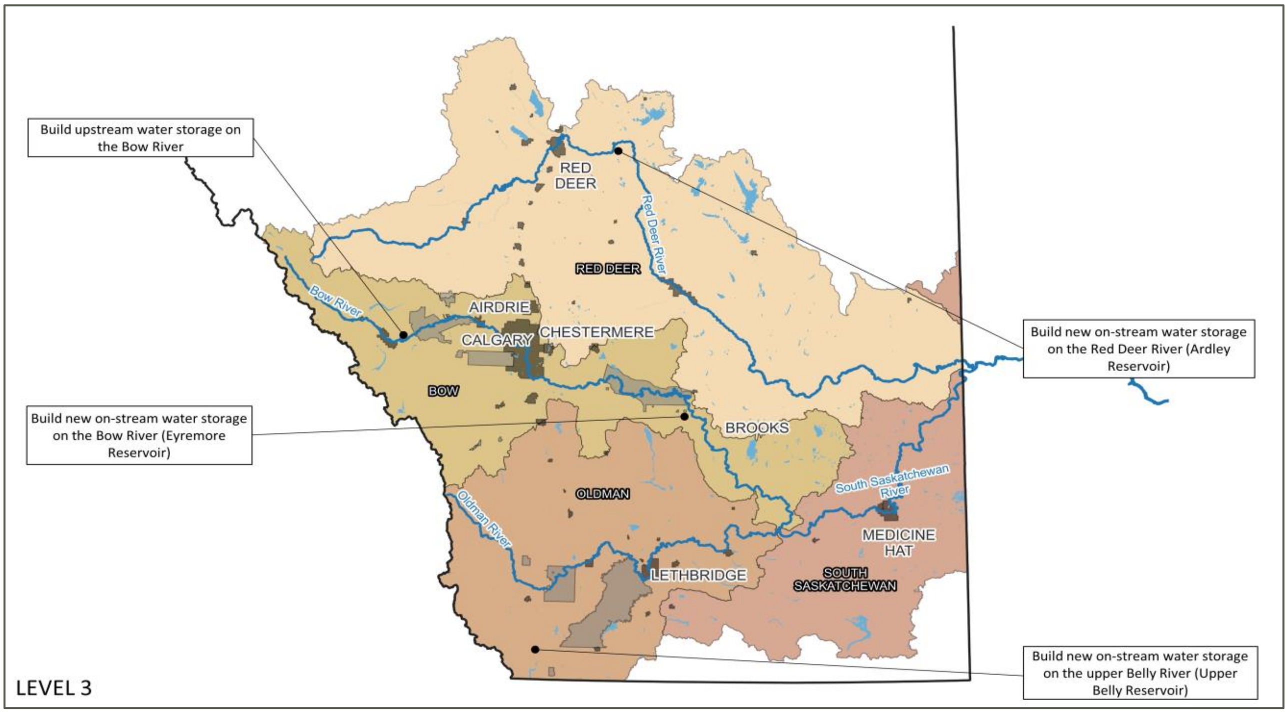
**Build off-stream water storage in the Red Deer River basin (to support Acadia and Special Areas Irrigation Project).** This option explores additional expected future water demand within the Red Deer River basin. The main purpose of the project is to provide water for irrigation purposes, as well as water storage needed for irrigation, as part of the Acadia and Special Areas Irrigation Project. This project is currently in the feasibility stage, with funding from Special Areas Board, the MD of Acadia, the GoA, and Canada Infrastructure Bank.

**Build new Western Irrigation District (WID) water storage** to increase the available water storage capacity in the WID. This storage will provide flexibility to the WID, regardless of the specific location of the storage within their system. This option provides an additional 37,000 dam$^3$ (30,000 acre-feet) of storage within the WID, which can be used to mitigate shortages in low flow years.

**Construct weir at Medicine Hat to increase water level at intake.** The reliance on river flows poses a risk to the City of Medicine Hat in times of drought, as it becomes more difficult to maintain this level. Installation of a weir could provide incremental flow needed for the City's water intake.

**Develop clear and comprehensive provincial stormwater and effluent reuse policies and guidelines** around the reuse of water and the use of stormwater. Guidance will be used to include the direction on application of stormwater/reused water and the required treatment level for safe use.

### SSRB Adaptation Roadmap for the SSRB Level 3



Build upstream water storage on the Bow River

Build new on-stream water storage on the Red Deer River (Ardley Reservoir)

Build new on-stream water storage on the Bow River (Eyremore Reservoir)

Build new on-stream water storage on the upper Belly River (Upper Belly Reservoir)

**Figure 4. Identified options in Roadmap Level 3 shown across the SSRB.**

**Build upstream water storage on the Bow River** to reduce irrigation shortages in the irrigation districts along the Bow River (i.e., WID) and provide positive benefits to environmental flows, and which can work with other Bow River on-stream storage to improve water security throughout the Bow River basin. The project will also be used for flood and drought mitigation for downstream users (e.g., the City of Calgary) to mitigate climate change. A feasibility study continues to explore several flood and drought mitigation options.

**Build new on-stream water storage on the Bow River (Eyremore Reservoir)** to support overall water management on the Bow River and capture water during times of higher streamflow, as well as supporting apportionment. The proposed location is the Eyremore site located below Bassano Dam. This work assumed Eyremore Reservoir would be a large storage facility with an approximate live storage capacity of 616,741 dam$^3$ (500,000 acre-feet).

**Build new on-stream water storage on the Red Deer River (Ardley Reservoir)** to provide water supply security for future licenses, mitigate potential flooding for communities downstream, facilitate substantial future growth in the sub-basin, and support apportionment.

**Build new on-stream water storage on the upper Belly River (Upper Belly River Reservoir)** to support irrigation and maintain environmental flows in the area. The reservoir is projected to be 68,000 dam$^3$ (55,000 acre-feet) in storage and to be located upstream of the United Irrigation District.

## Climate Change and Future Growth Impacts

To understand how the potential projects within the Adaptation Roadmap for the SSRB would perform under potential future climate scenarios, with particular focus on which options would complement one another, a multi-option buildout scenario was developed which included the projects determined by the Working Group (WG) to be the highest performing adaptions. This multi-option buildout scenario was tested against the future climate conditions. The multi-option buildout scenario consisted of the following:

- Build upstream water storage on the Bow River (mixed operations).
- Build new on-stream water storage on the Bow River (Eyremore Reservoir).
- Build new on-stream water storage on the Red Deer River (Ardley Reservoir).
- Restore Spray Lake Reservoir to its full supply level.
- Build new WID water storage.
- Increase minimum flow past Lethbridge for additional dilution.
- Remove canal bottleneck between Waterton Reservoir and St. Mary Reservoir.
- Build new on-stream water storage on the upper Belly River (Upper Belly River Reservoir).

Overall, it was found that the multi-option buildout allowed for more flexible water management within the SSRB, especially during severe droughts, by reducing shortages for major water users such as municipalities and irrigation districts, as well as maintaining flows throughout the basin to maintain environmental health (i.e., fish). This was particularly apparent with the introduction of climate change scenarios. The multi-option buildout was able to effectively mitigate the impacts of the climate change model runs, showing that these adaption strategies are necessary to mitigate climate change into the future. The modelling demonstrated there are potential risks to environmental flows in the multi-option buildout, resulting in the need for careful operation. Further analysis of these options, paying specific attention to operational considerations, will be required for each adaptation strategy during engineering and design studies associated with the options. Basin-wide impacts should be considered during these studies.

In addition, the multi-option buildout scenario was tested with additional future growth assumptions, including population growth and additional irrigated agricultural growth. It was found that this scenario was able to manage demand growth in the basin. The multi-option scenario buildout provides water to ensure water security for a growing population in the SSRB. For this work, the growth assumptions made in the modelling are summarized in Table 11, ranging from 0.94% to 1.5% year over year growth.

### Economic Analysis

In addition to understanding the impacts of the options on water management in the basin, this project also aimed to understand the potential economic value the various options could contribute.

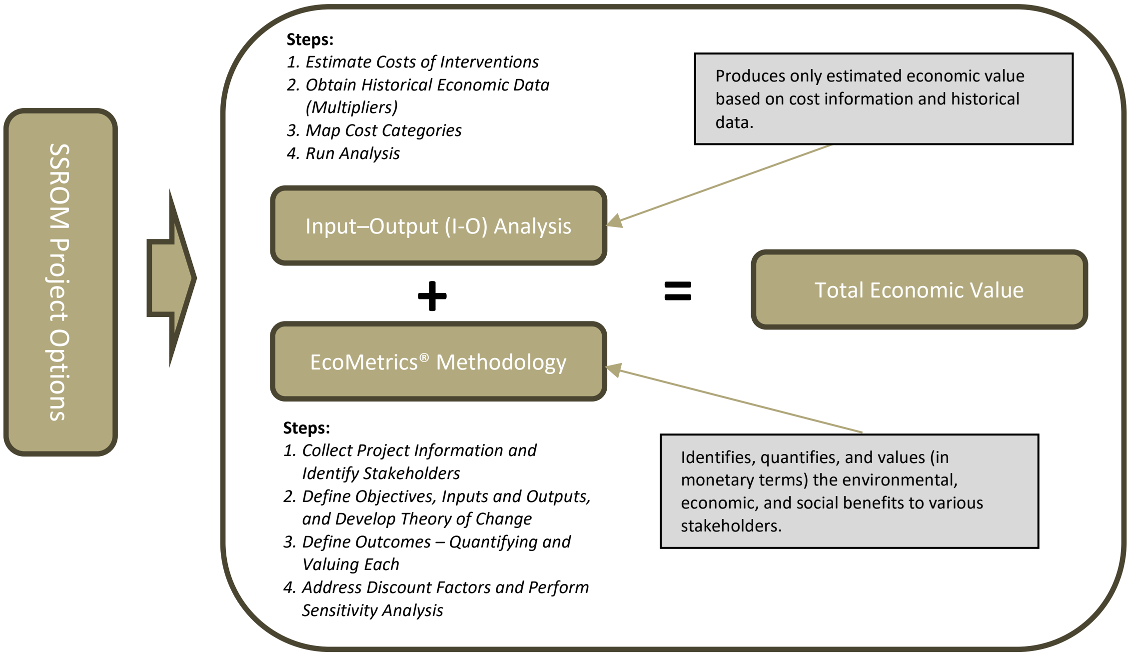


**Figure 5. Input-Output methodology in conjunction with the EcoMetrics® methodology.**

The EcoMetrics® methodology was used to determine a full social and environmental valuation. This methodology is accredited by Social Value International (SVI). It uses stakeholder input to determine the potential impacts of the option, and then assigns valuation to those impacts based on peer-reviewed data and methodology. This is a much broader approach than a traditional input-output economic modelling assessment, as it considers a range of social outcomes, including the recreational value of a project and its potential environmental value. It also considers non-beneficial outcomes, such as increased phosphorus loading in projects where additional fertilizer would be used.

To complete this assessment, the water management modelling was used to determine the potential water availability resulting from each option, which could then be reinvested into either agricultural expansion, municipal and industrial growth, or environmental benefits. Generally, the water was directed in equal portions to each of the three areas, unless otherwise specified. This report represents the values created due to the investment in each of these categories, not the value created for these stakeholders. For the options on the Adaptation Roadmap for the SSRB, the EcoMetrics® methodology demonstrates value creation for the environment and the general public, as well as direct benefits to key stakeholders and funders.

The economic analysis was conducted for key projects where data was available. While it provides a valuable conceptual analysis for the projects there remains room for more detailed assessments as more information becomes available for each of the projects.

### Findings

This project demonstrates how implementation of the adaptive water management strategies outlined in the Adaptation Roadmap for the SSRB can facilitate economic growth while maintaining or improving environmental outcomes in many cases across the basin. With a broad range of these strategies implemented, the basin is more resilient to extreme events such as multi-year droughts; this is especially important given the pressures of climate change, which could lead to earlier freshets and drier summers throughout the SSRB as noted previously. Improved resiliency, coupled with more tools for water managers to draw on in an emergency, leads to less frequent and less severe impacts to rights holders, licence holders, water users and the environment.

The findings indicate efforts should be made to implement projects at all levels of the Adaptation Roadmap for the SSRB, and time is of the essence. The Level 2 and Level 3 projects provide the greatest individual improvements to water security; however, the regulatory processes and engineering timelines needed to implement projects in Level 2 and 3 mean the impacts of climate change may be felt more severely before these projects can be executed, even if they are started imminently. This makes the projects highlighted in Level 1 and under the Continuous Implementation category all the more important, as these projects can be quickly implemented and cumulatively scaled over time to improve water security. In addition to the larger projects, the cumulative effects of projects such as natural infrastructure development are key to improving basin resilience.

# 1.0 Introduction

## 1.1 The opportunity

Alberta is currently facing economic challenges that call for innovative and broad-minded strategies to facilitate growth. The effects of climate change are becoming evident, adding an additional layer of complexity when contemplating economic growth within the province. Provincial growth cannot be achieved without water, as it is key for municipalities, the agriculture industry, the energy sector, and the environment. Without a suitable water management strategy, pressure will increase on water supply as availability becomes limited. Availability of water may shift throughout the year as the climate continues to change, which may lead to competition for water at certain times of the year. Effective water management can alleviate the pressure on water supplies and ensure water is available for the environment, as well as economic and municipal growth.

Alberta is currently experiencing drought conditions and, as of December 2023, had 51 Water Shortage Advisories active across central and southern Alberta. Across many water management areas, Alberta Environment and Protected Areas (AEPA) has implemented Stage 4 of 5 in the Water Shortage Procedures for the South Saskatchewan River Basin (SSRB). The procedure indicates widespread drought conditions with an elevated risk to human safety, due to insufficient water supply and health concerns from poor water quality, resulting in a significant number of licensees, including traditional agriculture and household users, impacted and unable to divert water per their approved licences. Stage 4 of the Water Shortage Management Plan also indicates the conditions are expected to persist, and the Government of Alberta (GoA) is preparing for the potential of widespread droughts throughout the summer of 2024. This current drought status is a critical reminder of the importance of both short and long-term planning for water management and adaptation strategies.

Understanding the potential impacts of individual projects is a key part of water management. The development of a truly effective water management strategy considers how multiple water management opportunities interact, influence, and complement one another under multiple flow scenarios to provide a secure water supply for Albertans. The effectiveness of this approach was shown in the 2016 Adaptation Roadmap for the SSRB, and the 2024 Assessment of Strategic Management Projects to Support Economic Growth (the Adaptation Roadmap for the SSRB) is an opportunity to ensure water is available to future Albertans in the SSRB.

## 1.2 Water and the South Saskatchewan River Basin

The SSRB is vital for Alberta's environmental, social, and economic prosperity. This river basin supports municipalities, manufacturers, tourism, resource extraction, and agriculture. The SSRB encompasses four sub-basins: the Bow River, the Oldman River, the Red Deer River, and the South Saskatchewan River sub-basin. In total, the SSRB covers an area of 112,000 km$^2$ and is home to approximately 1.8 million Albertans (Red Deer River Watershed Alliance, 2023; Oldman Watershed Council, 2022; Bow River Basin Concil, 2023). Water utilization within the SSRB is carefully managed through the priority system to ensure water is available for anthropocentric needs, while upholding the ecological well-being of the basin. Management of water as a resource requires a diligent approach to ensure municipal and economic growth is facilitated, while meeting the needs of the environment. While there can be challenges with always meeting environmental flows under normal flow years, since many water licences in the SSRB are not required to meet environmental targets such as the Water Conservation Objectives (WCO), this becomes particularly important during low flow periods when demand is high and water availability is reduced.

It is imperative for water users, managers, and decision-makers to understand how development decisions affect water accessibility, and to identify opportunities to enhance water governance throughout the basin. AEPA is responsible for regulatory decisions pertaining to water management practices in Alberta (other than oil, gas, coal and minerals). The regulatory mechanisms for managing water in the SSRB include:

- The *Water for Life* strategy and action plan - Reaffirms Alberta's commitment to the wise management of the province's water resources for the benefit of all Albertans (Government of Alberta, 2003).
- The *Water Act* (1999) – Provides considerable flexibility in terms of water reallocation among licence holders for new and existing purposes (Government of Alberta, 2023) for those basins with an approved water management plan.
- The South Saskatchewan River Basin Water Management Plan – Since its approval in 2006 by the Lieutenant Governor in Council, no applications for new water allocations have been accepted within the sub-basins in the SSRB, except for the Red Deer sub-basin (Government of Alberta, 2006), although transfers are now activated.
- The Master Agreement on Apportionment (1969) – Enacted between the Governments of Alberta, Saskatchewan, Manitoba, and Canada, this agreement requires 50% of the natural annual flow by volume of eastward-flowing watercourses to be passed from Alberta to Saskatchewan, and for a minimum flow of 42.5 $m^3/s$ (1500 cfs) to be maintained. If the total annual flow will be less than 4.2-million-acre feet, Alberta is entitled to divert over 50% of the natural flow to a maximum of 2.1-million-acre feet, provided the 1500 cfs minimum flow is maintained. Historically, the average proportion of the river passed on to Saskatchewan has typically been closer to 75% (Government of Canada, Government of Alberta, Government of Saskatchewan, Government of Manitoba, 1969).
- The Boundary Waters Treaty (1909) – Establishes the terms and conditions for water sharing between the United States and Canada. In the case of Alberta and Montana, it is relevant to the Milk and St. Mary River systems. Historically, Alberta has received more water than its entitlement allows, due to lack of diversion and storage infrastructure in Montana. It is not known if and when the United States might take the full allotment of water to which it is entitled in the St. Mary system, which could considerably reduce the amount available to Alberta (Canada - United States, 1909).
- Irrigation Districts Act (2000) - Sets out the procedures for an irrigation district to change its

expansion limit (acres served). It also sets out the procedures an irrigation district must follow before applying to transfer any portion of its water licence(s) to another entity.

- Oldman River Basin Water Allocation Order (2003) – Sets aside 11,000 ac-ft of water in the Oldman River Sub-basin annually for the Oldman River Reservoir Area Projects to utilize for a variety of regional uses, including commercial, recreational, and municipal applications.
- Bow, Oldman and South Saskatchewan River Basin Water Allocation Order (2007) - Establishes a Crown Reservation for unallocated water in the Bow, Oldman, and South Saskatchewan River sub-basins.

## 1.3 Drivers for change

As the climate continues to change, balancing the water supply and demand for sustaining a growing population and fostering economic development has become increasingly important. Adaptive water management is essential for Alberta's continued prosperity. An adaptive management approach aims to develop a resilient and adaptive capacity to respond to a wide range of different circumstances by exploring what can be done with the current infrastructure and operations, and what can be done in the future to reduce the risk to both water users and the environment resulting from climate change impacts. Initiatives are frequently taken at an individual level by industry, agriculture, and municipalities. For example, many municipalities are implementing water conservation, efficiency, and productivity plans along with water reuse opportunities to better manage water within their existing licence allocation. While individual actions are needed, a broader understanding of impacts and opportunities is essential to basin wide water security. The project drivers can be summarized as:

- Support Regional Investment Growth
    - Improve regional water management to leverage opportunities for further economic and municipal development within fully allocated basins or basins approaching full allocation.
    - Identify opportunities from increasing efficiencies in water use that will enable new or expanded agriculture, agri-food, and irrigation projects.
    - Provide confidence for investment in irrigation, which is shown to have a 3:1 return for each GoA dollar invested (Acera Consult Inc., 2021).
    - Drive growth in agriculture, a principal sector in Alberta's Investment and Growth Strategy.
- Position Alberta as a Leader in Water Management
    - Demonstrate expertise and commitment to strategic water management and responsible watershed stewardship.
    - Proactively identify and manage water supply risks facing our communities, economy, and environment such as flood and drought, drinking water security, water as a limiting factor for economic growth, and health of aquatic ecosystems.
    - Recognize and act on water management opportunities to build a stronger, more resilient Alberta.
    - Understand water supply risks associated with the growth of the Alberta economy and

potential water available for additional development.

- Align with National and Global Priorities
    - Respond to increasing national focus on water over the last decade.
    - Prepare for upcoming discussions on provincial water management considering the developing Canada Water Agency (CWA).
    - Highlight the updated Adaptation Roadmap for the SSRB as an example of Alberta's ongoing and successful regional water management to our provincial and national partners.
    - Establish Alberta as an example of implementing regional water management.
    - Develop tools which can prepare Alberta for potential changes to cross-border flows resulting from investments in water infrastructure in the United States.

The current water management challenges within the SSRB present a timely opportunity to leverage the expertise and insights of communities, business leaders, economic development organizations, governmental bodies, irrigation districts, environmental advocates, First Nations, and watershed associations. Watershed management and climate change adaptation pose multifaceted issues that require collaboration on multiple levels.

# 2.0 Adaptation Roadmap for the SSRB: Strategic Water Management Projects to Support Economic Development in the South Saskatchewan River Basin Project

## 2.1 Project history and process

WaterSMART has led several collaborative modelling projects with the purpose of identifying strategies to increase resilience in the SSRB. The South Saskatchewan River Operational Model (SSROM) is an amalgamation of over 15 years of collaborative modelling in the SSRB, facilitated by WaterSMART, Hazen and Sawyer (formerly HydroLogics), and MacDonald Hydrology Consultants Ltd. (MacHydro). Figure 6 below shows a subset of the work completed by this team in the creation and application of the SSROM Model.

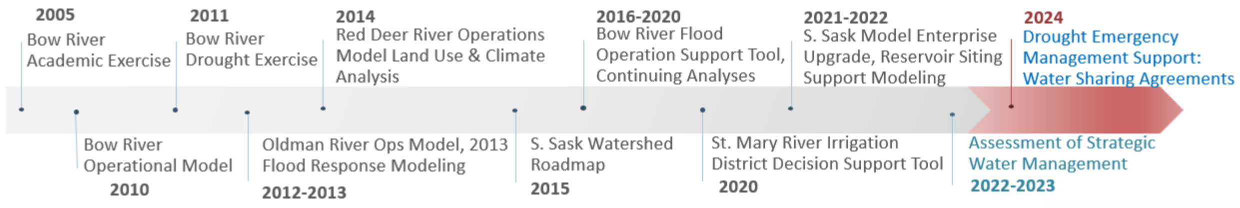


**Figure 6. Development of the SSROM model.**

The development of the SSROM began in 2005 as an assessment of options and strategies for water management in the Bow River basin through an academic exercise. This ultimately led to the development of the Bow River Operational Model (BROM) in 2010.

Building from the BROM, other projects were developed to explore other subsets of the larger basin, including the Oldman and South Saskatchewan River Operational Model (OSSROM, 2012-2013) and the Red Deer River Operational Model (RDROM, 2014). The intent of the models was to support analysis of drought conditions and their effects on the sub-basins of the SSRB. Following the Calgary area floods in 2013, these models were adapted to explore high-flow conditions at appropriate timescales for operational assessment.

In 2015, the three individual sub-basin models were combined to form SSROM, becoming the analytical foundation for the SSRB Adaptation Roadmap for the SSRB published in January 2016 (WaterSMART Solutions Ltd., 2016). This Adaptation Roadmap for the SSRB collected adaptation strategies, sorting them into three levels:

1. Strategies which could be implemented now to adapt to current flows and conditions,
2. Strategies which would add another level of resilience to the basin, and
3. Strategies which would make the basin more resilient to climate change (3).

Each strategy was evaluated using the SSROM. These strategies included operational changes, water sharing agreements, irrigation expansion and optimization projects, and new on-stream and off-stream reservoirs.

Since the publication of the SSRB Adaptation Roadmap for the SSRB in January 2016, approximately two thirds of the over 30 project adaptations have already been implemented or are in progress.

## 2.2 Project purpose and objectives

Several projects have been completed in the SSRB which leveraged the SSROM, including the previously mentioned SSRB Adaptation Roadmap for the SSRB. Since 2016, collaborative efforts in the SSRB included a 2022 update of the SSROM to better align with changes to basin infrastructure and operational challenges, specifically for on and off-stream reservoirs, irrigation and surface water demands, naturalized flows, and input from the City of Calgary and City of Lethbridge to reflect actual use. The project was completed with input from representatives of AEPA and Alberta Agriculture and Irrigation (AGI).

To foster greater confidence in suggested investments and to support the continuous development and planning of future projects, a collaborative watershed management initiative was undertaken in the SSRB. The purpose of the Assessment of Strategic Management Projects to Support Economic Growth (SSROM Phase 3) Project was to continue the work of the 2016 Adaptation Roadmap for the SSRB, engaging knowledgeable water managers within the SSRB to determine how the proposed projects relying on water resources in Southern Alberta fit together into a comprehensive plan, one which realizes economic potential while respecting existing treaties and legislation and without stressing the watershed. Transformative water management strategies in Southern Alberta were identified and assessed through a collaborative process. The project aims to create a Water Management Adaptation Roadmap for the SSRB for the SSRB, which will allow water users and managers to:

- Identify, understand, and manage water supply risks.

- Engage local experts in water management to enable sustainable economic development.
- Initiate new projects which will provide a secure water supply to support industrial, municipal, and agricultural growth while protecting and improving environmental outcomes.
- Communicate publicly regarding climate change's impacts on water resources.

The objectives of the project are to:

- Produce an updated Water Management Adaptation Roadmap for the SSRB for the SSRB aimed at water managers, development planners, and the general public.
- Demonstrate the degree to which economic development can be pursued while protecting water for humans and animals and ensuring healthy aquatic ecosystems.
- Develop an understanding of the amount of water available in the SSRB and how it is currently managed with the infrastructure and processes in place.
- Demonstrate economic opportunities for industry, agriculture, and municipal growth which will continue to increase efficiency in water use.
- Demonstrate the potential impacts of climate change on the SSRB on water supply risks and identify climate adaptation opportunities.
- Identify complementary and mutually beneficial water management opportunities across the SSRB.
- Identify potential projects for further development which provide water management or economic opportunities for the SSRB (e.g., additional built or natural infrastructure).

## The collaborative modelling process

Collaborative modelling is designed to explore and test water management techniques and concepts based on the best available data and knowledge in the basin. The intention is not to seek or attain total consensus, but rather identify plausible and positive options. In the face of uncertainty in water supply, demand, and climate, SSRB decision-makers need a robust and well-informed collection of options for the future. The discussions and conclusions from the SSROM Phase 3 Project provide this guidance in the form of an "Adaptation Roadmap for the SSRB."

No single entity or initiative can address the challenge of building resilience and sustainability in the face of climate change and economic development; these challenges require an adaptive water management approach across all water users. Therefore, a key component to any collaborative modelling project is the active participation of an engaged and diverse Working Group (WG). For this project, and past collaborative projects, members of the WG were selected to represent major water users and managers from a variety of sectors in the basin, bringing their perspectives and expertise to the table. A full list of WG members is presented in Appendix B. This results in objective assessments, strong relationships between proponents which last beyond the duration of the project, a trusted tool, and the development of a water management Adaptation Roadmap for the SSRB for the future.

WG members collaborated throughout the project, contributing information, advice, and understanding derived from their combined expertise and experience. WG meetings are conducted under the Chatham

House Rule, which states when a meeting, or part thereof, is held under the Chatham House Rule, participants are free to use the information received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant, may be revealed. This allowed WG members to actively contribute ideas and remarks to progress the conversation, while respecting the contributions of others.

The Assessment of Strategic Management Projects to Support Economic Growth project consisted of seven WG meetings. Leveraging the OASIS software (see Section 2.3.1), live modelling was conducted throughout several of the WG meetings.

**Kick-off**

- Held virtually via Microsoft Teams, the kick-off brought together WG members and provided project background and purpose. It introduced the SSROM model, reviewed the previous Adaptation Roadmap for the SSRB completed in 2016, and solidified the Terms of Reference for the WG. The SSROM WG Terms of Reference can be found in Appendix A.

**Working Group 1: Performance metrics**

- Working Group Meeting 1 was held in Calgary to explore prior performance measures, suggest new measures, and identify preliminary adaptation options to examine throughout the project.

**Working Group 2-4: Regional Exploration**

- Meetings 2-4 were held in Calgary, Lethbridge, and Drumheller, respectively. These meetings engaged sub-basin stakeholders in live modelling exploration and testing. The sessions were designed to build trust in the SSROM tool, identify basin-specific infrastructure and policy options, and offer an opportunity to enunciate regional concerns to ensure the project addressed each sub-basin appropriately.

**Working Group 5: Whole Basin Exploration**

- Following the regional meetings, the collective WG joined together in Calgary to explore issues, impacts, and strategies for the whole SSRB. This session allowed WG members to review the identified sub-basin infrastructure and policy options from sub-basin specific WG meetings. It also provided an opportunity to test, refine, and combine/recombine identified alternatives.

**Working Group 6: Climate Change**

- Held again in Calgary, this meeting reviewed results following WG Meeting 5, additionally layering in climate change scenario projections to allow for an assessment of how options identified to date held up against potential future climates. Descriptions of the social and economic value of water management within the EcoMetrics® framework were also introduced to familiarize WG members with the economic analysis being done as part of the project.

**Working Group 7: Finalizing the Adaptation Roadmap for the SSRB**

- The final Calgary meeting reviewed the group's assessment of the most promising adaptation strategies and actions with an eye toward timing and difficulty of implementation. These conclusions were synthesized into the final Adaptation Roadmap for the SSRB document presented in this report.

### 2.2.1 Adaptation Roadmap for the SSRB development process

Figure 7 outlines the process through which the project options were analyzed once identified by the WG. It is important to highlight that input from the WG was incorporated into the analysis by an iterative process, and members were provided the opportunity to review and adjust the analysis throughout.

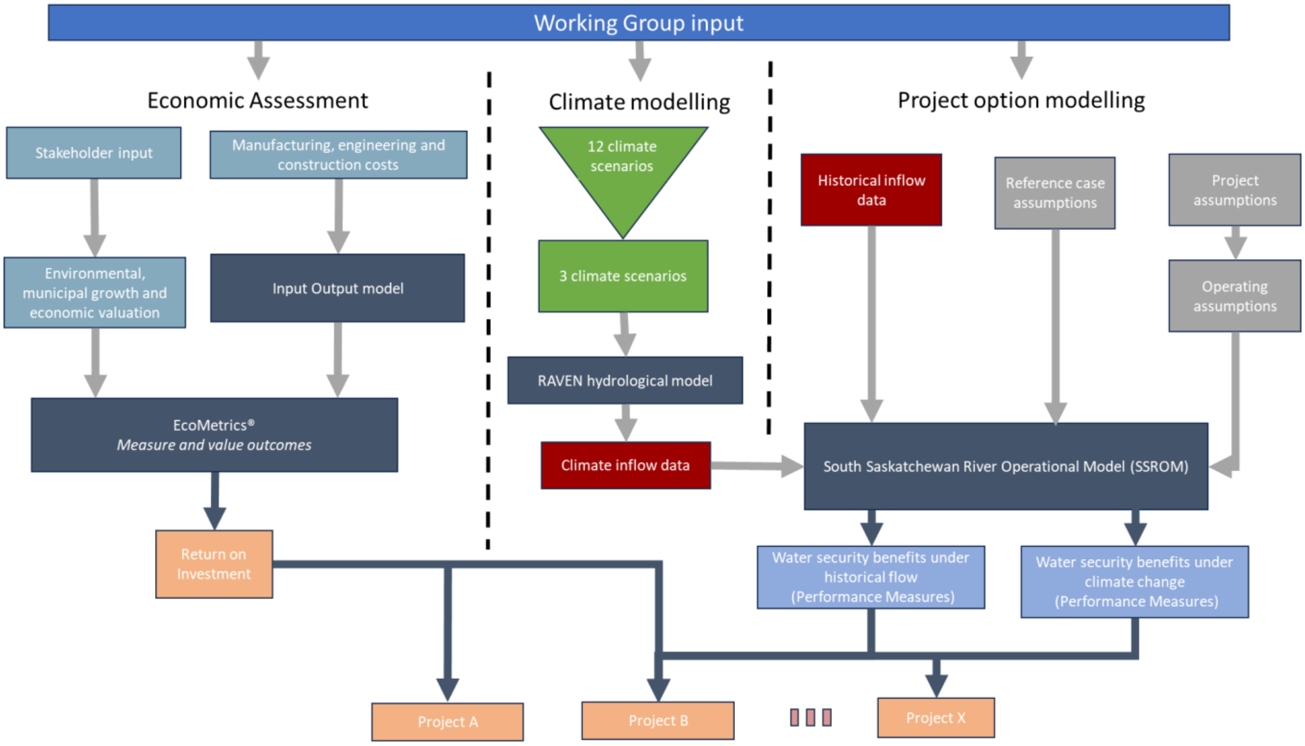


**Figure 7. Process used to assess projects brought forward by the WG.**

## 2.3 The SSROM

The overall SSROM model utilizes a variety of tools. The OASIS 2.0 platform forms the central model architecture but integrates inputs from several sources (including the Raven hydrologic model). Sections 2.3.1 and 2.3.3 provide brief discussions on each OASIS and Raven, respectively. For discussion on how climate change scenarios were incorporated, see Section 2.4.2. The overall construction of the SSROM is discussed in Section 2.3.2. As with any model, there are assumptions and limitations. For more information on these models, and specifically on the SSROM, see the detailed report from the 2021/2022 Update (WaterSMART Solutions Ltd. 2022).

### 2.3.1 OASIS modelling platform overview

Operational Analysis and Simulation of Integrated Systems (OASIS) is a unique software designed to allow users to model quickly and accurately. It was designed based on real-world water resource systems management experiences and has continually evolved over the past 25 years. The OASIS modelling platform is flexible, transparent, data-driven, and based on mass balance. Continuity of flow equations are automatically written, reducing error and time compared to building river basin models using other tools like spreadsheets.

OASIS is tailored using weights on variables or elements, where positive weights encourage actions and negative weights discourage them. Attribution of weights is ordinal; a variable with a higher weight is given preference over one with a lower weight, regardless of the magnitude of the difference. A comprehensive list of weights in the model, inclusive of reservoirs and demands, can be found using the "Special Output" button in OASIS and selecting "Weights.out". For more complex operations, OASIS uses the specially designed operations control language (OCL), a macro-like programming language, which allows users to define additional variables, targets, and constraints.

More information about the OASIS platform can be found on the Hazen and Sawyer website, at: https://www.hazenandsawyer.com/articles/oasis-modeling-for-water-people.

### 2.3.2 The South Saskatchewan Operational Model (SSROM) overview

The SSROM, built under the OASIS platform, is a comprehensive, daily, mass balance river model, collaboratively constructed through numerous working groups between 2008 and 2015. It represents the culmination and connection of many preceding years of regional modelling. During the development of the SSROM, each of the major basins (Red Deer, Bow, Oldman & Southern Tributaries) were individually modelled and analyzed before combining to form the SSROM. Each of these sub-basin model borders are identified in the schematic shown in Figure 8, with stars noting points of interconnection.

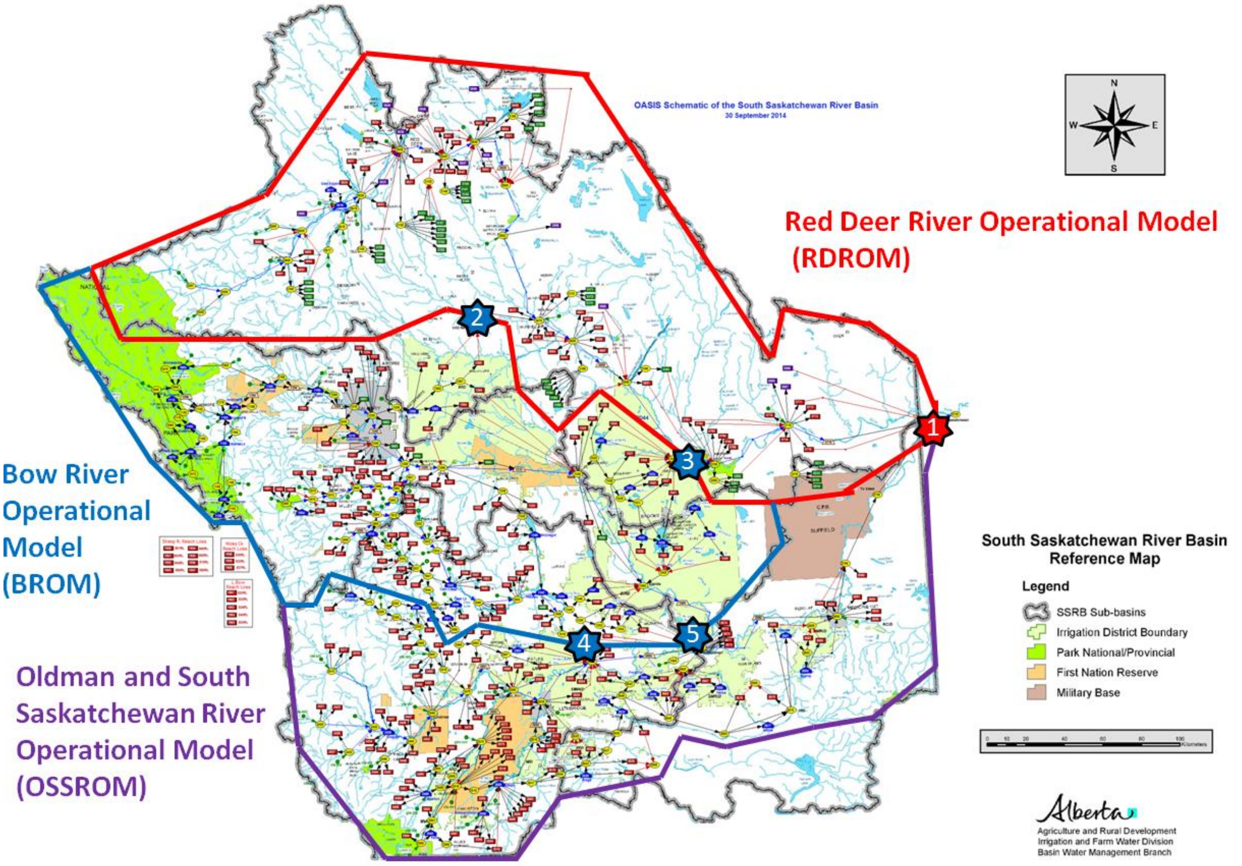


**Figure 8. Schematic of the SSROM noting the delineation and points of interconnection between basins.**

Table 1 below lists the detailed reports produced for each of the sub-basins in the SSRB with a brief discussion on the sub-basin models and the comprehensive model update from 2021/2022.

**Table 1. SSRB sub-basin final reports.**

| Report title | Date |
|---|---|
| South Saskatchewan River Basin Adaptability to Climate Variability Report: Adaptation Strategies for Current and Future Climates in the Bow Basin; Final Report (Alberta Innovates & WaterSMART Solutions Ltd., 2013) | June 2013 |
| South Saskatchewan River Basin Adaptation to Climate Variability Project Final Report; Phase III: Oldman and South Saskatchewan (OSSK) River Basins Summary Report (Alberta Innovates & WaterSMART Solutions Ltd., 2014) | April 2014 |

| Report title | Date |
|---|---|
| Climate Variability and Sustainable Water Management in the SSRB Project: Red Deer River Basin Modelling, Final Report (Alberta Innovates & WaterSMART Solutions Ltd., 2015) | February 2015 |

The SSROM runs on a daily timestep and is a comprehensive mass balance model which includes a wealth of information about facility operations, power costs, unofficial sharing arrangements, and other topics. As a result, the model produces findings in line with operational expectations. Primary inputs include naturalized flows, evaporation and precipitation, licensed allocation for the whole system or consumptive use (in some cases actual use numbers were provided by users), return flows, and physical data for diversions and reservoirs with associated operations. The SSROM provides a useful way to look at the supply of water from across the SSRB.

Generally speaking, the model uses conservative assumptions around water use, and the work completed during this project did not take into consideration water conservation efforts which will likely be implemented in the future due to climate change resiliency initiatives. Therefore, the assessment results of the options developed during this project are potentially conservative in terms of water availability.

#### 2.3.2.1 Red Deer River Operational Model (RDROM)

A key element of the RDROM is how licence allocation is managed. Based on feedback from WG members in the Red Deer River Basin during initial development, default assumptions in this basin assume full license allocation for all users except irrigation, which uses annually adjusted crop demands (discussed later).

#### 2.3.2.2 Bow River Operational Model (BROM)

The BROM includes Elbow, Highwood, and Sheep Rivers' operations, including large off-stream canals and storage reservoirs. The BROM model extends from the Bow headwaters to the confluence with the Oldman River. The BROM also includes representative TransAlta operations and incorporates several informal agreements among water managers, reflecting how the system actually functions.

#### 2.3.2.3 Oldman-South Saskatchewan River Operational Model (OSSROM)

The OSSROM includes the Oldman and South Saskatchewan, as well as the Southern Tributaries (the Belly, Waterton, and St. Mary Rivers). The base case relates the river's current operations to historical flows (1929–2015) within the framework of permitted priorities and water management plans. The Oldman River basin has seen a progression in reservoir development; however, as the goal of the OSSROM is to simulate both current and future situations, it does not take this history into consideration. Instead, it suggests all the basin's infrastructure existed during the model period. The sub-basin only presumes incoming St. Mary flows at the minimum level agreed to under the Boundary Water Treaty (entitlement flows) in our analyses. Note that this assumption can be relaxed in future or alternative work.

Given the significant changes in the basin since 2015 (e.g., irrigation district expansions, water infrastructure-related projects, and changes to the operation of the system), the SSROM underwent an update process in 2021/2022 to reflect current conditions (WaterSMART Solutions Ltd., 2022). The GoA was a critical player in this update, not only as a funder, but also as the source for many of the updated datasets integrated into the SSROM.

As many updates resulted from changes to infrastructure managed by irrigation districts or the Province, a WG was formed with representatives from: irrigation districts, AEPA, AGI, and other key GoA departments. Other rightsholders, including municipalities, were engaged individually. Per the advice of the WG, the following major elements of SSROM were confirmed or updated:

- Operational regimes for key on-stream and off-stream reservoirs on all river basins.
- Irrigation surface water demand (from the Irrigation Demand Model Data) and acreage (from the irrigation districts).
- Surface water demands (from AEPA).
- Extended naturalized flows (from AEPA) from 2008 to 2015.
    - New period of record for SSROM: 1928-2015.
- Municipal demand for the City of Calgary and the City of Lethbridge.

This update not only achieved the primary objective of reflecting current basin operations, but also enabled:

- The platform transition of SSROM from OASIS Classic to OASIS Enterprise, for more efficient modelling of complex scenarios and an updated interface.
- Access to SSROM for interested parties and stakeholders through a public hosting platform for an initial one-year period and a provincial AEPA copy and license for internal use.

As a byproduct of the update process, potential scenarios were identified for future assessment. These included: optimization of water management in the upper SSRB, assessing options for rural and economic development in a closed system, and evaluating ecosystem health within the context of new irrigation projects.

### 2.3.3 Raven hydrological model overview

Raven is a hydrological modelling framework designed to be fully object-oriented, providing flexibility in spatial discretization, interpolation, process representation, and forcing function generation (Craig, et al., 2020). The semi-distributed hydrological model used in this study is an adapted version of the HBV-EC model, emulated within the Raven Hydrological Modelling Framework version 3.7 (Craig et al., 2023). The model simulates streamflow and other hydro-climatic variables (i.e. snowmelt, evaporation, etc.) at a daily timestep. The model spatially distributes daily minimum and maximum air temperature, precipitation, and relative humidity from all weather stations across the study region. The model simulates major hydrological processes, including canopy interception, snow accumulation and melting, evaporation, soil infiltration, percolation, and baseflow, as well as surface runoff. Major processes are described below, while a comprehensive discussion of model algorithms can be found in Bergström (1992), Jost et al. (2012), and Chernos et al. (2020).

In the hydrological model, water inputs occur as precipitation, which is partitioned into rain or snow following the HBV linear transition based on air temperature. Precipitation interception by the forest canopy is estimated as a function of Leaf-Area Index (LAI; Craig et al., 2020; Hedstrom and Pomeroy, 1998). Snowmelt is calculated using a spatially corrected temperature index model, which accounts for aspect, slope, and day length (Jost et al., 2012, Craig et al, 2020). Potential evapotranspiration is calculated using the Priestley–Taylor equation over land and Hargreaves (1985) over water and varies between vegetation types. Once water infiltrates the three-layer soil, it moves downwards through percolation and upwards through capillary rise. Soil water becomes surface runoff (i.e. streamflow) through (faster) interflow and (slower) baseflow pathways.

## 2.4 Climate change and land use cover change

### 2.4.1 Irrigation Demand Model updates

A key input to the SSROM is data from Alberta Agriculture and Irrigation's (AGI) Irrigation Demand Model (IDM). The IDM calculates the volume of irrigation necessary for 90% ideal growth based on temperature and precipitation records. Under the climate change scenarios, notable changes to the volumes available and timing of the irrigation season were observed due to an earlier freshet and lower late summer flows under the selected climate scenarios described in Section 2.4.2. It was critical to run the climate precipitation and temperature data through the IDM to fully capture the effect of irrigation demand. AGI was a crucial partner in this effort, providing IDM irrigation timeseries model results for use in the SSROM.

Daily average air temperature (°C), total evapotranspiration (mm), and total precipitation (mm) outputs from the hydrological model were used as inputs to the IDM. The following climate scenarios were run through the IDM:

1. **IPSL-CM6A-LR (SSP 1-2.6)**: Driest annual hydrograph; largest reductions in Mean Annual Flow.
2. **IPSL-CM6A-LR (SSP 1-2.6)**: Hottest and driest combination scenario; leads to large shifts in timing and more frequent low flow events in the late summer.
3. **BCC-CSM2-MR (SSP 3-7.0)**: A drier and hotter future scenario, with reductions in annual as well as late summer flows.

Outputs from IDM for each scenario were provided and incorporated as time series data into the SSROM. Due to the wide range of climate change scenarios available in public space, it is important to note these were selected from the 12 scenarios provided by AEPA. Additional modelling scope could be completed using additional climate changes scenarios for specific scopes of work in the future.

### 2.4.2 Climate change scenarios

Future climate change scenarios were run to identify potential future stress cases to run through the SSROM and IDM. Future climate change scenarios were provided by AEPA based on work detailed in datasets from a climate data evaluation system (Erm & Gupta, 2019). Based on discussion with the WG on August 1, 2023, 12 future scenarios were run through the Raven hydrological model under two land-cover scenarios:

- Current Conditions — This scenario reflects the existing glacier coverage in the SSRB headwaters.
- No Glaciers – This scenario reflects one in which glacier melt no longer contributes to river flow at any point in the year (i.e. the glaciers have melted and no longer exist).

The No Glaciers land cover was used to understand the implications of an extreme scenario, in which there would be no glaciers remaining in the headwaters of the South Saskatchewan River.

All scenarios were run through the hydrological model and outputs were analyzed at a high level and summarized into hydrologic indicators, which capture the changing volume and timing of flow in major rivers within the SSRB. Given the goal for the climate scenarios was to identify future conditions which would lead to additional stress on the system, scenarios were selected for management analysis if they resulted in lower water availability and/or a shift in timing to less summer water availability. Following those principles, the following scenarios were further explored in the SSROM:

1. **IPSL-CM6A-LR (SSP 1-2.6):** Driest annual hydrograph; largest reductions in Mean Annual Flow.
2. **IPSL-CM6A-LR (SSP 3-7.0):** Hottest and driest combination scenario; leads to large shifts in timing and more frequent low flow events in the late summer.
3. **BCC-CSM2-MR (SSP 3-7.0):** A drier and hotter future scenario, with reductions in annual as well as late summer flows.

There were large differences in water availability (especially during the late summer) between the Current Conditions and No Glaciers land cover scenarios. In the current system, glaciers provide meaningful late summer flows. However, under many future climate scenarios, warming air temperatures will likely lead to substantial reductions in glacial volume. As such, assuming current glacier contributions into the future will likely overestimate water availability, with the overestimate greater in scenarios with higher air temperature increases. This is due to both faster ice melt and the fact that these conditions would lead to greater glacier retreat than under a cooler future scenario. As such, in the stated goal of performing stress tests, the lower bound for flows under each climate scenario was determined.

Additional information on the selection process for the climate change scenarios can be found in Appendix C. Additionally, more information on Socio-economic Pathways (SSPs) used for climate change analysis can be found on the Government of Canada website (Government of Canada, n.d.). The scenarios were selected to be the most stressful for the system based on the 12 climate scenarios from the GoA. Future work could investigate how the Adaptation Roadmap for the SSRB options would perform under different climate scenarios.

### 2.4.3 Glacier contributions to streamflow

Contributions from glaciers are an important seasonal component of streamflow for glacierized headwater basins. Within the study area, glacier coverage is highest in the Bow River basin, primarily upstream of Lake Louise (Figure 9). In the Bow River, glaciers contribute to streamflow during the summer months, peaking in August where air temperatures are high, and the winter snowpack is mostly depleted. During August, in an average year, glaciers could contribute as much as a third of streamflow at Bow River at Lake Louise and up to 10% of streamflow at Bow River at Banff. During dry years, when the winter snowpack is low, glaciers could contribute greater streamflow, both as a proportion of streamflow and as an absolute amount, since earlier glacier ice exposure will lead to a higher and more prolonged melt. This dynamic highlights how glaciers can be buffers to maintain adequate streamflow and aquatic conditions during low flow periods. However, this source of water should be considered non-renewable since dry years lead to mass wastage and glacier retreat.

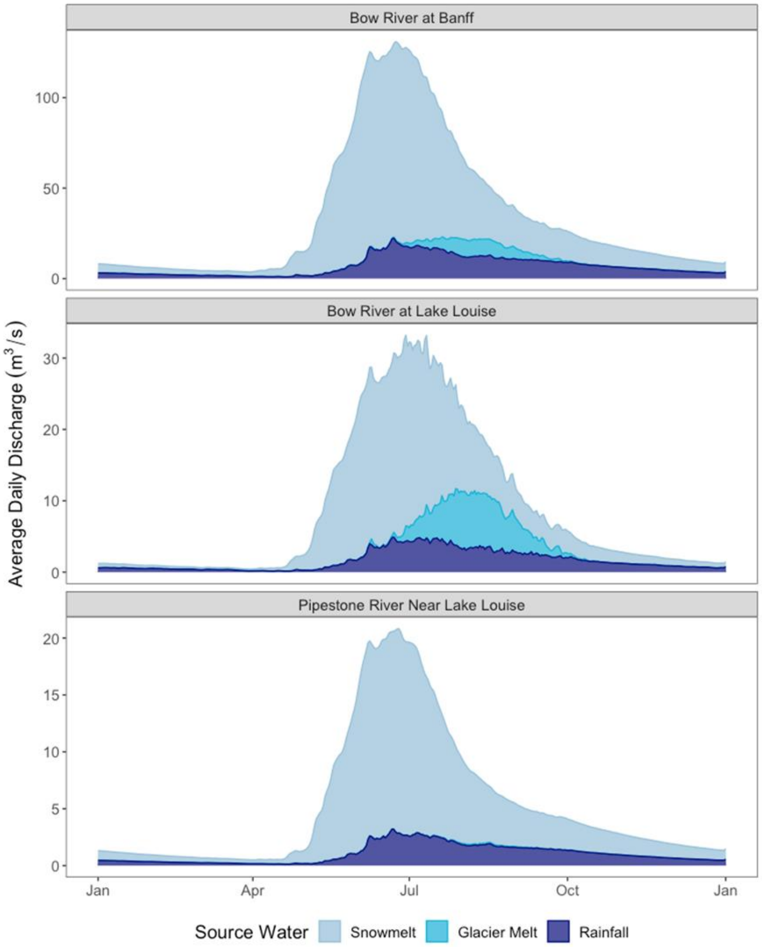


**Figure 9. Average streamflow for major sub-watersheds in the upper Bow River under historical (1991-2020), with flow contributions delineated by source using Raven's built-in tracer algorithm.**

Under future conditions, continued glacier retreat is likely to exacerbate this dynamic (DeBeer & Pomeroy, 2010). Furthermore, glacier buffers most significant in the Bow River, but also present in the Red Deer River and St. Mary River watersheds, are unlikely to be able to offer the same level of streamflow contributions into the future. Additionally, under projected future conditions with warmer air temperatures, glacier contributions would be overestimated under current areal coverage.

The average hydrologic indicator under the full suite of future climate change scenarios provided is summarized as the change relative to Current Conditions (1991-2020). The ensemble of scenarios projects generally small increases in flow at an annual scale, but this is driven mostly by increases in winter flows, and partially offset by relatively substantial decreases in summer flows. Notably, both indicators of summer low flows (10-Year Summer Low Flow, Aug-Sept Low Flow) are buoyed by current glacier coverage. For instance, by 2051-2080, Bow River at Cochrane is projected to see an increase in August to September Low Flow of 1%; however, under the No Glaciers scenario, the site is projected to experience a 23% reduction in the indicator. A similar dynamic is also present in the St. Mary River and Red Deer River. This is not seen in the Oldman basin, as there is no glacier contribution to current stream flows. Future changes in flow in the Oldman basin are driven by precipitation and temperature by climate change.

**Table 2. SSRB flows.**

| Location | LandCover | 10-Year Low Flow | 10-Year Summer Low Flow | 2-Year Peak Flow | 20-Year Peak Flow | Mean Annual Flow | Mean Aug-Sept Flow | Peak Flow Timing |
|---|---|---|---|---|---|---|---|---|
| *1991-2020* | | | | | | | | |
| Bow River Near Cochrane | NoGlaciers | 2% | -5% | -0% | 1% | -3% | -12% | 1.2 days |
| Oldman River Near Brocket | NoGlaciers | 0% | 0% | 0% | 0% | 0% | 0% | 0.0 days |
| Red Deer River Near Sundre | NoGlaciers | 2% | -3% | -0% | 0% | -1% | -6% | 0.0 days |
| St. Mary River at Highway No. 501 | NoGlaciers | 1% | -10% | 0% | 0% | -1% | -7% | 0.0 days |
| *2021-2050* | | | | | | | | |
| Bow River Near Cochrane | CurrentConditions | -4% | -9% | 7% | 5% | 2% | -1% | -0.8 days |
| Bow River Near Cochrane | NoGlaciers | -2% | -20% | 6% | 5% | -4% | -19% | -2.1 days |
| Oldman River Near Brocket | CurrentConditions | 3% | 0% | 1% | 9% | 1% | 6% | 5.3 days |
| Oldman River Near Brocket | NoGlaciers | 3% | 0% | 1% | 9% | 1% | 6% | 5.3 days |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Red Deer River Near Sundre | CurrentConditions | 4% | -10% | 5% | 13% | 2% | -1% | 6.1 days |
| Red Deer River Near Sundre | NoGlaciers | 6% | -17% | 5% | 13% | -1% | -11% | 5.7 days |
| St. Mary River at Highway No. 501 | CurrentConditions | 19% | 5% | 11% | 8% | 5% | -15% | -5.6 days |
| St. Mary River at Highway No. 501 | NoGlaciers | 20% | -9% | 11% | 8% | 3% | -24% | -6.0 days |
| *2051-2080* | | | | | | | | |
| Bow River Near Cochrane | CurrentConditions | 8% | -8% | 12% | 16% | 7% | 1% | -6.4 days |
| Bow River Near Cochrane | NoGlaciers | 11% | -23% | 11% | 16% | -2% | -23% | -8.0 days |
| Oldman River Near Brocket | CurrentConditions | 29% | -5% | 2% | 21% | 2% | 1% | 4.9 days |
| Oldman River Near Brocket | NoGlaciers | 29% | -5% | 2% | 21% | 2% | 1% | 4.9 days |
| Red Deer River Near Sundre | CurrentConditions | 17% | -10% | 10% | 27% | 6% | -1% | 2.9 days |
| Red Deer River Near Sundre | NoGlaciers | 18% | -19% | 9% | 26% | 1% | -15% | 2.6 days |
| St. Mary River at Highway No. 501 | CurrentConditions | 44% | 1% | 14% | 14% | 9% | -22% | -9.5 days |
| St. Mary River at Highway No. 501 | NoGlaciers | 45% | -16% | 14% | 15% | 6% | -32% | -9.6 days |

### 2.4.4 Future scenarios used in SSROM

In general, the greatest changes in hydrographs under the climate change scenarios relate to a change in timing, rather than magnitude of flow. The climate scenario assessed in this work showed an increase in winter streamflow and earlier freshet due to greater winter precipitation and air temperatures, leading to periodic winter rainfall and earlier spring snowmelt. Correspondingly, late summer conditions are projected to be drier due to less precipitation and earlier freshet, leading to a longer post-snowmelt period (Eum & Gupta, 2019).

There are potentially large differences in water availability (especially during the late summer) between the Current Conditions and No Glaciers land cover scenarios. Glaciers provide important late summer flows. Under future climate scenarios, warming air temperatures are likely to lead to reductions in glacier areas. As such, assuming current glacier coverage into the future will overestimate water availability; this overestimate will be greater under scenarios with greater air temperature increases. This is both because hotter air temperatures will lead to greater simulated glacier ice melt, and because these conditions would lead to greater glacier retreat than under a cooler future scenario. As such, in the stated goal of performing stress tests, the No Glacier land cover configuration was used as a lower bound for flows under each climate scenario.

Given the stated goal of identifying future conditions which could lead to additional stress on the system, scenarios were identified which resulted in lower water availability and/or a shift in timing to less summer water availability. Based on these outputs, and the stated goal of seeking out scenarios which lead to reductions in water availability in the SSRB, the following climate scenarios were run through the water management model, IPSL-CM6A-LR (SSP 1-2.6), IPSL-CM6A-LR (SSP 3-7.0), BCC-CSM2-MR (SSP 3-7.0) as seen in Figure 10 below.

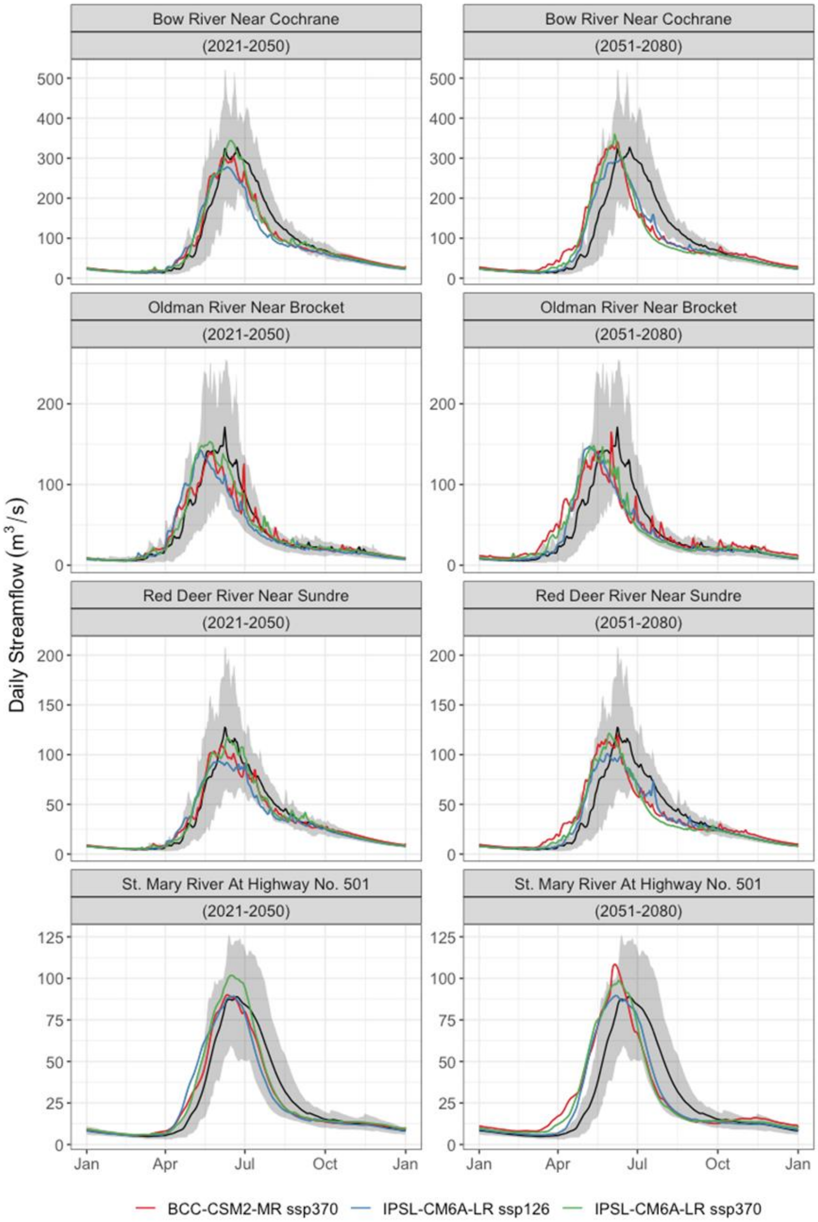


**Figure 10. Hydrographs for historical (1991-2020) baseline conditions and the three future climate change scenarios with No Glacier land cover under future periods. The hydrographs show that there is an overall shift in flows earlier in the spring and lower flows in the late summer. The black, solid lines correspond to average flows, while the shaded grey area represents 10-90% of Historical flows.**

Hydrologic indicators are provided for each scenario and each 30-year period, as a change relative to the Historical 1991-2020 period (Table 3). Over the 2021-2050 period, the ISPL-CM6A-LR (SSP 1-2.6) scenario shows the largest reductions in mean annual flow, with greatest decreases in the Bow River at Cochrane site. In addition, this scenario contains the largest decreases in average summer flows. Notably, the BCC-CSM2-MR (SSP 3-7.0) scenario shows greater reductions in 10-Year Summer Low Flow, suggesting the scenario is particularly prone to future drought. Conversely, small increases in mean annual flow are projected for the period under the ISPL-CM6A-LR (SSP 3-7.0) scenario.

Over the 2051-2080 period, mean annual flow is projected to decrease under both IPSL scenarios, while the BCC scenario showed a small increase. Under all three scenarios, the St. Mary River site was projected to see increases in mean annual flow. Substantial (20-30%) decreases in late summer flows (Aug-Sept Low Flow and 10-Year Summer Low Flow) were projected under all three climate change scenarios over this period, with greatest decreases in the Bow and Red Deer, in part due to the lack of glacier contributions to streamflow. Additional details regarding the climate change scenarios analysis can be found in Appendix C.

**Table 3. SSRB flow runs under climate change scenarios.**

| Climate | Location | Mean Annual Flow | Mean Aug-Sept Flow | 2-Year Peak Flow | 20-Year Peak Flow | 10-Year Low Flow | 10-Year Summer Low Flow | Peak Flow Timing |
|---|---|---|---|---|---|---|---|---|
| *2021-2050* | | | | | | | | |
| BCC-CSM2-MR ssp370 | Bow River Near Cochrane | -4% | -18% | 5% | 1% | 2% | -27% | -7.3 days |
| BCC-CSM2-MR ssp370 | Oldman River Near Brocket | -2% | 4% | 4% | 29% | 1% | -10% | 5.4 days |
| BCC-CSM2-MR ssp370 | Red Deer River Near Sundre | -1% | -9% | 0% | 5% | 13% | -25% | -0.4 days |
| BCC-CSM2-MR ssp370 | St. Mary River at Highway No. 501 | -1% | -26% | 7% | 3% | 17% | -13% | -7.8 days |
| IPSL-CM6A-LR ssp126 | Bow River Near Cochrane | -11% | -24% | -16% | -18% | -1% | -15% | -0.3 days |
| IPSL-CM6A-LR ssp126 | Oldman River Near Brocket | -6% | -7% | -17% | -25% | -4% | -4% | -7.8 days |
| IPSL-CM6A-LR ssp126 | Red Deer River Near Sundre | -7% | -12% | -11% | -1% | 9% | -6% | 8.9 days |
| IPSL-CM6A-LR ssp126 | St. Mary River at Highway No. 501 | -1% | -30% | 1% | -3% | 11% | -10% | -9.5 days |
| IPSL-CM6A-LR ssp370 | Bow River Near Cochrane | -2% | -15% | 2% | -3% | 4% | -13% | 0.7 days |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| IPSL-CM6A-LR ssp370 | Oldman River Near Brocket | 3% | 4% | 1% | 1% | 3% | 2% | 0.2 days |
| IPSL-CM6A-LR ssp370 | Red Deer River Near Sundre | 2% | -3% | 7% | 13% | 13% | -9% | 14.0 days |
| IPSL-CM6A-LR ssp370 | St. Mary River at Highway No. 501 | 6% | -24% | 15% | 19% | 21% | -10% | -6.1 days |
| *2051-2080* | | | | | | | | |
| BCC-CSM2-MR ssp370 | Bow River Near Cochrane | 0% | -28% | 11% | 27% | 26% | -28% | -15.7 days |
| BCC-CSM2-MR ssp370 | Oldman River Near Brocket | 5% | -2% | 18% | 64% | 51% | -9% | 11.6 days |
| BCC-CSM2-MR ssp370 | Red Deer River Near Sundre | 3% | -21% | 3% | 21% | 35% | -26% | -7.7 days |
| BCC-CSM2-MR ssp370 | St. Mary River at Highway No. 501 | 8% | -37% | 19% | 43% | 70% | -19% | -11.3 days |
| IPSL-CM6A-LR ssp126 | Bow River Near Cochrane | -7% | -26% | -4% | -3% | 6% | -20% | -13.0 days |
| IPSL-CM6A-LR ssp126 | Oldman River Near Brocket | -6% | -14% | -11% | -17% | 22% | -6% | -2.8 days |
| IPSL-CM6A-LR ssp126 | Red Deer River Near Sundre | -5% | -17% | 2% | 24% | 13% | -16% | 7.1 days |
| IPSL-CM6A-LR ssp126 | St. Mary River at Highway No. 501 | 1% | -34% | 5% | -4% | 25% | -13% | -10.0 days |
| IPSL-CM6A-LR ssp370 | Bow River Near Cochrane | -7% | -33% | -1% | 6% | 15% | -28% | -18.3 days |
| IPSL-CM6A-LR ssp370 | Oldman River Near Brocket | -1% | -14% | -1% | 28% | 36% | -14% | -9.4 days |
| IPSL-CM6A-LR ssp370 | Red Deer River Near Sundre | -5% | -28% | -3% | 6% | 22% | -25% | -3.1 days |
| IPSL-CM6A-LR ssp370 | St. Mary River at Highway No. 501 | 5% | -37% | 11% | 14% | 47% | -19% | -14.7 days |

## 2.5 Modelling assumptions

### 2.5.1 Performance Measures

Performance Measures (PMs) are key assessment criteria reflecting outcomes of importance. PMs are used to look at the relative difference between alternative scenarios, with special focus on the direction and magnitude of change.

As part of the 2022 update to SSROM, 14 basin-wide and sub-basin PMs were created and are shown in Table 4. The PMs were confirmed by the current WG at the outset of this project. Note that this list is not comprehensive but reflects the summary measures most often considered by the WG. Additional consideration of reservoir storages or direct timeseries of flows at various locations of interest were made and presented where appropriate.

**Table 4. Performance measures used to assess options.**

| Relevant Sub-basin(s) | Performance Measure (PM) | Description |
|---|---|---|
| SSRB | Cross-border apportionment contribution | This PM captures the contribution to apportionment annually by sub-basin using entitlement flows. |
| SSRB | Flow less than 42 $m^3/s$ at the Alberta/Saskatchewan border | This PM looks at the number of days where flow of water at the Alberta/Saskatchewan border falls below 42 $m^3/s$ (one version of an apportionment proxy). |
| SSRB | Minimum flows by year | This PM shows the minimum flows at Bindloss, Bassano, Calgary, Lethbridge, and Medicine Hat. |
| SSRB | Percentage of days meeting or exceeding 85% naturalized flow | This PM shows the percentage of days meeting or exceeding 85% of naturalized flows (surrogate for IFN) during the open water season (April to October) and winter (November to March). |
| SSRB | Shortage Volume | This PM captures the total volume of all shortages experienced by various groups of licence holders on the Bow River. This is a sum of all shorted volumes over the entire 30-year climate variability scenario record (10,950 total days) or 87-year historical record (approximately 32,000 days). |

| Relevant Sub-basin(s) | Performance Measure (PM) | Description |
|---|---|---|
| SSRB | Municipal water shortages | This PM explores the municipal water shortages for the cities of Red Deer, Calgary, Lethbridge, and Medicine Hat. |
| Red Deer | Shortages | This PM explores shortages in the Red Deer River Basin. It can be toggled to view shortages to municipalities, existing irrigation, temporary diversion licenses, or future irrigation. |
| Red Deer | Flow into Bindloss | This PM shows the flow of water past Bindloss which shows an indicator of water to support environmental health of the river. |
| Red Deer | Red Deer Flow at Mouth | This PM captures the flow of the Red Deer River at the mouth of the South Saskatchewan River. Similar to the flow into Bindloss PM, this PM shows the flow of water for environmental health of the river. |
| Red Deer | Water Conservation Objective (WCO) Violations | Established in 2005 as part of the SSRB Water Management Plan, represents the major driver for minimum flows. From the Dickson Dam to the confluence with the Blindman River, the WCO is established as 45% of the natural flow rate or 16 $m^3/s$, whichever is greater at any point in time. From the Blindman River to the Saskatchewan border, the WCO is 45% of the natural flow rate or 16 $m^3/s$ in the winter (November 1 to March 31) and 45% of the natural flow rate or 10 $m^3/s$ in the summer (April 1 to October 31). Where licenses were retrofit, the summer WCO is applied year-round. These WCOs apply only to licences issued after May 1, 2005. For licences issued prior to May 1, 2005, the minimum flow applied is the older instream objective (IO) of 4.25 $m^3/s$ for industrial demands or 8.5 $m^3/s$ for non-industrial demands. This PM counts the number of days where the WCO is violated across the SSROM timeseries. |

| Relevant Sub-basin(s) | Performance Measure (PM) | Description |
|---|---|---|
| Bow | Shortages | This PM captures shortages within the Bow basins. These include major licence users such as the City of Calgary, BRID, EID, and WID. It can be toggled to view shortages to municipalities, existing irrigation, temporary diversion licenses, or future irrigation. |
| Bow | Flow Past Bassano | This PM captures the number of low flow days below Bassano Dam. It is the same performance measure as shown in previous reports using BROM. It captures the number of days in which flow below Bassano falls into the < 11 $m^3/s$ (400 cfs), 11 $m^3/s$ – 22 $m^3/s$ (400-800 cfs), 22.6 $m^3/s$ – 40 $m^3/s$ (801-1,200 cfs), and > 40 $m^3/s$ (1,200 cfs) categories. As flow which passes below Bassano has necessarily been in the river all the way to Bassano, this PM is used as a surrogate for whole river health. |
| Bow | Flow Past Carseland | This PM is identical to the Flow Past Bassano PM, except it measures flow in the river just after the Carseland diversion. In runs including Eyremore Reservoir, the flow past Bassano is no longer indicative of whole river health, as Eyremore makes releases downstream of Bassano. Carseland flow is thus used as a replacement surrogate for upstream river health in strategies which include Eyremore Reservoir. |
| Bow | Days of water temperature above 22°C at Carseland | This PM uses air temperature and water flow to determine stream temperature. Similar to the Flow Past Carseland PM, it indicates river health across the entire historical record (1928-2015). |

| Relevant Sub-basin(s) | Performance Measure (PM) | Description |
|---|---|---|
| Oldman | Fish Rule Curve violations | This PM shows the number of days with Fish Rule Curve Violations (FRCs). FRCs are guidelines used by water managers when operating water management structures to ensure instream needs of fish are met. Three locations are targeted for these releases:<br>Reach 1 –downstream of Lethbridge;<br>Reach 3 –Fort Macleod/Rocky Coulee confluence to the Belly River confluence; and<br>Reach 4 –downstream of the LNID Weir. |
| Oldman | Shortages | This PM captures the irrigation shortages within the Oldman basin for LNID, MID, MVID, RID, SID, SMRID, UID. It can be toggled to view shortages to municipalities, existing irrigation, temporary diversion licenses, or future irrigation. |

### 2.5.2 Modelling Reference Case assumptions

Given efforts already underway on several major infrastructure projects (i.e., projects with significant scoping or analysis completed, or already under regulatory review), these projects were included within a Reference Case Scenario. The Reference Case Scenario factors in near-term infrastructure projects with a high likelihood of development, although it does not guarantee their development. Their inclusion in the Reference Case helps to contextualize other infrastructure options and factor in any foreseeable changes to water allocation or availability in the SSRB tied to these projects.

Off-stream storage and associated additional acres updated from the 2022 current conditions are found in Table 5, and additional deviations from the 2022 Base Case are listed in Table 6.

**Table 5. Additional off-stream storage and associated irrigated acres are included in the modelling Reference Case.**

| Project Name | Associated new live storage | Associated expansion |
|---|---|---|
| East Central Irrigation Project (Acadia and Special Areas Irrigation Project) | 167,000 $dam^3$ | 108,000 acres |
| Deadhorse Coulee Reservoir | 12,000 $dam^3$ | 10,000 acres |
| Chin Reservoir Expansion | 128,000 $dam^3$ | 41,000 acres |
| Snake Lake Reservoir Expansion | 65,000 $dam^3$ | 5,000 acres |

**Table 6. Reference Case assumptions which deviate from the 2022 SSROM Updates.**

| Sub-basin | Description | Model conditions |
|---|---|---|
| Red Deer | Dickson Dam – releases to meet downstream water demands | In addition to WCO releases, Dickson Dam releases water to meet demands within the Red Deer basin. |
| Red Deer | Acadia and Special Areas Irrigation Project – diversion conditions | Canal limits – 8 $m^3/s$.<br>Diversion season – Apr 1 – Sep 30. |

The Red Deer sub-basin is unique within the SSRB, as it is the only basin remaining open to applications for new surface water license applications. However, certain licensees in certain areas can still apply for a water licence under the Bow, Oldman and South Saskatchewan (BOSS) River Basin Water Allocation Order. As this basin provides an attractive opportunity for near term economic development, the WG indicated that presuming growth was the best course of action for the modelling reference case. Given the Red Deer sub-basin is already under consideration for several projects (ranging from irrigation to hydrogen development), it was reasonable to extract data from existing project reports to enact one example of how that growth might play out. As the Acadia and Special Areas Irrigation Project recently concluded the first phase of its feasibility study (WaterSMART Solutions Ltd., 2022) and could take the basin to its presumed full-allocation limit, it seemed an appropriate example of a growth scenario in the Red Deer.

One key element of additional growth in the Red Deer is the reoperation of Dickson Dam. Based on prior modelling efforts, substantial growth in the system requires revisions to Dickson Dam operations. At present, Gleniffer Reservoir releases water based primarily on rule curve elevations, without explicit calculation and consideration of downstream withdrawals. The revised dam operations implemented in the Reference Case identify downstream demands and make releases to meet both consumptive and in-stream river needs. The revised operations and outcomes are fully described in Section 2.7.3.2.

The Reference Case includes all the assumptions, infrastructure, and operations of the SSROM Base Case. While the full assumptions list is available in the 2022 SSROM Update Report (WaterSMART Solutions Ltd., 2022), the following are highly relevant for contextualizing the SSROM Reference Case results:

- Springbank Off-stream Reservoir (SR1) – Construction is underway on this off-stream dry dam on the Elbow River. While the SSROM is not set up for flood analysis (as flood requires hourly time steps for analysis), this is included in the model to provide protection against high flow events.
- All municipalities in the Red Deer are modelled at full licence allocation as historically modelled in the SSROM. This is different than the Bow and Oldman sub-basins, as major municipalities (i.e., City of Calgary, City of Medicine Hat, and City of Lethbridge) used actual and predicated demands instead of full licence allocation. In the case of the City of Red Deer, full licence allocation was used. This approach provides a conservative approach to demands in the Red Deer basin.
- Most non-irrigation uses in Red Deer are modelled at full license allocation. This provides a

conservative demand estimate. Only wetland licenses held by Ducks Unlimited are not modelled at full allocation, as these are only used during flood events.

## 2.6 Economic Analysis

To complement the SSROM and the Raven hydrologic model, an economic analysis was performed to assess the economic benefit that may be likely to result from the identified/selected project options as outlined by the WG. The results of the economic analysis – which are based on several assumptions (outlined later in this section) – are not meant to support an investment decision nor do they imply that one option is better of worse than the other. In other words, the purpose of the economic analysis is to provide an economic lens of comparison between the project options.

The economic analysis performed utilizes two complementary approaches. The first is the **Input-Output Analysis (I-O)** approach that many stakeholders will be familiar with, and the second is the **EcoMetrics ® Methodology** which identifies, quantifies, and values (in monetary terms) the environmental, economic, and social benefits to various stakeholders. Both approaches – described in more detail below – together generate the results of the entire economic analysis. Figure 11 shows the overall process followed for the economic analysis.

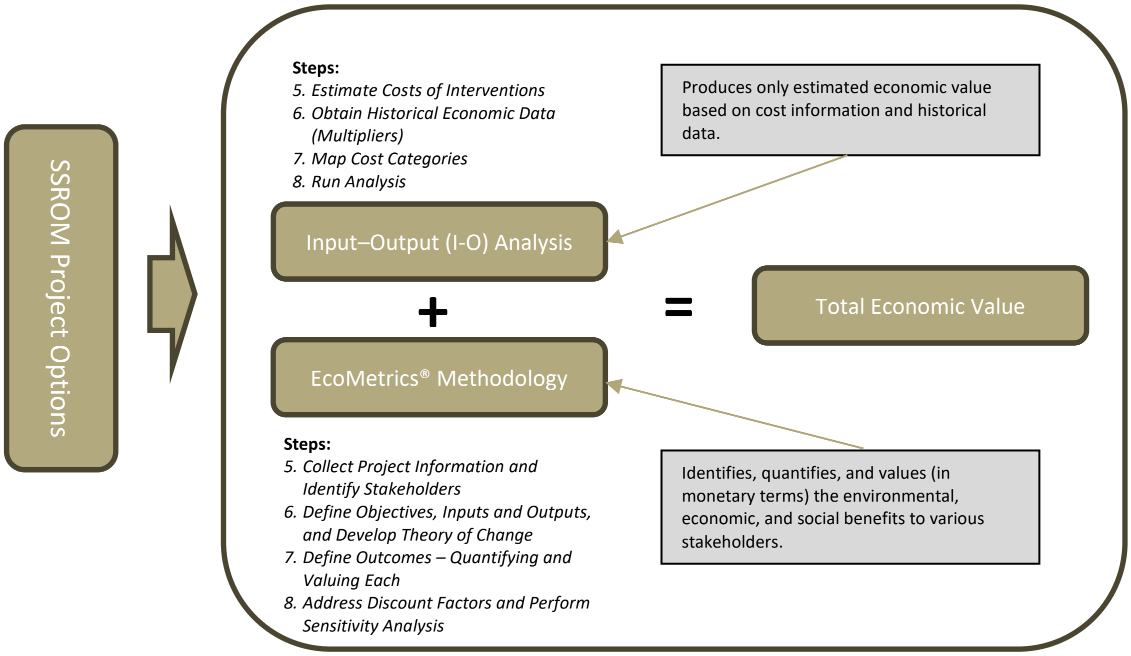


**Figure 11: Overall Economic Analysis Approach**

**General Assumptions and Notes:**

- Each option was reviewed independently. If multiple options are implemented at the same time, especially those which may affect each other, the valuation would need to be corrected to avoid "double counting".
- The additional water available was divided among three primary uses: increasing agricultural development, supporting municipal growth, and enhancing environmental flows in the rivers. Because each of these uses of water has its own unique set of outcomes, the water volume was determined for each. The allocation of water between the three was based on the projected needs stemming from population growth, agricultural requirements, and environmental flows, where known. In cases where this allocation was unknown or uncertain, it was assumed that the water would be distributed evenly among the three. In a detailed analysis of the Adaptation Roadmap for the SSRB options for specific projects, this assumption would need to be refined.
- The methods of quantification and valuation were kept consistent across all options. This allowed comparative analysis of options. As options are further defined and evaluated, assumptions can be customized more accurately for each option in future phases of work.

**Input-Output Analysis Overview:**

This approach utilizes historical economic data that describes interdependent supply chains between sectors within an economy and quantifies the flows of outputs from one industry as inputs into another. Through this approach, the total economy-wide impact of an economic event (such as the construction of a reservoir) can be analyzed from the initial demand change and its direct, indirect, and induced impacts (Corporate Finance Institute, n.d.)

- **Direct impacts** are the impacts of a change in final demand on the consumption of the directly associated inputs. For example, building a dam requires steel, concrete, workforce, and construction machinery. It therefore has a direct impact on these inputs.
- **Indirect impacts** are the impacts because of the suppliers of the directly associated inputs hiring workforce to meet the increased demand.
- **Induced impacts** account for the increase in personal consumption of goods and services resulting from the workers of suppliers.

The economic categories of Gross Domestic Product (GDP), and Labour Income have been estimated in the three previously mentioned categories (direct, indirect, and induced impacts), primarily for the construction efforts in certain options. These outcomes are in addition to the outcomes created using the additionally available water. These use-related outcomes are recurring, as compared to the essentially "one time" benefits associated with the construction phase.

It is important to note that the I-O approach utilizes historical data. The data set on economic activity and economic multipliers developed by the GoA for 2019 (Government of Alberta, 2023) was used for this analysis. The analysis and its results have been adjusted for the time value of money and are shown in 2023 dollars.

**EcoMetrics® Methodology Overview:**

The second, and complementary approach is the EcoMetrics® methodology which identifies, quantifies, and values (in monetary terms) the environmental, economic, and social benefits to various stakeholders. This methodology combines quantitative and qualitative values across numerous social, economic, and environmental categories to forecast the relative economic outcomes. Although the EcoMetrics® methodology also contains economic results, care has been taken to ensure there is no double-counting between the results of the Input-Output Analysis and the EcoMetrics® methodology. The EcoMetrics® methodology also aligns with the guiding principles of Social Value International's (SVI) Social Return on Investment (SROI) Methodology and the International Integrated Reporting Council's (IIRC) International Integrated Reporting Framework (IIRF). To fully measure and evaluate the impacts of the proposed options, this methodology incorporates scientific data on the objective impacts into the SROI evaluation. This data is directly tied to the outcomes defined by the key stakeholders and used to quantify the value of social and environmental change. The SROI methodology presents these social and environmental values in terms of financial equivalents, which allows stakeholders across the board to evaluate the cost/benefit favourability or unfavourability of proposed interventions. Such valuation of outcomes allows stakeholders to understand the internalized financial benefits and externalized societal benefits of making investments.

EcoMetrics® is comprised of two types of analysis scenarios; forecast planning and evaluative, both of which can be used for a single project.

- Forecast planning: Analysis of options, actions, and scenarios to predict the desired impact, outcomes, and value created for stakeholders.
- Evaluative: Determination of value in the current state, useful to evaluate progress of active efforts or to establish a baseline.

For the Adaptation Roadmap for the SSRB Options analysis, EcoMetrics® was used in a predictive capacity, to determine the incremental value of outcomes created by implementing the option. Detailed results are provided in the full report in 0.

Through a robust and comprehensive process, the EcoMetrics® methodology leverages subject matter experts, information gathered from numerous credible sources, and most importantly, relevant stakeholder feedback to determine the outcomes and the value gained or lost. In other words, in the EcoMetrics® methodology, outcomes can be positive (i.e., a benefit) or can be negative, where the project results in loss of existing value. The details of the EcoMetrics® analysis of the Adaptation Roadmap for the SSRB options are in the full EcoMetrics® report in 0 of this document.

In summary, the EcoMetrics® methodology determines the quantity of an outcome using peer-reviewed and accepted methods. These outcome quantities are then multiplied by financial proxies to determine the value created (or lost) by implementing the option.

### 2.6.1 Input-Output Analysis: Inputs, Assumptions, and Results

The Input-Output Analysis approach was used only to determine the economic benefits resulting from construction activities (where applicable) from the project options.

**Estimated Costs**

The construction costs were estimated using a combination of historically available data (where relevant and adjusted for inflation), and expert input from working group members. Table 7 shows the estimated construction costs for the relevant project options.

| Option | Estimated Construction Cost *(millions)* |
|---|---|
| Upstream Bow | $1,052 |
| Eyremore | $1,500 |
| Ardley | $1,500 |
| Belly River | $300 |
| Kananaskis Dam Improvements | $310 |
| Spray Lakes | $125 |
| Waterton and SMC | $130 |
| WID Off-stream | $79 |

**Table 7: Estimated Construction Costs**

**Construction Cost Categories**

Broadly, the two main categories for costs associated with construction activities are **Goods** and **Services**. Goods include concrete, aggregate, architectural/structural metal, machinery/equipment. Services include architectural and engineering services, and construction services. Since this analysis is very broad, detailed cost categories or estimates were not available. In order to ensure that the cost categories and the breakup of costs between the categories had a robust basis, the economic analysis performed for the Springbank Off-Stream Reservoir Project (Government of Alberta, 2024)available in the public domain) was used as a reference.

**Industry Categories/Codes**

To perform the Input-Output Analysis, the following industry and commodity codes, as defined by the GoA Economic Multipliers were utilized. These codes map to the cost categories that are expected to make up the major costs associated with the construction activities. It is important to note that this is not an exhaustive list and is used primarily as a basis for comparison. The codes are listed in alphabetical order:

- Architectural, engineering and related services [BS541300]
- Cement [MPG327301]
- Fabricated steel plate and other fabricated structural metal [MPG332302]
- Logging, mining and construction machinery and equipment [MPG333102]
- Other engineering construction [BS23C500]
- Other miscellaneous general-purpose machinery [MPG333909]
- Stone [MPG212310]

### The Alberta I-O Model

As described by the Government of Alberta’s Alberta Economic Multipliers – 2019 publication (Government of Alberta, 2023), Alberta Treasury Board and Finance has developed an I-O model for the Alberta economy based on the structure of Statistics Canada’s inter-provincial model. Although the Alberta model accounts for the interaction of imports and exports on the Alberta economy (both inter-provincial and international), the Alberta model only provides impacts for Alberta. The model has the capacity to run impact analysis on industry expenditures, output and changes in final demand.

The key inputs to the model are the Alberta Supply-Use tables, produced annually by Statistics Canada through the System of National Accounts (SNA). The Supply-Use tables consist of the output, input and final demand matrices. The output matrix is a table that shows the value of goods and services produced by each industry. The input matrix shows the makeup of the inputs needed for each industry to produce its output, and the final demand matrix shows the final consumption of goods and services in the economy.

A “Safety Net” feature was added to the model. This enables the assumption that a certain number of jobs required for a change in output of a project will come from people who are receiving employment insurance. When this new feature is activated, the induced impacts resulting from a project will be lower. This means that the amount of additional income earned will be lower than if those employees had not been receiving employment insurance benefits.

### Limitations of I-O Models

The limitations of I-O models as described by the GoA are explained below. (Government of Alberta, 2023).

I-O analysis is based on various assumptions about the economy and the linkages among industries and commodities. While I-O models are very useful tools in the decision-making process, users should be aware of the caveats and limitations when applying them:

- The relationship between industry inputs and outputs is linear and fixed, meaning that a change in demand for a commodity or for the outputs of any industry will result in a proportional change in production. The model cannot account for economies/diseconomies of scale or structural changes in production technologies, an assumption which does not necessarily hold in the actual economy.

- Prices are fixed in the model.
- I-O models reflect industry averages for technology use and average input costs. For these and other reasons, an I-O model will not provide a totally complete or absolute measure of the impact of economic change.
- I-O models are static and do not take into account the amount of time required for changes to happen.
- There are no capacity constraints, and all industries are operating at capacity. This implies that an increase in output results in an increase in demand for labour (rather than simply re-deploying existing labour). It also implies that displacement will not occur in existing industries, as new projects are completed.

## Limitations of I-O Multipliers

As described by the Government of Alberta's Alberta Economic Multipliers – 2019 publication (Government of Alberta, 2023), economic multipliers are subject to the same caveats and limitations as the I-O models. This includes the caveats associated with fixed prices, production technology and capacity. In addition, there are several other things to keep in mind when using multipliers:

- Multipliers are specific to regions and economies. The multipliers in this publication are for the Alberta economy, and thus cannot be used to estimate impacts for other jurisdictions.
- The size and interpretation of a multiplier depend on how it is defined. There are multipliers that measure the impact on gross output, while others measure GDP. GDP multipliers are often more desirable because they eliminate the double counting of expenditures or benefits. It is important to carefully consider which multiplier is appropriate for a project.
- Impacts reflect the structure of the economy and industry linkages at a point in time (e.g., 2019). If these linkages have changed, the calculation of the impacts in another year (e.g., 2023) will be less valid. Generally, the further the year of analysis from the year of the multipliers, the greater the limitations.
- Since I/O models are static, the multipliers do not give any indication about the time it takes for changes to happen.

**Results**

Acknowledging all the assumptions and limitations described above, Table 8 shows the results of the I-O analysis.

| Option ↓ | Estimated Construction Cost | GDP at Market Prices | Labour Income | Total Economic Effect (Only Alberta) |
|---|---|---|---|---|
| | | Direct, Indirect, and Induced Impacts Combined (with Safety Net) | | |
| | *(millions)* | | | |
| **Upstream Bow** | $1,052 | $749 | $496 | **$1,245** |
| **Eyremore** | $1,500 | $1,068 | $707 | **$1,776** |
| **Ardley** | $1,500 | $1,068 | $707 | **$1,776** |
| **Belly River** | $300 | $214 | $141 | **$355** |
| **Kananaskis Dams Improvements** | $310 | $221 | $146 | **$367** |
| **Spray Lakes** | $125 | $89 | $59 | **$148** |
| **Waterton and SMC** | $130 | $93 | $61 | **$154** |
| **WID Off-stream** | $79 | $56 | $37 | **$93** |

**Table 8: Summary of Results of Input-Output Analysis.**

The results above assume that the GDP and Labour Income are generated within one year. This has been done to keep the overall economic analysis consistent. Construction projects of the scale envisioned will take multiple years in some cases. These results also show the economic impacts occurring only within Alberta. In reality, the economic effects will be felt across Canada (and in some cases will involve imports) since materials and services are likely to be sourced from beyond Alberta's borders. However, it is noteworthy that even with this conservative analysis, the total economic effect (just through the I-O analysis) shows a benefit that outweighs the costs. The following section summarizes the EcoMetrics® valuation methodology for social and ecological benefits, the results of which only add to the estimated results from the I-O analysis above.

### 2.6.2 EcoMetrics® Methodology: Inputs, Assumptions, and Results

For this Adaptation Roadmap for the SSRB Options analysis, the primary and overarching result of implementing an option would be an increase in water availability. Outcomes are related to this increase in water availability and represent impacts and changes which may occur. Table 8 (below) shows the outcomes that were identified, quantified, and valued as well as the stakeholder groups the are associated with. Stakeholder categories used for the analysis are based on those distinct groups which would be affected by specific outcomes. The groups used in the analysis are:

- General Public
- Local Economy
- Local Government
- Recreational Users
- Producers
- Environment

This category grouping differs slightly from the groupings used in the WG discussions and engagement in large part because, for the valuation component, the categories need to align with the specific outcomes associated with that group. Clearly, there is overlap of actual individual stakeholders because producers are part of the general public, and benefits to the environment will manifest from a valuation standpoint as impacts to other stakeholders. For example, improved aquatic ecosystems can mean more fish, thereby increasing recreational opportunities. Table 9 (below) shows all the outcomes that result across the six broad stakeholder categories. Because several of these options include infrastructure development and related construction, there are several outcomes specific to that aspect. For this analysis, EcoMetrics® incorporates results from the Input-Output (I-O) Analysis (captured in the 'Local Economy' stakeholder category as 'Construction: Total GDP Increase' and 'Construction: Total Labor Income'.

**Table 9. Outcomes by Stakeholder Category**

| Stakeholder Group | Outcome |
|---|---|
| Environment | Agriculture Developed: Biological Control |
| | Agriculture Developed: Habitat and Biodiversity |
| | Agriculture Developed: Nutrient Cycling |
| | Agriculture Developed: Pollinator Population Support |
| | Agriculture Developed: Soil Formation |
| | Agriculture Developed: Soil Stabilization |
| | Agriculture Developed: Waste Treatment |
| | Agriculture Developed: Water Filtration |
| | Agriculture Developed: Water Regulation |
| General Public | Agriculture Developed or Environmental Flows: Aesthetic Value |
| | Agriculture Developed: Carbon sequestration- social value |
| | Agriculture Developed: Cultural Value |
| | Agriculture Developed: Drought Resiliency (for Ag) |

| Stakeholder Group | Outcome |
|---|---|
| | Agriculture Developed: Food Provisioning |
| | Agriculture Developed: Nitrogen Retention- social value |
| | Agriculture Developed: Phosphorus Retention- social value |
| | Agriculture Developed: Property Value |
| | Environmental Flows: Physical Health |
| | Municipal Growth: GDP |
| | Enhanced Environmental Flows |
| Local Economy | Agriculture Developed: Agricultural Economy |
| | Agriculture Developed: Wildfire Risk Reduction |
| | Construction: Total GDP Increase |
| | Construction: Total Labor Income |
| Local Government | Agriculture Developed: Storm Flooding Protection |
| Recreational Users | Environmental Flows: General Recreation |
| Producers | Agriculture Developed: Market value of Carbon Credits |

It is important to note that in EcoMetrics®, the increase in water availability is not itself an economic outcome. The outcomes are the changes experienced by a water user or by the environment. For example, stored water may mean the ability to support a larger population, which in turn creates benefits by way of economic development, as well as more water for irrigation, which leads to more food, which can lead to population growth.

EcoMetrics® categorizes outcome values as “Market” and “Non-Market” values. Both are reflected in monetized terms, in this case Canadian dollars. However, Market Value is directly realized by a stakeholder, usually the funder or owner of the attribute. A typical example of Market Value is the income from carbon credit sale or direct revenue from the project. Most values are Non-Market and relate to value created for many other stakeholders. Since most outcomes benefit the environment, the general public, other key stakeholder groups, as well as site owners and funders, the overwhelming majority of value created is Non-Market value. A good example is agriculture development. Environmental, economic, and social impacts (benefits and costs) are realized through agricultural land use, which based on the input from the working group was valued and, in most cases, resulted in a great deal of value generated. However, this value is not direct revenue to the producers and growers. Instead, it is value realized by a much broader set of stakeholders, who benefit from the related outcomes above and beyond the actual sale of crop or livestock. Agricultural land management has many positive impacts to air quality, water quality, biodiversity, flood protection, and others, all of which provide tangible benefits to many stakeholders.

In Section 2.5, alongside the river basin impacts, a selection of the options also includes a summary of the EcoMetrics® results. To fully understand the results presented, we have provided an outline of the key assumptions and points to note, and an explanation of what is being reflected in the pie charts.

**EcoMetrics®-specific Assumptions and Notes**

- EcoMetrics® uses publicly available information to obtain quantification and valuation methodologies and proxies. These sources can include project-specific data, peer-reviewed research, credible databases, and verified stakeholder input.
- Valuation of benefits (except the construction elements) is based on annual recurrence. In other words, values presented herein are for a single year, but would be expected to recur each year; therefore, the results below reflect a conservative view. The options could create much greater value over time. EcoMetrics® can calculate this cumulative value created over any desired time frame.
- The environment is considered a stakeholder and therefore environmental attribute value is created. However, this value is realized in an indirect way for other stakeholders. For example, one outcome of better surface water quality is reduced cost of treatment infrastructure for municipalities and more opportunity for recreational users. It is not the environment or ecosystem which is being valued, but the ecosystem service.
- Some outcomes are qualitative at this point because of difficulty or lack of information to quantify and value. This is particularly true for enhanced environmental flows, in that many of the related outcomes are environmental and ecosystem-related and difficult to value. We know qualitatively that conditions are improved and more resilient, but that impact may not be quantifiable or valued.
- The impact of any given option was related to the entire sub-basin. For example, population impacts of an option in the Bow River sub-basin used numbers for the entire basin. Once the impact of an option can be more defined to a specific area, a more accurate population growth percentage can be used.

A significant benefit of establishing a customized version of EcoMetrics® for the options is that any change to assumptions can be easily made and values recalculated.

**Understanding the Charts**

The analysis of options creates a significant amount of information. The EcoMetrics® methodology uses many adjustments and corrections to ensure the results are valid, credible, and avoid overclaiming and double counting. The full report (Appendix E) explains these adjustments in detail. The most important point to consider in reviewing the charts is this is an analysis of potential annual recurring outcome value created for many stakeholders, and it is not representing direct income to any one entity. It is important to consider that the EcoMetrics® methodology assumes ideal conditions for the start of each year.

For each option evaluated, the following information is provided:

- Annually recurring outcome categories for a project (with only Year 1 values shown) - Circular chart.

- Annually recurring outcome categories of project (with gained and lost value shown only for Year 1 - Bar Chart
- Supplementary information
    - Investment costs
    - One-time benefits
    - Maximum population potentially supported by the water secured by the project.

**Indication of Annually Recurring Project Value Gained – Circular chart**

This chart shows a proportional representation of the positive value created by each outcome and proportionately which outcomes receive the largest increase in value. The outcomes are grouped by stakeholder type (inner donut) which broadly denotes which stakeholder group will receive the positive valuation. It should be noted that this chart type only shows positive benefits of the project. A net value that accounts for negative benefits is not shown in this chart. An example chart is show in in Figure 12.

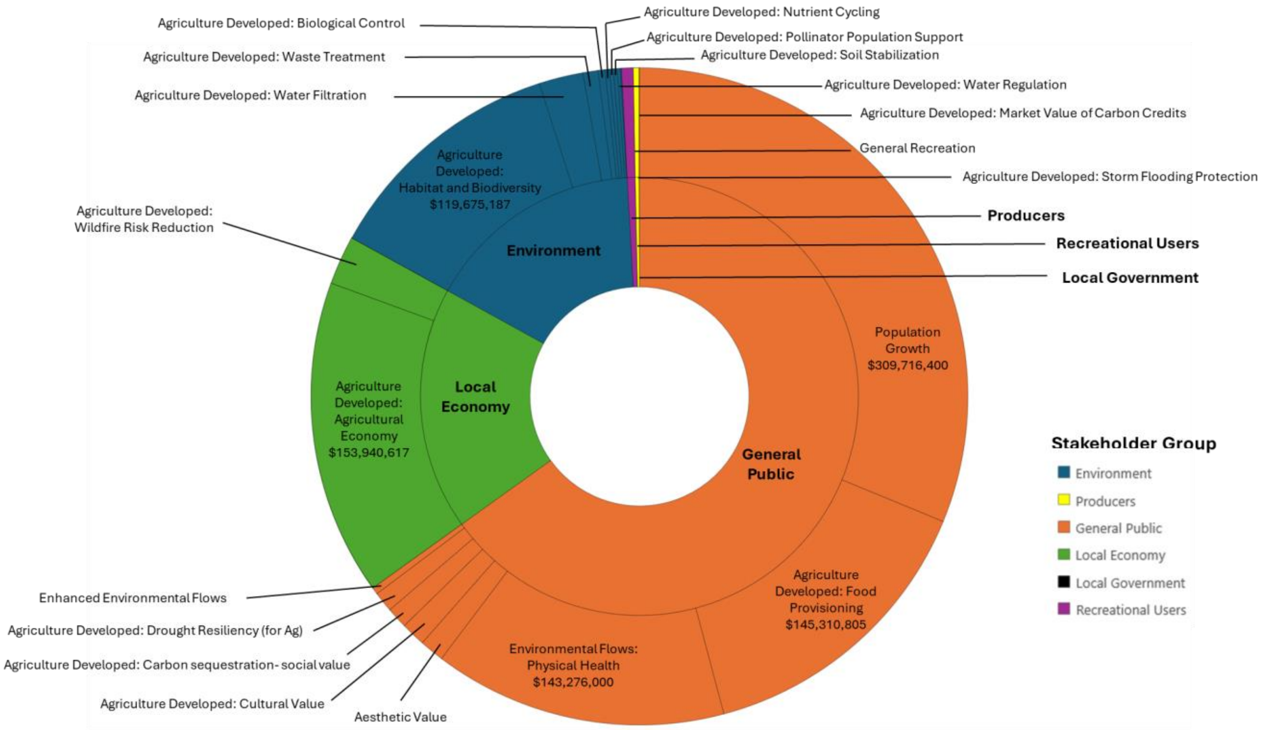


**Figure 12. Example chart showing annually recurring outcome categories for a project (with only Year 1 values shown)**

All outcomes depicted in the chart have an annual recurring value associated with them, and one-time values associated with the implementation of the project are provided as supplementary information.

Some outcomes such as population growth will change year-to-year, so the chart only truly depicts the Year 1 benefit from the project as the compounding benefit from continued population growth is not accounted in this chart.

The population growth is also based on an assumed growth projection. For each potential project the water assigned to population growth was based on the projected population growth of the major municipalities within the sub basin as shown in the breakdown below. This was based on the average population growth in the population projections from 2021 – 2046 (Government of Alberta, 2021) (CMRB, 2018):

- Red Deer River sub-basin population growth: 1.4% YoY.
- Bow River sub-basin population growth: 1.5% YoY.
- Oldman and South Saskatchewan sub-basin population growth: 1.13% YoY.

Processing population growth in this way will only show the incremental benefit provided by the additional municipal growth in the first year the project is operating, however, this benefit will compound and grow in subsequent year up to a maximum value which indicates the maximum population that could be supported by the water secured by the project.

**Indication of Annual Recurring Project Value Gained and Lost – Bar Chart**

The bar chart shows total monetary value created and total monetary value lost as a result of project implementation. An example is provided in Figure 13.

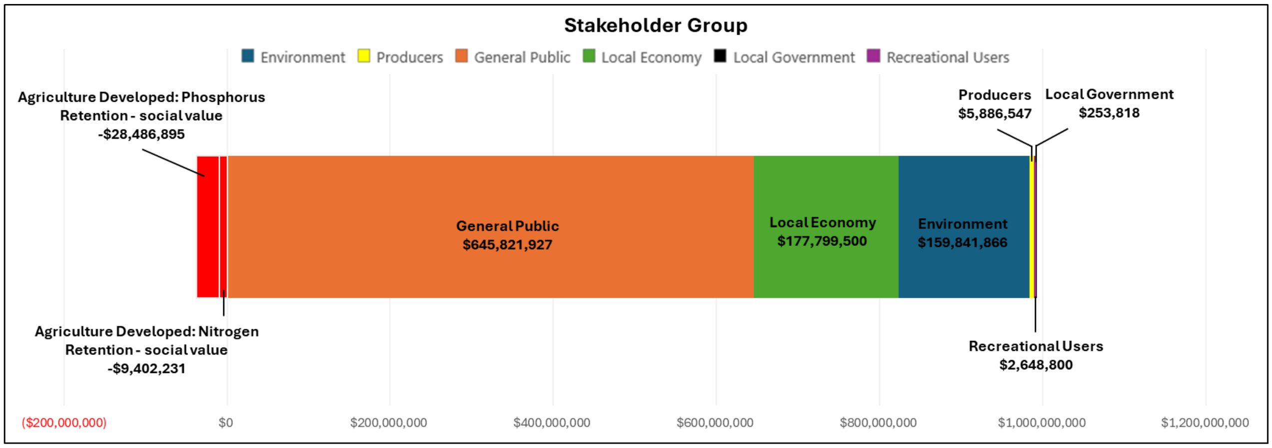


**Figure 13. Example of annually recurring outcome categories of project (with gained and lost value shown only for Year 1)**

In this chart positive value generation is shown to the right of zero and value lost as a result of project implementation are shown to the left of zero. Net project value can be calculated by adding the two sides together.

Individual outcomes that generate a positive value are not called out explicitly and instead the total value provided to the stakeholder group is shown. Individual outcomes that result in a loss of value are explicitly labelled and shown in red.

The assumptions that have been used to generate this chart are the same as for the circular chart in that all outcomes include in the bar chart recur annually, but the compounding effect of population growth is not shown so the bar chart is only a true representation of the total value generated and lost in Year 1 following project implementation. This chart also does not include one-time values generated as a result of project construction or increase in property value.

**Supplementary information provided for each economic analysis**

Each project summary that includes an economic analysis includes relevant supplementary information to provide a broad overview of potential value generated by the project. As previously noted, the charts depict an annually recurring outcome categories (the values of which may change from year-to-year), however, there are a number of one-time implications that result from the construction of some projects. Many of these are discussed as part of the I-O analysis and directly relate to investment, materials and job creation. Some additional information provided includes:

- **Agricultural property value change** – This relates to the change in value of land as dryland farmland becomes irrigated. This value is directly related to the water provided to Agriculture in each project.
- **Potential maximum population that could be supported by the project** – The potential maximum population is directly related to the volume of water assigned for municipal use for each project and how many people that could support in a year assuming an average consumption of 375 litres per capita per day. This differs from the annual recurring value provided in the chart in that it is no related to projected population growth or a specific timeline.

It is understood there is necessary additional investment (capital and operation/maintenance) to realize the various noted outcomes. For this phase of work, other than for the construction costs, that information was not clearly defined for each option and hence outcome values are “total value” created and are not corrected for investment necessary, which would be “net value” created.

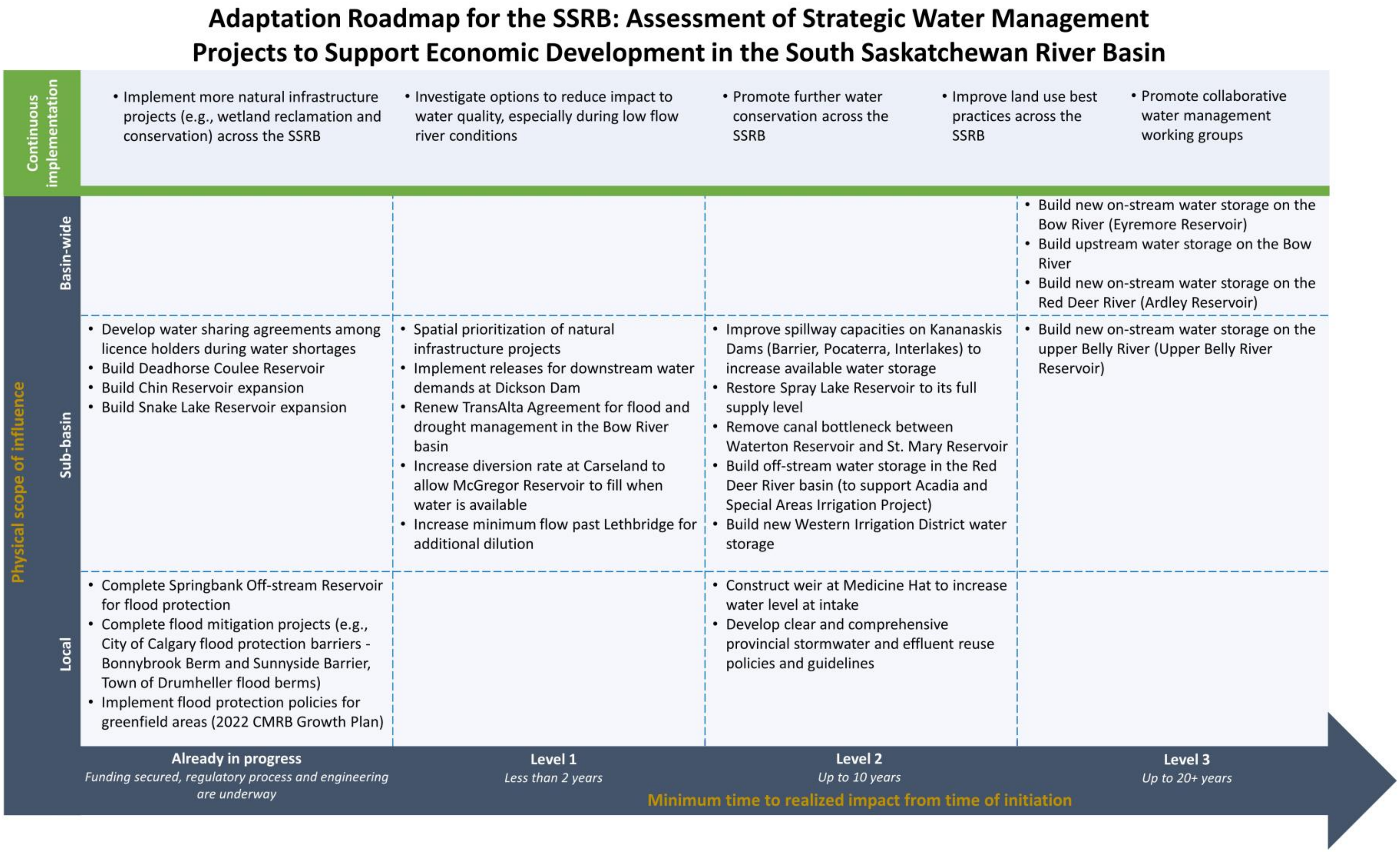
## 2.7 Adaptation Roadmap for the SSRB

The Adaptation Roadmap for the SSRB includes the options which were deemed most promising by the WG and does not reflect the full suite of options assessed throughout the project.

The Adaptation Roadmap for the SSRB (Figure 14) highlights a path toward sustainable water management in the SSRB under a changing climate. The Adaptation Roadmap for the SSRB contains the following project categories:

- Continuous implementation – Long-term projects which can be built on a continuous basis. The benefits of these projects are strengthened with time when implemented continuously.
- Already in progress – Projects which have already been initiated and will be completed in the near term. Some of these projects are included in the SSROM Reference Case and no modelling assessment was carried out.
- Level 1 – Projects which once approved and initiated could be realized within two years.
- Level 2 – Projects which once approved and initiated could be realized within 10 years.
- Level 3 – Projects which once approved and initiated could be realized within 20 years.

It is important to note that the Adaptation Roadmap for the SSRB project categories do not denote the priority or importance of a project. Within the Adaptation Roadmap for the SSRB, all projects are considered of equal priority and critical to sustainable water management in the SSRB in the face of a changing climate, while supporting continued growth in the basin.



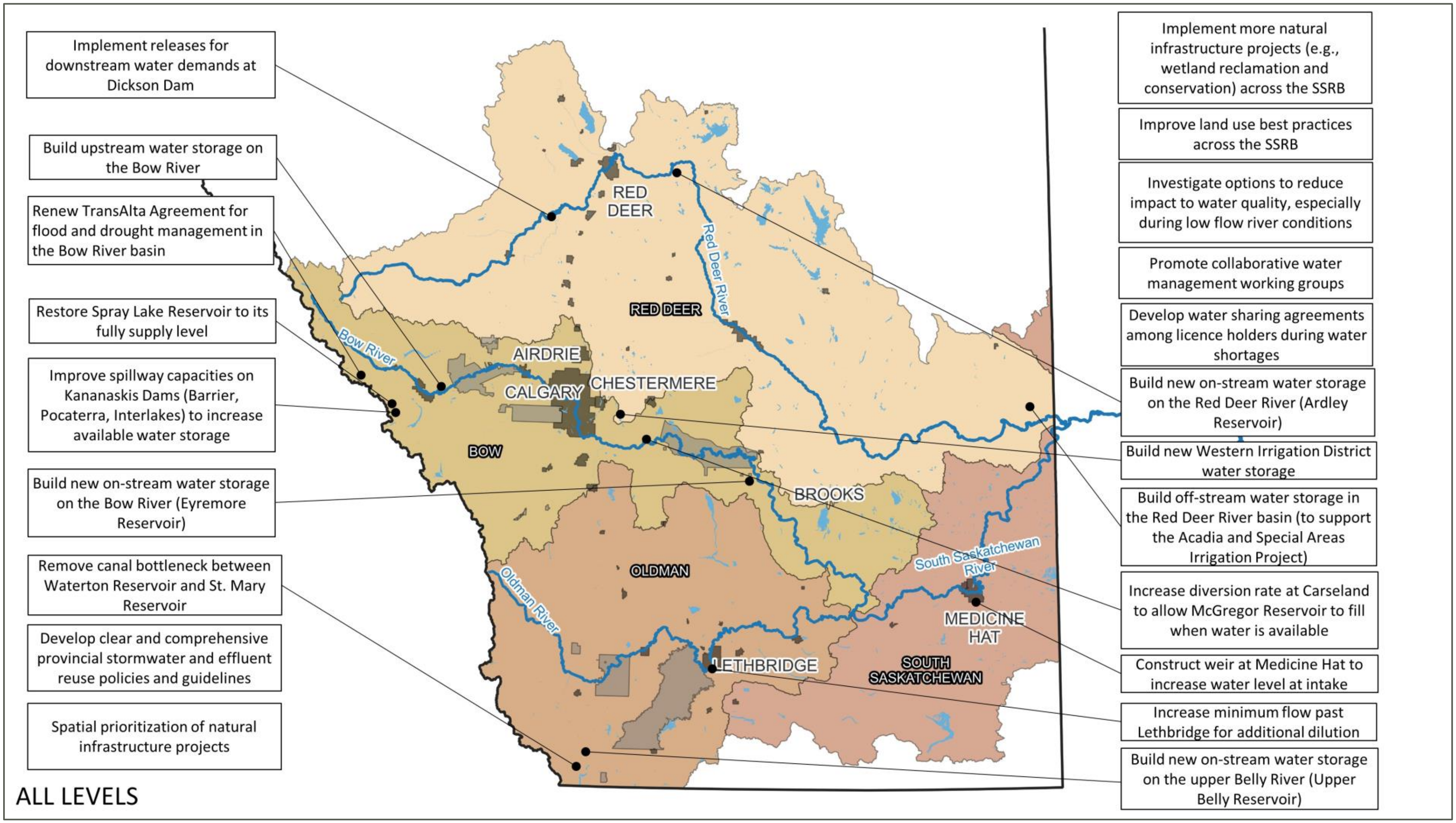
**Adaptation Roadmap for the SSRB: Assessment of Strategic Water Management Projects to Support Economic Development in the South Saskatchewan River Basin**

**Continuous implementation**

- Implement more natural infrastructure projects (e.g., wetland reclamation and conservation) across the SSRB
- Investigate options to reduce impact to water quality, especially during low flow river conditions
- Promote further water conservation across the SSRB
- Improve land use best practices across the SSRB
- Promote collaborative water management working groups

| Physical scope of influence | **Already in progress**<br>*Funding secured, regulatory process and engineering are underway* | **Level 1**<br>*Less than 2 years* | **Level 2**<br>*Up to 10 years* | **Level 3**<br>*Up to 20+ years* |
|---|---|---|---|---|
| Basin-wide | | | | • Build new on-stream water storage on the Bow River (Eyremore Reservoir)<br>• Build upstream water storage on the Bow River<br>• Build new on-stream water storage on the Red Deer River (Ardley Reservoir) |
| Sub-basin | • Develop water sharing agreements among licence holders during water shortages<br>• Build Deadhorse Coulee Reservoir<br>• Build Chin Reservoir expansion<br>• Build Snake Lake Reservoir expansion | • Spatial prioritization of natural infrastructure projects<br>• Implement releases for downstream water demands at Dickson Dam<br>• Renew TransAlta Agreement for flood and drought management in the Bow River basin<br>• Increase diversion rate at Carseland to allow McGregor Reservoir to fill when water is available<br>• Increase minimum flow past Lethbridge for additional dilution | • Improve spillway capacities on Kananaskis Dams (Barrier, Pocaterra, Interlakes) to increase available water storage<br>• Restore Spray Lake Reservoir to its full supply level<br>• Remove canal bottleneck between Waterton Reservoir and St. Mary Reservoir<br>• Build off-stream water storage in the Red Deer River basin (to support Acadia and Special Areas Irrigation Project)<br>• Build new Western Irrigation District water storage | • Build new on-stream water storage on the upper Belly River (Upper Belly River Reservoir) |
| Local | • Complete Springbank Off-stream Reservoir for flood protection<br>• Complete flood mitigation projects (e.g., City of Calgary flood protection barriers - Bonnybrook Berm and Sunnyside Barrier, Town of Drumheller flood berms)<br>• Implement flood protection policies for greenfield areas (2022 CMRB Growth Plan) | | • Construct weir at Medicine Hat to increase water level at intake<br>• Develop clear and comprehensive provincial stormwater and effluent reuse policies and guidelines | |

**Figure 14. SSRB Adaptation Roadmap showing projects with high potential to improve basin waters security.**



Implement releases for downstream water demands at Dickson Dam

Build upstream water storage on the Bow River

Renew TransAlta Agreement for flood and drought management in the Bow River basin

Restore Spray Lake Reservoir to its fully supply level

Improve spillway capacities on Kananaskis Dams (Barrier, Pocaterra, Interlakes) to increase available water storage

Build new on-stream water storage on the Bow River (Eyremore Reservoir)

Remove canal bottleneck between Waterton Reservoir and St. Mary Reservoir

Develop clear and comprehensive provincial stormwater and effluent reuse policies and guidelines

Spatial prioritization of natural infrastructure projects

ALL LEVELS

Implement more natural infrastructure projects (e.g., wetland reclamation and conservation) across the SSRB

Improve land use best practices across the SSRB

Investigate options to reduce impact to water quality, especially during low flow river conditions

Promote collaborative water management working groups

Develop water sharing agreements among licence holders during water shortages

Build new on-stream water storage on the Red Deer River (Ardley Reservoir)

Build new Western Irrigation District water storage

Build off-stream water storage in the Red Deer River basin (to support the Acadia and Special Areas Irrigation Project)

Increase diversion rate at Carseland to allow McGregor Reservoir to fill when water is available

Construct weir at Medicine Hat to increase water level at intake

Increase minimum flow past Lethbridge for additional dilution

Build new on-stream water storage on the upper Belly River (Upper Belly Reservoir)

**Figure 15. Spatial map of the Adaptation Roadmap for the SSRB.**

All projects in the Adaptation Roadmap for the SSRB were discussed within the WG and, where possible, projects were modelled in SSROM or RAVEN to assess their water security benefits. These were then assessed through the EcoMetrics® methodology.

Projects which could not been modelled through the SSROM or Raven were discussed qualitatively by the WG and are included in the discussion below. No quantitative assessment was undertaken for projects under the "Already in Progress" category. Table 10 outlines which projects were modelled to quantify hydrological impacts, which were quantitatively assessed economically, and which projects were discussed qualitatively by the WG.

**Table 10. Continuous implementation and Level 1-3 Adaptation Roadmap for the SSRB projects that were quantitatively assessed.**

| Project Name | Hydrological modelling completed | Economic analysis completed | Discussed by the WG |
|---|---|---|---|
| **Continuous implementation** | | | |
| Implement more natural infrastructure projects across the SSRB | ✓ | ✓ | ✓ |
| Investigate options to reduce impact to water quality, especially during low flow river conditions | | | ✓ |
| Promote further water conservation across the SSRB | | | ✓ |
| Improve land use best practices across the SSRB | | | ✓ |
| Promote collaborative water management working groups | | | ✓ |
| **Level 1** | | | |
| Spatial prioritization of natural infrastructure projects | | | ✓ |
| Implement releases for downstream water demands at Dickson Dam | ✓ | ✓ | ✓ |
| Renew TransAlta Agreement for flood and drought management in the Bow River basin | | | ✓ |
| Increase diversion rate at Carseland to allow McGregor Reservoir to fill when water is available | | | ✓ |
| Increase minimum flow past Lethbridge for additional dilution | ✓ | ✓ | ✓ |

| Project Name | Hydrological modelling completed | Economic analysis completed | Discussed by the WG |
|---|---|---|---|
| **Level 2** | | | |
| Improve spillway capacities on Kananaskis Dams (Barrier, Pocaterra, Interlakes) to increase available water storage | | ✓ | ✓ |
| Restore Spray Lake Reservoir to its full supply level | ✓ | ✓ | ✓ |
| Remove canal bottleneck between Waterton Reservoir and St. Mary Reservoir | ✓ | ✓ | ✓ |
| Build off-stream water storage in the Red Deer River basin (to support Acadia and Special Areas Irrigation Project) | | | ✓ |
| Build new Western Irrigation District water storage | ✓ | ✓ | ✓ |
| Construct weir at Medicine Hat to increase water level at intake | | | ✓ |
| Develop provincial stormwater and effluent reuse policies and guidelines | | | ✓ |
| **Level 3** | | | |
| Build new on-stream water storage on the Bow River (Eyremore Reservoir) | ✓ | ✓ | ✓ |
| Build upstream water storage on the Bow River | ✓ | ✓ | ✓ |
| Build new on-stream water storage on the Red Deer River (Ardley Reservoir) | ✓ | ✓ | ✓ |
| Build new on-stream water storage on the upper Belly River (Upper Belly River Reservoir) | ✓ | ✓ | ✓ |

### 2.7.1 Adaptation Roadmap for the SSRB strategies: Continuous Implementation

Options categorized in the Continuous Implementation section are strategies which can be implemented on an ongoing basis and throughout the Adaptation Roadmap for the SSRB and are in various stages of work. The following are in the Continuous Implementation level:

#### 2.7.1.1 Implement more natural infrastructure projects (e.g., wetland reclamation and conservation) across the SSRB

**Description**

Natural infrastructure describes use of materials and aspects of the ecosystem that have been maintained, restored, or increased (e.g., water, native species of plants, sand, and stone) to achieve desired infrastructure results while offering a number of co-benefits to the economy, the environment, and the health and well-being of the community (Canadian Council of the Ministers of the Environment, 2021). The International Institute for Sustainable Development's State of Play on Natural Infrastructure describes a combination of built systems based on nature, restored ecosystems, and protected ecosystems which enable the provision of infrastructure services and offer side benefits. There are many different types of examples, such as riparian zones, wetlands, groundwater recharge zones, floodplains related to shallow aquifers, green roofs, soil cells, and even aquifer storage and recovery (ASR).

Natural infrastructure can take many forms, such as conserved, restored, nature-based built types. Identifying, quantifying, and in some cases valuing the benefits of diverse types of natural infrastructure are an important part of understanding how grey infrastructure and natural infrastructure can work together to support more sustainable and affordable infrastructure service delivery.

Natural infrastructure is a proven tool which helps to mitigate urban and climatic challenges by building with nature that has several socio-economic benefits. As such, there are multiple ongoing and future natural infrastructure projects being implemented within the SSRB. One example of a natural infrastructure project would be the reclamation of wetlands. Wetland loss within the SSRB is prevalent. These losses are a result of agricultural development and urbanization, which often entail draining and filling wetlands (Simieritsch, 2013). However, there is significant work being done within the SSRB to reclaim and conserve wetlands. It is important to note that wetlands are only one type of natural infrastructure, and their relationship with flood/drought is highly contextual. To understand and illustrate the relationship between natural infrastructure and water supply (using one example), we modelled wetland conservation and restoration in Fallentimber Creek.

For a more detailed description of the scenario used to build this analysis, see Section 2.7.3.1.

**Modelling assumptions**

As the spatial distribution and type of natural infrastructure projects are not known at this time, the hydrological benefits of natural infrastructure implementation have been assessed at a high level in Fallentimber Creek.

The modelling assumed all natural infrastructure projects in this watershed would be wetlands, and two scenarios were modelled:

- Wetland conservation – In this scenario, all wetlands in the Fallentimber Creek watershed were converted to agricultural land and then compared to the current conditions to determine the effect of conserving wetlands.
- Wetland restoration – Approximately five percent of the watershed was converted to wetlands from agricultural land.

**Performance under historical conditions**

To evaluate the effects of wetland conversion, three land cover scenarios were run in Fallentimber Creek, a small watershed in the headwaters of the Red Deer River. This sub-basin was chosen since it contains a relatively high coverage of wetlands relative to other sub-basins in the SSRB. In total, three scenarios were run through the hydrological model (Figure 16):

- Current Conditions: (2022) land cover.
- Wetland Restoration: approximately 5% of the sub-basin converted to wetlands (from Agricultural lands).
- Wetland Removal: all wetlands converted to Agricultural lands.

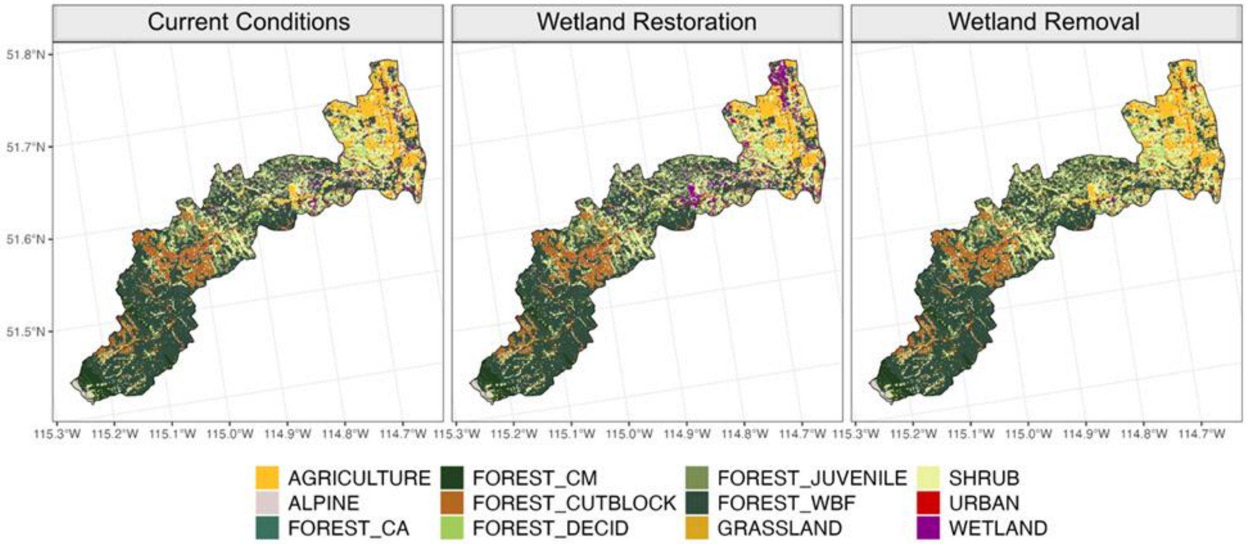


**Figure 16. Wetland scenario in Fallentimber Creek considered in this study.**

Overall, the results demonstrate how wetland removal leads to less water in Fallentimber Creek (Figure 17). This occurs primarily because agricultural lands intercept and consume more precipitation compared to wetlands. In addition, agricultural lands tend to have higher summer evapotranspiration rates and faster baseflow responses, while wetlands tend to store water on the landscape and attenuate flow.

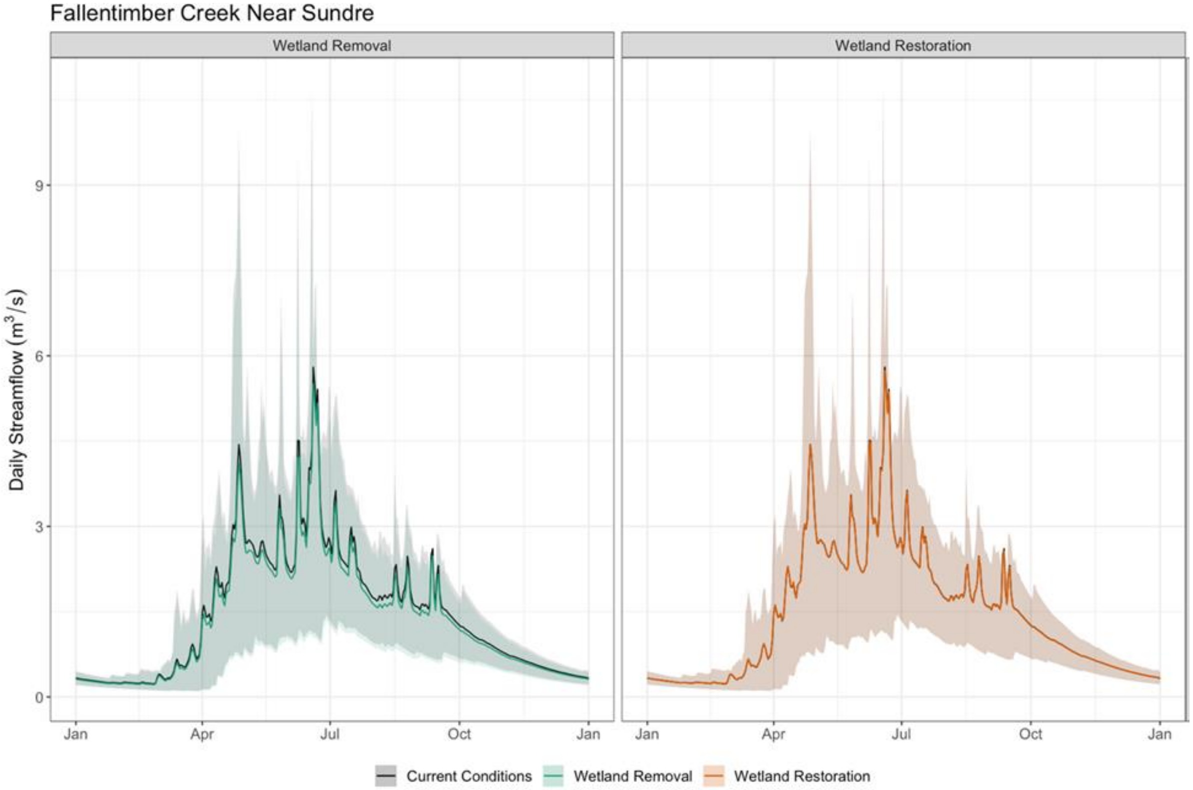


**Figure 17. Average annual hydrographs over the 1991-2020 period under the three land cover scenarios.**

Results summarizing hydrologic indicators for Fallentimber Creek highlight this pattern (Table 11). Under the Wetland Removal scenario, most hydrologic indicators see a decrease; notably lower 10-Year Summer Low Flow and 2-Year Peak Flow. Conversely, under the Wetland Restoration scenario, the changes are relatively negligible (<5%) but offer some indication wetland restoration can supplement streamflow during low flow periods. The 4% increase in the 10-Year Low Flow suggests wetlands can supplement winter flows during dry periods by attenuating and storing streamflow.

**Table 11. Change in hydrologic flow scenarios relative to the Current Conditions (2020) land cover configuration.**

| Fallentimber Creek Near Sundre | | | | | | |
|---|---|---|---|---|---|---|
| **Scenario** | **Mean Annual Flow** | **2-year Peak Flow** | **20-Year Peak Flow** | **10-Year Low Flow** | **10-Year Summer Low Flow** | **Peak Flow Timing** |
| *1991-2020* | | | | | | |
| Wetland Removal (conservation) | -7% | -9% | -4% | -6% | -9% | 0 days |
| Wetland Restoration | 0% | -1% | -1% | 4% | 0% | 0 days |

These results offer a first order approximation on the roles wetlands play along Alberta's Eastern Slopes. These simulations indicate that overall, at larger sub-basin scales, the effects of wetland conversion are relatively minimal; however, small volumes can add up. Wetlands can provide important ecological effects, including by acting as local off-stream storage. Many alternative water storage methods can offer more water yield or reduced water storage at the household or community level. But the demand for big, centralized water storage and treatment facilities, as well as associated distribution networks, can be decreased by combining the use of alternate water management and storage techniques throughout a watershed (Government of Alberta, 2011). Further work should consider what local environments can best support wetland restoration. While more arid environments may not be effective at storing water in wetlands (i.e. prairie potholes leading to high rates of evaporation), other more moist environments may provide important effects, particularly along the Foothills.

While wetlands may typically only affect water availability to modest degrees (again, variable), adding up their benefits across landscapes/watersheds could make a larger difference. The distributed benefits of wetlands and other types of natural infrastructure can add up to landscape scale outcomes which can reduce need for grey infrastructure, and/or enhance/protect the function of grey infrastructure (Arthur & Jochen, 2022).

These results are highly dependent on the selection of the Fallentimber watershed, and thus cannot be taken to represent the performance of wetlands for water supply/availability across the entire SSRB. Hence, there is a need for further spatial prioritization to understand the areas with highest volumetric benefit for water supply/storage across the SSRB.

### Contextualizing the Economic Analysis

Nature-Based Solutions (NBS) represent several approaches and practices that leverage ecosystem services to provide functions and services as a complement to grey infrastructure. Natural infrastructure, a subset of the broader field of nature-based solutions, considers the role of nature in either direct infrastructure service delivery, or in protecting/enhancing function from grey infrastructure. Some common NBS approaches include constructed wetlands or riparian buffers along rivers. Unlike built infrastructure, which tends to provide a specific role or purpose, NBS typically provides a suite of benefits, thereby significantly increasing the value created per unit investment.

For example, a constructed wetland generates benefits including soil stabilization, water filtration, waste treatment, nutrient cycling, biological control, habitat and biodiversity, genetic resources, medicinal/ornamental resources, raw materials, cultural value, aesthetic value, air quality (other greenhouse gases), food provisioning, rural community resources, carbon sequestration, nitrogen retention, phosphorus retention, scientific educational opportunities, and water supply.

These many benefits affect a number of rightsholders. To demonstrate value created, a valuation analysis was done for a hypothetical 100-acre wetlands creation. The various benefits create a total annually recurring value of $11 million with proportions of value by stakeholders as depicted in Figure 18.

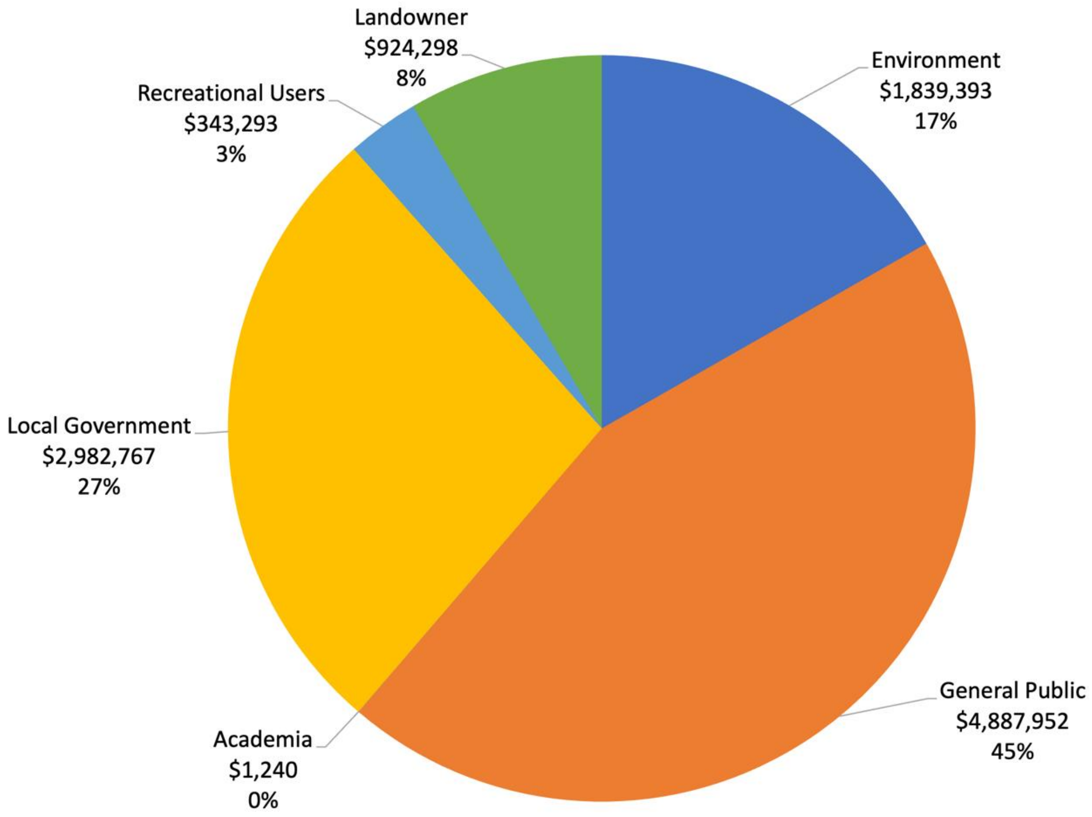


**Figure 18. Nature-based solutions created 100-acre case study It is important to consider the analysis of outcome value created for many stakeholders and does not result in direct income to any one entity.**

#### 2.7.1.2 Investigate options to reduce impact to water quality, especially during low flow river conditions

**Description**

As demand continues to increase within municipalities, it is important to consider the impacts to water quality from discharge from municipal wastewater treatment plants. With the growth of major municipalities expected to continue in the future, existing infrastructure will be under increased pressure to maintain effluent quality. Poor effluent quality leads to oxygen depletion of rivers, resulting in poor ecosystem health. Ensuring wastewater treatment plants are upgraded to maintain surface water quality will be critical to minimize anthropogenic impact on the environment. Poor quality effluent requires higher dilution flow, which may make water unavailable for other uses.

**Modelling assumptions**

Modelling for this option was not undertaken, as the SSROM is unable to quantify hydrological benefits associated with this option. It is suggested that a future study fully explores the hydrological opportunities associated with this option.

**Contextualizing the Economic Analysis**

This option was not considered as part of the economic analysis. It is suggested that a future study fully explores the economic opportunities associated with this option.

#### 2.7.1.3 Promote further water conservation across the SSRB

**Description**

Though most municipal water usage is dependent on aging infrastructure, technological advancements may offer the biggest opportunity for improvement in this sector. The last 20 years have seen a rapid and significant improvement in technology in several areas, including stormwater runoff management, water treatment facilities, water reuse technologies, extremely efficient water heating systems, low and no flush toilets, efficient showerheads, smart controls, and more. More is anticipated, especially since the market acceptance and consumer appeal of currently available, extremely water-efficient technology shows great potential for lowering the amount of water used in metropolitan areas.

Better tools for identifying and assessing water main leaks are among the other encouraging advancements in the conservation of municipal water use. The overall efficiency of urban water use can be further enhanced by replacing and repairing aging water mains, enhancing stormwater systems, and making sure the two are kept apart. Significant advancements in water-efficient technology have also been made in commercial water use under municipal license allotment. While higher population densities, more urban xeriscape parks and lawns, rooftop gardens, and green roofs reduce runoff and ultimately reuse rainwater more effectively, more efficient HVAC systems save some incremental water use in high-rise buildings. Numerous golf courses have discovered methods to lower their overall water consumption, such as through drought-tolerant grasses and automatic watering systems.

Greater natural wetlands retention next to source water bodies, enhanced river systems, increased river flow rates during crucial dry or hot times, decreased risk to fish populations, and less need to draw down source water reservoir storage—thus lowering risk and extending water supply during drought periods—are some advantages of further urban water conservation.

In addition to municipal water conservation, efficiencies in other industries such as irrigation have implemented efficiencies in the field (e.g., pivot irrigation systems, construction of pipelines to carry water to reduce evaporation from canals), which help to conserve water. Major work has been and is continuing to be done to conserve water in irrigation.

Throughout the SSRB, conservation of water continues to improve. While acknowledging that new technologies are always emerging and there is always room for improvement and cost and risk reduction, these efforts should be praised and rewarded.

**Modelling results**

Modelling for this option was not undertaken, as the SSROM is unable to quantify hydrological benefits associated with this option. It is suggested that a future study fully explores the hydrological opportunities associated with this option.

**Contextualizing the Economic Analysis**

This option was not considered as part of the economic analysis. It is suggested that a future study fully explores the economic opportunities associated with this option.

#### 2.7.1.4 Improve land use best practices across the SSRB

**Description**

The option identifies the inclusion of improving land use best practices across the SSRB. Effective land-use planning ensures lands, which are finite resources, are used and developed to meet the current and future needs of communities and the people who live in them, while safeguarding valuable resources such as agricultural lands, wetlands, forests, and distinctive natural features and landscapes. The WG identified that land use best practices are to be continued along the Adaptation Roadmap for the SSRB to ensure effective strategies are in place for sustainable development within the SSRB.

**Modelling assumptions**

Modelling for this option was not undertaken, as the SSROM is unable to quantify hydrological benefits associated with this option. It is suggested that a future study fully explores the hydrological opportunities associated with this option.

**Contextualizing the Economic Analysis**

This option was not considered as part of the economic analysis. It is suggested that a future study fully explores the economic opportunities associated with this option.

#### 2.7.1.5 Promote collaborative water management working groups

**Description**

The SSROM WG members valued the importance of collaborative water management working groups which share, discuss, and evaluate current water issues. As discussed in Section 0, collaboration among a diverse group of water users from a diverse set of expertise and knowledge can be used to identify options and opportunities for better water management within the SSRB.

Collaborative water management working groups allow for information to be tested and verified. Unforeseen and unintended consequences to municipalities, licence holders, and others could be mitigated or avoided by testing overall system effects caused by changes to the basin. Continued engagement of key water managers, licence holders, and rights holders is key to effectively managing water under changing climate and basin growth conditions.

**Modelling assumptions**

Modelling for this option was not undertaken, as the SSROM is unable to quantify hydrological benefits associated with this option. It is suggested that a future study fully explores the hydrological opportunities associated with this option.

**Contextualizing the Economic Analysis**

This option was not considered as part of the economic analysis. It is suggested that a future study fully explores the economic opportunities associated with this option.

### 2.7.2 Adaptation Roadmap for the SSRB strategies: Already in progress

The strategies presented in the *Already in progress* level outlines projects which are funded and/or currently underway.

#### 2.7.2.1 Develop water sharing agreements among licence holders during water shortages

**Description**

Water sharing agreements are voluntary agreements between licence holders to share water and to ensure no licence holder in the agreement calls priority on their licence at the expense of a junior licence holder who has also entered the agreement. A water sharing agreement was reached during the 2001 drought to ensure key licence holders such as municipalities could maintain their water supply. The 2001 water sharing agreement was developed during the drought and was not formalized into a long-term agreement.

The GoAis undertaking an effort to more widely implement water sharing agreements across the SSRB. Such agreements are intended for use during future droughts based on a scientific approach to quantify available water in severe low flow conditions. Input from licensees will be critical during development. Final versions of such agreements are intended to be produced before the end of 2024.

**Modelling assumptions**

Exceptional or emergency operations, which would be undertaken during extreme low or high river flow conditions, were not modelled in SSROM as part of this project. Water sharing agreements would be implemented under extreme low flow conditions. Modelling should be undertaken as part of the development of water sharing agreements to identify impacts to licence holders and understand to what extent water withdrawals can be reduced to minimize harm from extreme drought.

#### 2.7.2.2 Build Deadhorse Coulee Reservoir

**Description**

The Deadhorse Coulee Reservoir project is an ongoing reservoir development project being undertaken by the Bow River Irrigation District (BRID). The reservoir is located on the BRID main canal approximately 10km south of Enchant. The proposed live storage of the new reservoir will be 12,000 dam$^3$ (9,730 acre-feet). The construction of this reservoir is expected to support an expansion of approximately 10,000 acres in BRID.

Funding for the Deadhorse Coulee Reservoir was announced by the GoA as part of the Alberta Irrigation Modernization (AIM) program funding in 2020. Conceptual modelling of this project has been completed and the reservoir is undergoing engineering design studies. It is anticipated this reservoir will be in operation before 2028.

**Modelling assumptions**

Deadhorse Coulee reservoir is modelled in SSROM as part of the Reference Case, and as such it was not individually assessed as part of this project. In the SSROM, Deadhorse Coulee makes releases to support the BRID, including an additional 10,000 irrigated acres.

#### 2.7.2.3 Build Chin Reservoir expansion

**Description**

The expansion of Chin Reservoir was announced in 2020 under the AIM program funding. The reservoir expansion will add 128,000 dam$^3$ (103,770 acre-feet) of live storage to the existing Chin Reservoir. It is anticipated this will facilitate an expansion of 41,000 acres in the St. Mary River Irrigation District (SMRID).

The Chin expansion is currently undergoing an Environmental Impact Assessment (EIA) to assess the environmental implications of the reservoir expansion. The anticipated completion date of the expansion is before 2028.

There may be bottlenecks in the SMRID main canal from Ridge Reservoir to Chin Reservoir which need to be addressed to be able to fill Chin effectively when water is available.

**Modelling assumptions**

The expansion of Chin reservoir is modelled in SSROM as part of the Reference Case, and as such was not individually assessed as part of this project. In the SSROM, Chin makes releases to support the SMRID, including an additional 41,000 irrigated acres.

#### 2.7.2.4 Build Snake Lake Reservoir expansion

**Description**

In 2020, an expansion of Snake Lake was announced as part of the AIM program funding. This project will add an additional 65,000 $dam^3$ (52,700 acre-feet) of live storage to Snake Lake reservoir. The Snake Lake expansion project is being led by Eastern Irrigation District (EID).

It is anticipated that the additional storage will primarily be used to support existing irrigation acres, which are currently dependent on flow in the Bow River. The additional storage will increase water security for the existing irrigated acres in EID.

**Modelling assumptions**

The expansion of Snake Lake reservoir is modelled in SSROM as part of the Reference Case, and as such was not individually assessed as part of this project. In the SSROM, Snake Lake makes releases to support the EID. This project mainly reduces the risk of shortage within the EID. However, in SSROM an additional 5,000 irrigated acres are also modelled for a more conservative estimate of EID demand.

#### 2.7.2.5 Complete Springbank Off-stream Reservoir for flood protection

**Description**

The Springbank Off-stream Reservoir (SR1) is an off-stream dry dam located on the Elbow River. The primary purpose of SR1 is flood mitigation to protect the City of Calgary from high flow in the Elbow River. The project is located approximately 15km west of Calgary just east of Highway 22. Construction of the off-stream reservoir began in 2021 and is expected to be completed by 2025.

**Modelling assumptions**

The Springbank reservoir is modelled in SSROM as part of the Reference Case. The reservoir is only used during high-flow events and has not been individually assessed as part of this project. The Springbank Off-stream Reservoir operates to protect Calgary from major flooding along the Elbow River.

#### 2.7.2.6 Complete flood mitigation projects (e.g., City of Calgary flood protection barriers such as Bonnybrook Berm and Sunnyside Barrier, Town of Drumheller flood berms)

**Description**

The City of Calgary is undertaking several flood protection projects, which include the construction of flood protection barriers throughout the City. One example is the ongoing project to enhance the flood protection at the Bonnybrook Wastewater Treatment Plant through the construction of a flood protection berm. The berm is being constructed in two phases as part of a broader upgrade and expansion project to the Bonnybrook plant. The east berm (700m) was completed in 2022, while construction of the south berm is ongoing.

The City of Calgary is also building flood protection barriers to protect the community of Sunnyside on the north bank of the Bow River. They will protect the community against a 1:100 year flood. This project is currently in the pre-construction phase, with construction scheduled to begin in 2024.

The Town of Drumheller is also undertaking several projects for flood protection, which include the construction of berms to protect communities from flooding along the Red Deer River. Construction is underway on berms to protect East Coulee, Downtown Drumheller, and Michichi Creek. All projects are expected to be constructed by 2025.

#### 2.7.2.7 Implement flood protection policies for greenfield areas (2022 CMRB Growth Plan)

**Description**

The Calgary Municipal Regional Board (CMRB) released the updated Regional Growth Plan effective August 15, 2022, which comprises several policies related to flood protection, including those specifically to ensure all New Area Structure Plans for greenfield development include protection measures to mitigate damage in hazard areas at the 1:200 flood level.

### 2.7.3 Adaptation Roadmap for the SSRB strategies: Level 1

Strategies in Level 1 are projects which are differentiated by their short lead time to implementation and can be realized in under two years. After a decision is made to proceed with a Level 1 project, a short regulatory process may be required (e.g. a water licence amendment). The following are included in Level 1 of the Adaptation Roadmap for the SSRB (Figure 19):

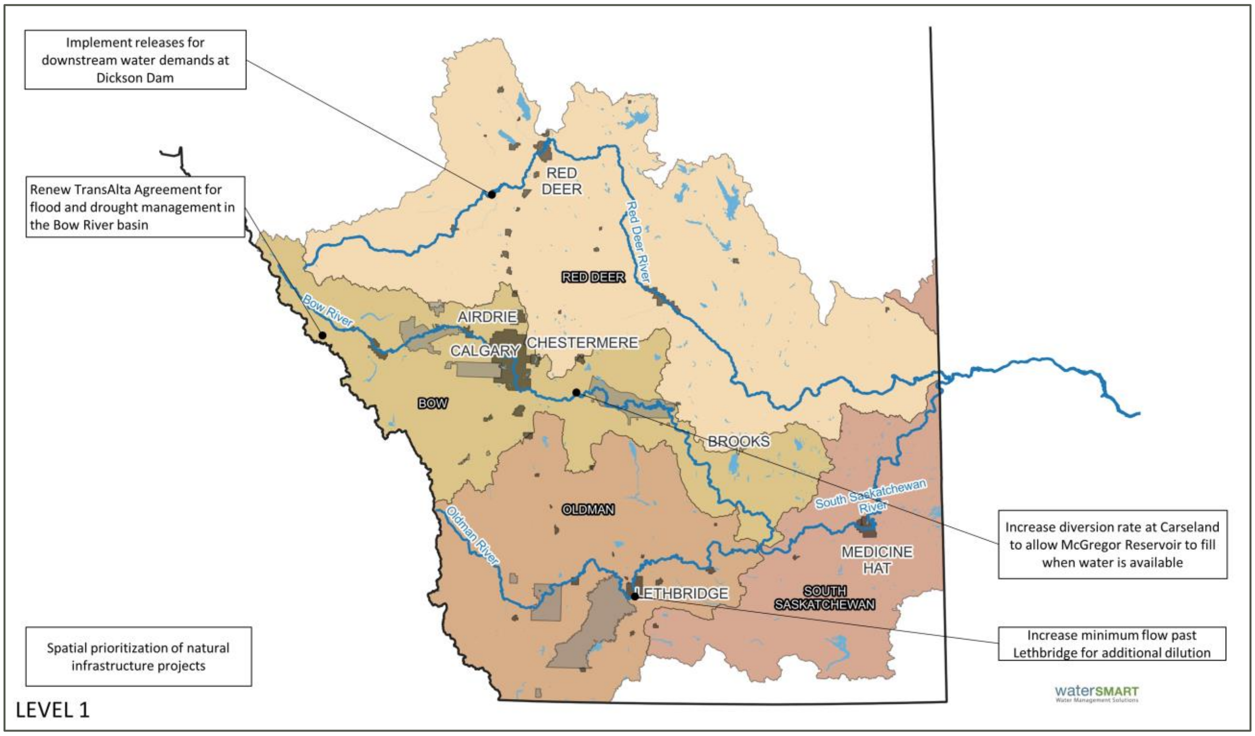


**Figure 19. Identified options in Roadmap Level 1 shown across the SSRB.**

#### 2.7.3.1 Spatial prioritization of natural infrastructure projects

**Description**

As defined previously, natural infrastructure describes use of materials and aspects of the ecosystem which have been maintained, restored, or increased (e.g., water, native species of plants, sand, and stone) to achieve desired infrastructure results while offering several co-benefits to the economy, the environment, and the health and well-being of the community (Canadian Council of the Ministers of the Environment, 2021).

The spatial prioritization of natural infrastructure projects for water supply and storage in the SSRB can be assessed using a combination of hydrologic models and geospatial analyses. LiDAR digital elevation models, land cover, soils, and hydrometric data can all be leveraged to assess the physical feasibility of natural infrastructure and to generate alternative land use maps. An evaluation of the physical feasibility for natural infrastructure will enable realistic target setting for project implementation and produce land use change maps which can be processed using existing hydrologic models (e.g. Raven) to assess changes to flood mitigation (reduced peak flows), drought resiliency (increased low flows), and water supplies (increased localized surface water storage and groundwater recharge). Some examples of natural infrastructure which can be evaluated to demonstrate these benefits include natural and constructed wetlands, small, naturalized dams for water retention, and vegetated riparian areas, among others. Identifying, quantifying, and valuing the benefits of natural infrastructure (whether related to water needs or more broadly) is a useful approach for infrastructure and resilience planning. Additionally, existing spatial targeting models could be used to assess water quality improvements (reductions to solids and nutrients), which will help quantify the other core benefits these practices provide for improving watershed health.

A complete spatial assessment of natural infrastructure will help to develop the economic and water security benefits of the continuous implementation of natural infrastructure discussed under Section 2.7.1.1, which considers a broadly defined development of natural infrastructure projects.

#### 2.7.3.2 Implement releases for downstream water demands at Dickson Dam

**Description**

Dickson Dam, which created Gleniffer Reservoir, is an on-stream reservoir located on the Red Deer River approximately 40 kilometres upstream of the City of Red Deer. The current primary objective of Dickson Dam is to maintain the WCO flowing in the Red Deer River. Between November and March, the WCO is maintained at 45% of naturalized flow or 16 $m^3/s$, whichever is larger. Between April and October, the WCO is 45% of naturalized flow or 10 $m^3/s$, whichever is larger. Operations of this reservoir are currently designed primarily to make releases based on current storage levels.

This project proposes revising the operations of Dickson Dam to introduce an additional operating criterion focused on anticipating the demands of water users downstream of the dam and making anticipatory releases. As the Red Deer River sub-basin continues to build out toward full allocation, this operation is expected to be necessary to sustain both current WCO flows and additional regional growth.

**Modelling assumptions**

Since the Reference Case includes the operational changes of the Dickson Dam downstream releases and the Acadia Special Areas Irrigation Project, a separate run was used to compare the option (No Dickson Dam downstream facing operations).

In SSROM, the alternative Dickson Dam operations are included in the Reference case, and Dickson Dam makes releases to meet downstream water demands. The release of Dickson Dam conditions are:

- Reference Case (include Dickson Dam downstream operations): There is a call on Dickson Dam to release when there would be a shortage downstream or when the Bindloss WCO is anticipating a violation.
- No Dickson Dam downstream operations: Dickson Dam does not consider downstream users. It operates per current criteria and rule curves. This operation is restored when the Ardley Reservoir option is online, as Ardley Reservoir supports downstream demand and anticipates needs.

To assess the impact of Dickson Dam operations, a scenario was run where current operations were used to support the demands of the Reference Case.

**Performance under historical conditions:**

Figure 20 to Figure 23 show the annual total water shortage to certain water users in the Red Deer basin, including irrigators both within and outside of the Acadia and Special Areas Irrigation Project, municipalities, and temporary diversion licences (TDLs).

Under current operation, senior license holders throughout the Red Deer are effectively preserved, even in the case of growth to full basin allocation (blue line, Figure 21). Shortages are small (less than 1,000 dam$^3$ in one year). However, junior or “potential growth” irrigators are at substantial risk (blue line, Figure 20), with over 10,000,000 dam$^3$ (10,000 kdam$^3$) shortage in several years and over 35,000,000 dam$^3$ (35,000 kdam$^3$) in the worst year. These Junior shortages can be eliminated by introducing downstream-looking operations to Dickson Dam (red line, Figure 20). The changes in operations do increase shortages to senior licensees (red line, Figure 21), but they remain relatively small (less than 2,000 dam$^3$, and only in dry years). This occurs as, with downstream looking operations, Dickson Dam eventually runs out of water in the driest years. Therefore, Gleniffer Reservoir would have trouble supporting a full basin allocation scenario in the Red Deer sub-basin; however, it is somewhat comforting to see how close it can come, even if the reservoir is fully drained. It is important to note in this analysis that no irrigation cutbacks or municipal reductions are enacted in droughts in this model. In the real world, drought response planning would lead to demand reductions, which would help prevent a zero-storage event. Nevertheless, if the Red Deer sub-basin grows to full basin allocation, Dickson Dam operations will have to make some effort to accommodate new licensees.

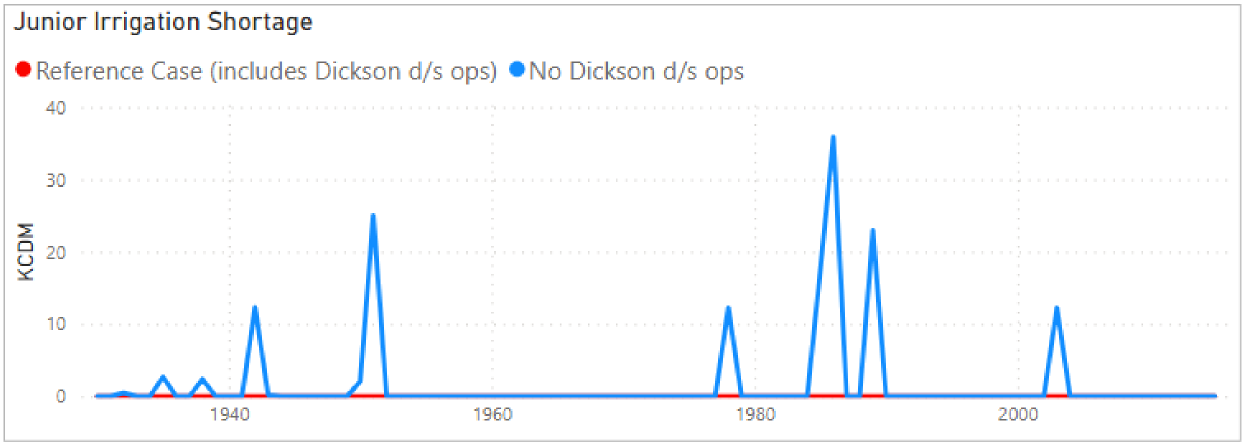


**Figure 20. Reference Case with Dickson Dam downstream operations (red) compared to no Dickson Dam downstream operations (blue) showing junior irrigation shortages.**

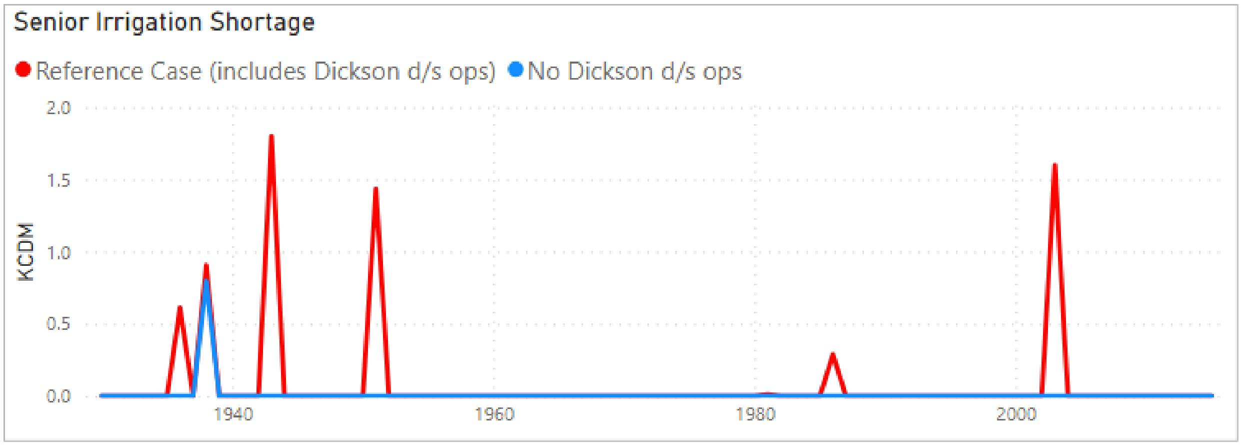


**Figure 21. Reference Case with Dickson Dam downstream operations (red) compared to no Dickson Dam downstream operations (blue) showing senior irrigation shortages.**

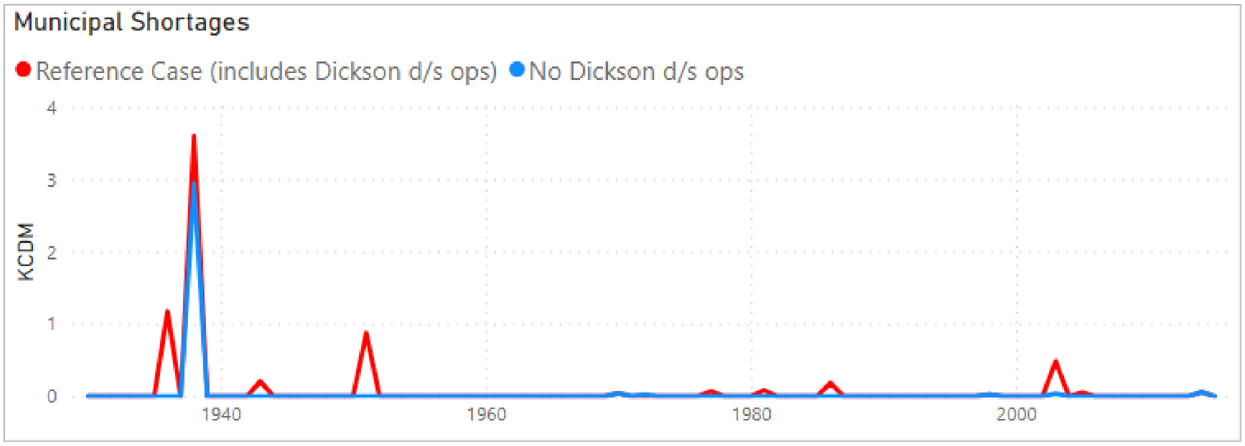


**Figure 22. Reference Case with Dickson Dam downstream operations (red) compared to no Dickson Dam**

**downstream operations (blue) showing municipal shortages.**

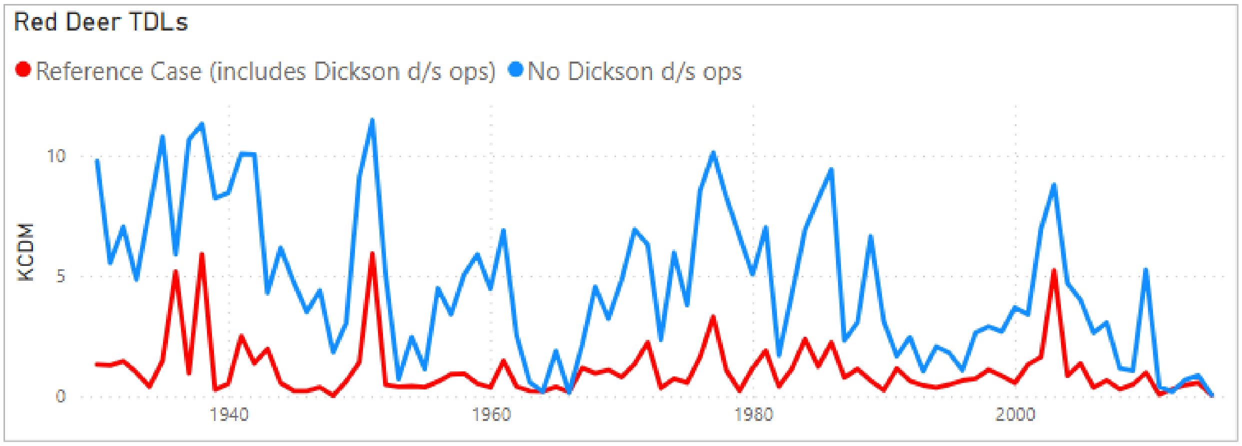


**Figure 23. Reference Case with Dickson Dam downstream operations (red) compared to no Dickson Dam downstream operations (blue) showing Red Deer TDLs.**

Operating Dickson Dam to make releases to meet downstream demands also provides benefits in terms of reducing WCO violations. Figure 24 shows with the revised operations in place there is a significant reduction in the frequency of WCO violations, both within irrigation season and over winter. Meeting the WCO in the Red Deer sub-basin is challenging in a full build out scenario, as most licences are senior to the WCO requirement. Implementing revised Dickson Dam operations would put more water in the river, resulting in substantial environmental benefit in addition to improving outcomes for license holders.

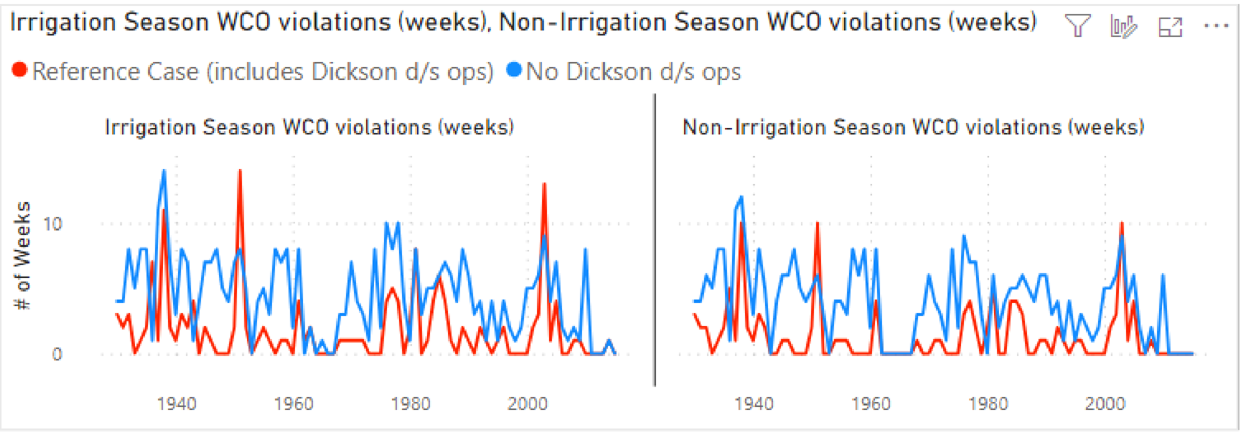


**Figure 24. Reference Case with Dickson Dam downstream operations (red) compared to no Dickson Dam downstream operations (blue) showing the number of WCO violations (weeks).**

As mentioned above, Dickson Dam shows substantially increased utilization in the new operations. In 2002, as shown below, the Gleniffer Reservoir reaches its dead storage level (although it nearly reached that level even under current operations). Looking across the whole record, the regular and deeper drawdown of the reservoir is apparent. This leads to impact downstream where the reservoir is drawn down significantly to meet downstream demands.

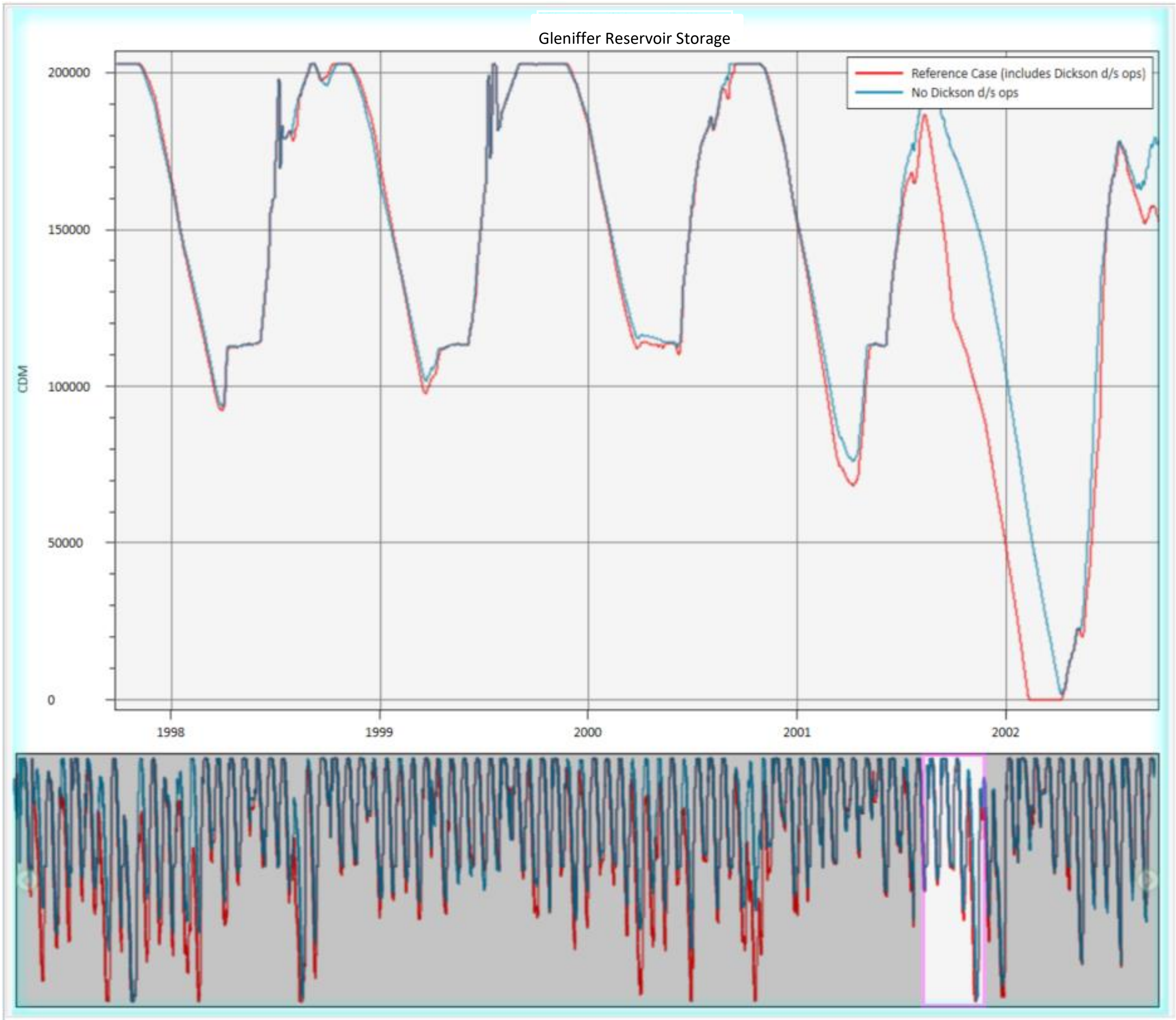


**Figure 25 Reference Case with Dickson Dam downstream operations (red) compared to no Dickson Dam downstream operations (blue) showing the number of WCO violations (weeks).**

Examining how the dam is now operated may reveal more advantages in terms of the environment and economy. Though storing more water earlier in the season may have other environmental benefits at other times of the year, adhering to the current rule curve does allow for more naturalized flows to occur in the spring and early summer, while still maintaining winter flows. Because of the annual reservoir drawdown, there is now little development of the littoral zone in Gleniffer Reservoir, which limits the recreational fishing opportunities. There should be minimal to no risk to the current fishing within the reservoir if additional downstream advantages can be realized. The WCO should meet over the winter months to maintain aquatic health and meet dilution needs for downstream municipalities like the City of Red Deer and Town of Drumheller.

**Contextualizing the Economic Analysis**

The economic analysis provides a highly conceptual indication of the potential value added and lost from the implementation of a project. Assumptions used in this analysis of Dickson Dam are influenced by the availability of data and there is room to perform a more granular analysis to refine the net value gained as more information is gathered on the project.

The SSROM modelling shows that altering operations in this way will result in additional reservoir drawdown up to a maximum volume of 40,000 dam$^3$ (32,430 acre-feet) to support downstream demands. In the economic evaluation, it was assumed that of this total additional release, one third would be used for additional irrigation, one third would be used for municipal growth and one third would remain in the river for environmental flow needs.

In Figure 26, the chart representing the recurring outcome categories and potential Year 1 benefit shows that the reoperation of Dickson dam leads to significant benefits to the general public. This includes support for year-on-year projected annual population growth at 1.4% in the Red Deer River basin up to a potential maximum of over 98,000 additional people.

There is also some agricultural benefit generated from this project which results from releases being able to meet downstream demands. In the economic analysis this benefit is shown as the development of over 9,000 new irrigated acres which also provides a benefit to the public through food provisioning in addition to the direct benefit created for the agricultural sector.

The total value created and lost in Year 1 is shown in Figure 27 and shows that some value is lost as a result of the reduced phosphorus and nitrogen retention resulting from increased agricultural activity. The reduced ability to retain nutrients results in a loss of value of approximately $3.5 million. It should be noted that the economic analysis does not include an assessment of any impact to hydropower generation that may result from reoperating the reservoir.

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| 9,239 | 98,273 | 34,400 | 9,239 | 0 | 13,334 | 13,334 | 13,334 |

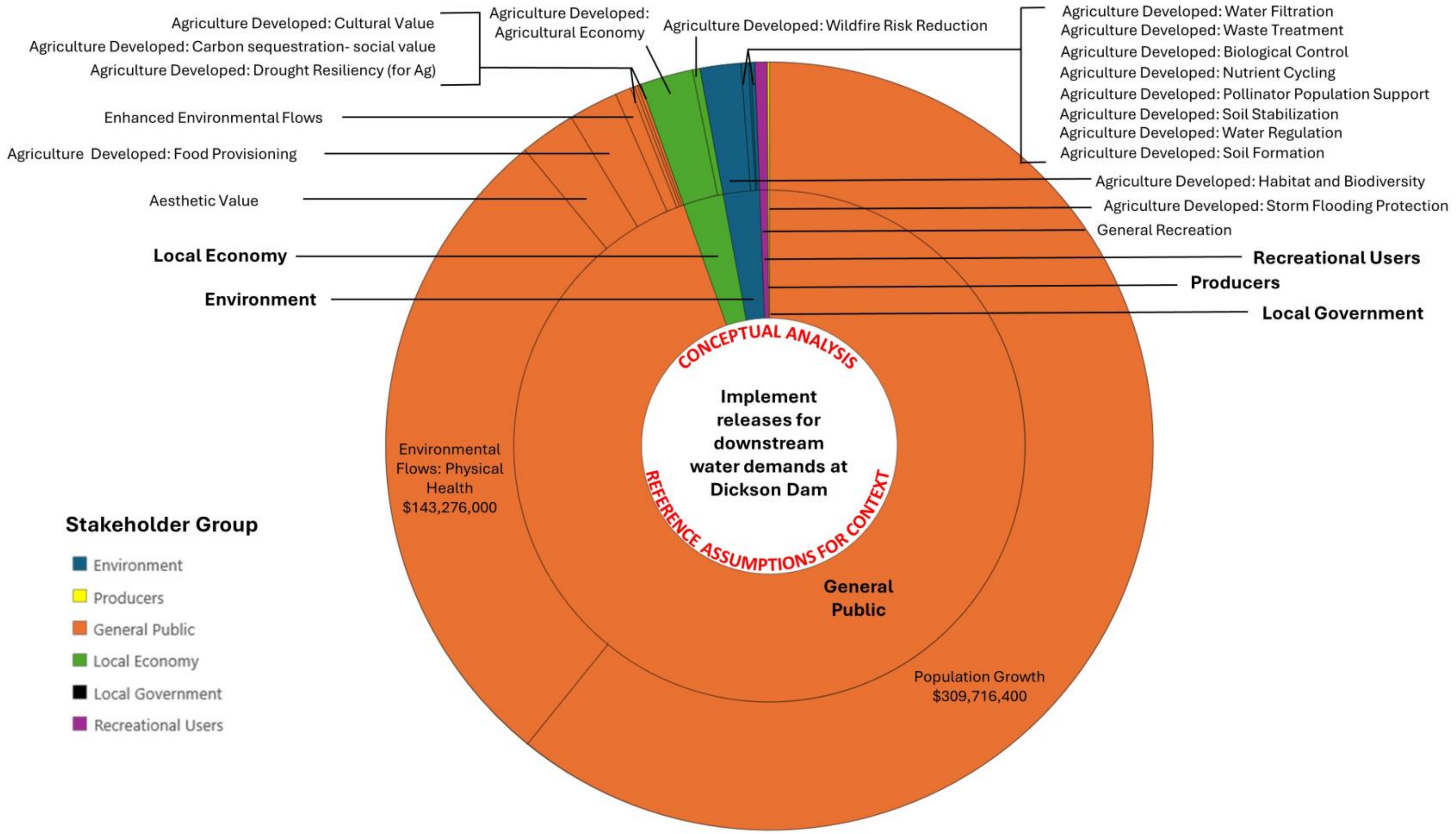


**Figure 26. Annually recurring outcome categories through reoperation of Dickson Dam (with only Year 1 values shown).**

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| 9,239 | 98,273 | 34,400 | 9,239 | 0 | 13,334 | 13,334 | 13,334 |

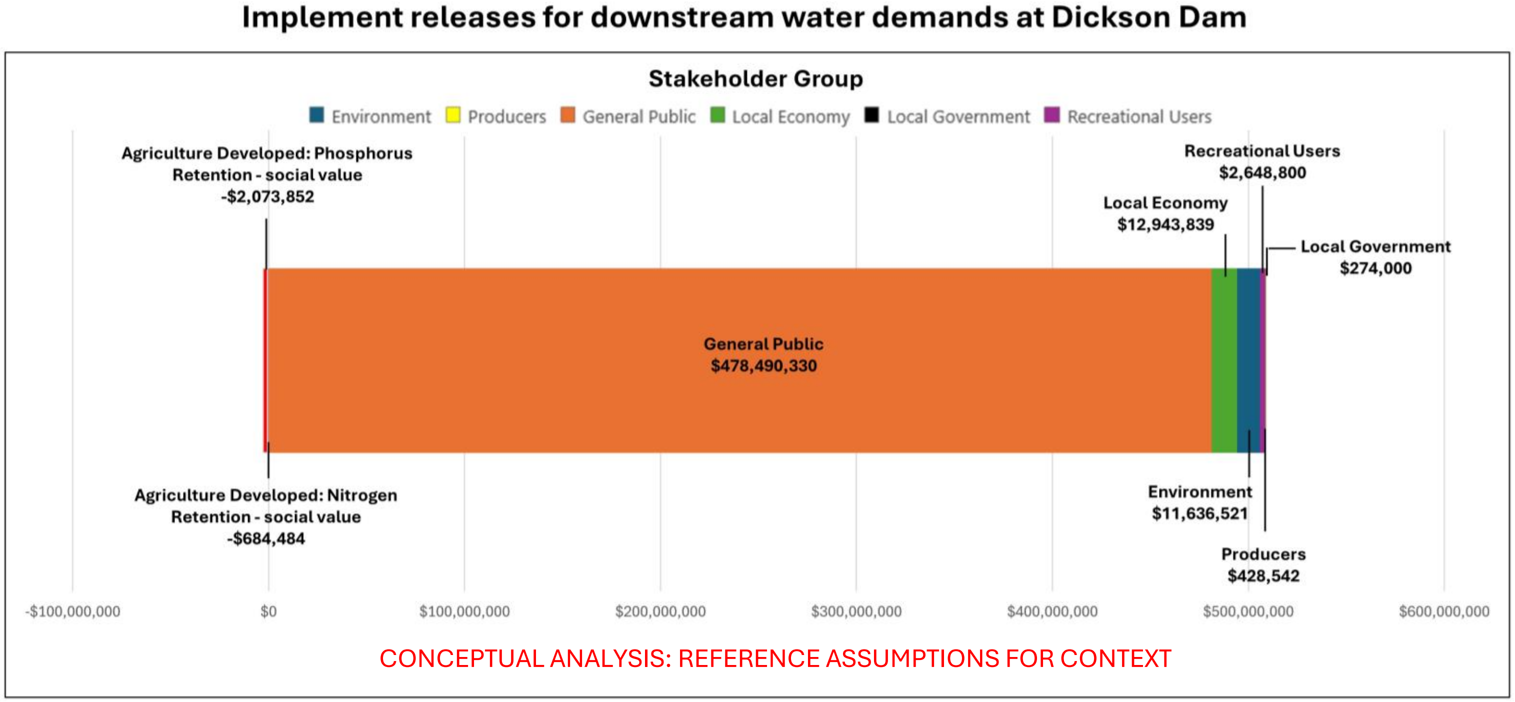


**Figure 27. Annually recurring outcome categories through reoperation of Dickson Dam (with gained and lost value shown only for Year 1).**

#### 2.7.3.3 Renew TransAlta Agreement for flood and drought management in the Bow River basin

**Description**

The 2021 TransAlta Agreement with the GoA allows the GoA to set the elevations of TransAlta owned Ghost Reservoir from May 16 to July 7. This agreement is bound by a five-year term and is set to expire in 2026. Keeping the reservoir lower during this period allows for more flexibility during potential flood events to reduce the downstream flows from the dam (Alberta, 2021). This option demonstrates that such an agreement continues to be seen as valuable by the parties with respect to flood mitigation in the Bow River basin.

This agreement also has a drought component to it, using the Kananaskis system to supplement flows when needed. There might not be more additional storage in the system, but the storage can be used by AEPA to help with additional flows downstream when needed.

**Modelling assumptions**

As a daily model, SSROM is ill-suited to flood prevention analysis. Hourly tools, such as the hourly Bow River Flood model (derived from SSROM), are better suited to that purpose. As such, this analysis was deemed outside the scope of this project at this time.

**Contextualizing the Economic Analysis**

Economic considerations were not undertaken as part of the project, as there was uncertainty of quantifying additional benefits associated with this option.

#### 2.7.3.4 Increase diversion rate at Carseland to allow McGregor Reservoir to fill when water is available

**Description**

This option outlines the increase in the diversion rate from GoA's Carseland diversion from the Bow River, which is the water source for the BRID and the Siksika Nation's irrigation project. By filling storage earlier in the season, BRID could relax pressure on river flows outside the freshet period. It is anticipated this would provide a direct water security benefit to BRID, as it would allow off-stream reservoirs to be filled earlier. There would be a direct environmental benefit, as BRID would not be drawing water to fill reservoirs when flow in the river is lower, leading to incrementally higher water levels and potentially lower temperatures for fish. It can also provide more water for other users at low flow.

However, fish entrainment is the main issue with raising the diversion rate from the Bow River. Fish that are unable to return to the river due to entrainment are lost to the population when they migrate into canals. Since entrainment is predicted to be directly correlated with the rate at which water is diverted, an increase in the rate of diversion is likely to result in a corresponding rise in entrainment rates. To limit or lessen entrainment, any suggested increase in the diversion rate should investigate fish exclusion mechanisms to reduce or minimize fish entrainment. Installing fish exclusion or deterrence systems could potentially divert water during periods of the year when it is abundant and makes up a smaller percentage of the overall flow. Fish populations in the Bow River may benefit net from this option if diversion rates were decreased in July and August when flows are normally lowest.

**Modelling assumptions**

Suggested late in the project, timelines did not allow for a thorough analysis of this option, although initial results showed some promise. A future study is recommended to explore the benefits of this alternative in more detail.

Level 1: Phase 1 – increase is from 51 to 53.7 $m^3/s$.

Level 2: Phase 2 – increase could be at least 60 $m^3/s$.

**Contextualizing the Economic Analysis**

Economic considerations were not undertaken as part of the project, as there was uncertainty of quantifying additional benefits associated with this option.

#### 2.7.3.5 Increase minimum flows past Lethbridge for improved effluent dilution

**Description**

This option outlines the additional flow past the City of Lethbridge targeting 16 $m^3/s$ for effluent dilution for their wastewater treatment plant. With a growing municipal demand, there will likely be more withdrawals from the river, resulting in more pressure on dilution. The City of Lethbridge relies on steady flows from the Oldman Reservoir upstream. As a result, more water being drawn from the Oldman Reservoir into the Oldman River may improve environmental flow in the Oldman River; however, it does draw down Oldman Reservoir to meet the 16 $m^3/s$ target for the City of Lethbridge. A more detailed breakdown of this option can be found below.

**Modelling assumptions**

Oldman Reservoir releases water to meet 16 $m^3/s$ past Lethbridge at all times.

**Performance under historical conditions**

Targeting 16 $m^3/s$ in the Oldman River past Lethbridge appears to be a generally achievable target as shown by Figure 28.

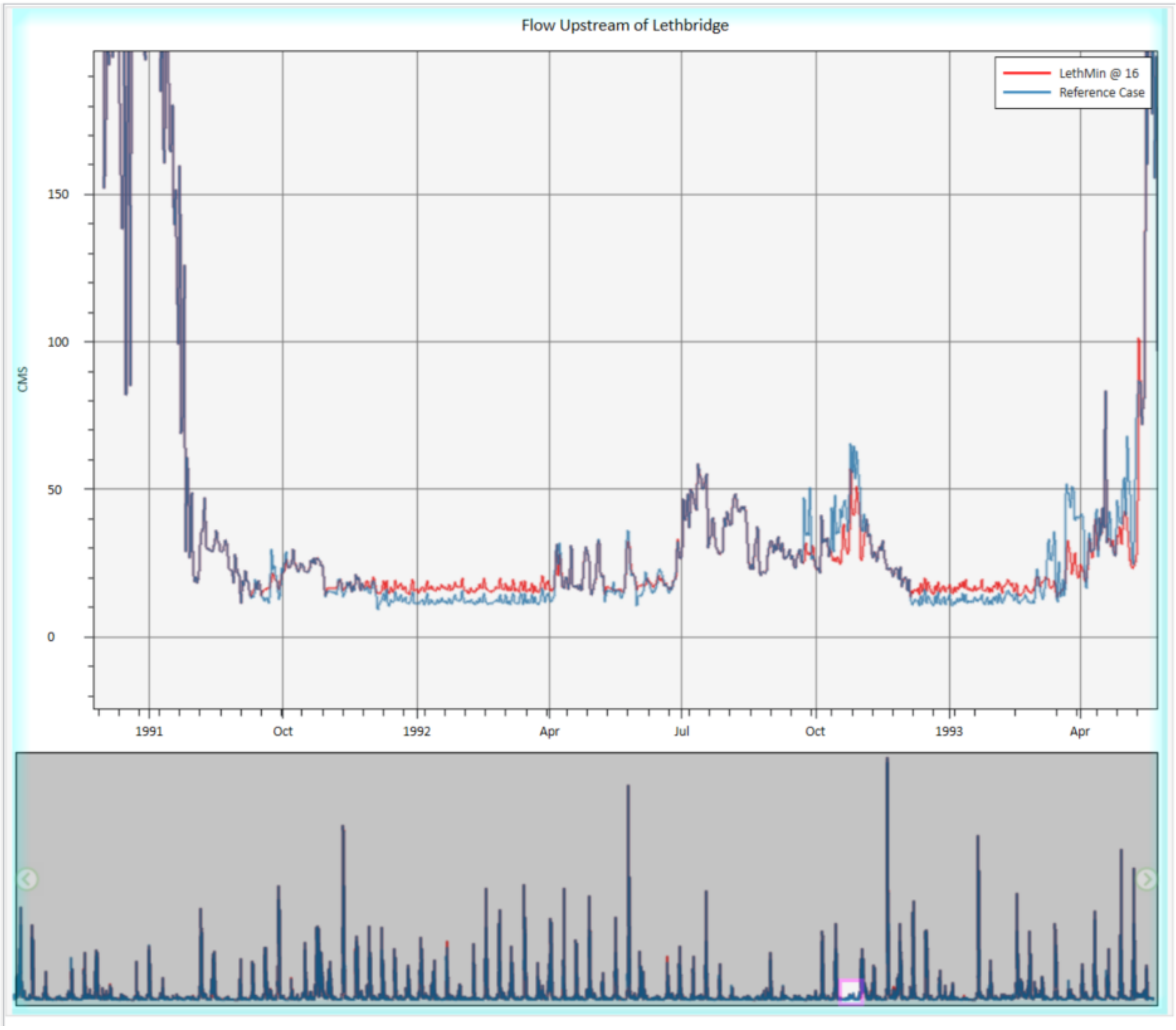


**Figure 28. Increased minimum flows past Lethbridge for improved effluent dilution (red) compared to the Reference Case (blue) showing the flow upstream of Lethbridge.**

Meeting the minimum flow target consistently is not without cost. However, as initially seen in Oldman Reservoir storage, adding the 16 m$^3$/s minimum flow on top of the reservoir's existing responsibilities puts additional pressure on storage. As such, the reservoir is drawn down deeper and more frequently (Figure 29). In extreme drought years, this results in the Oldman Reservoir being emptied. This presents an additional risk to the Oldman River sub-basin from extreme multi-year drought events.

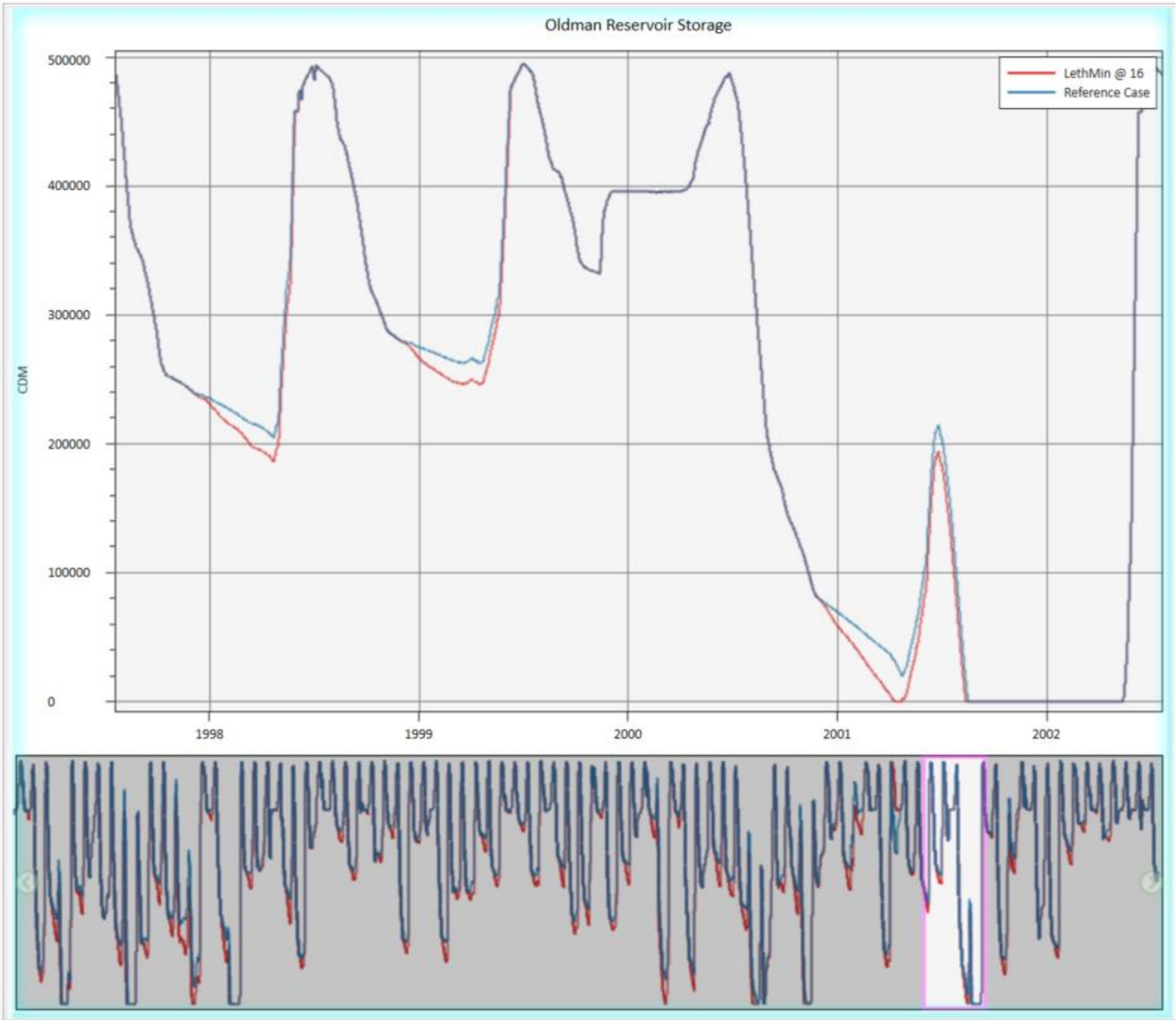


**Figure 29. Increased minimum flows past Lethbridge for improved effluent dilution (red) compared to the Reference Case (blue) showing the Oldman Reservoir storage level.**

A direct consequence of this increased pressure shows the Fish Rule Curve (desirable flow levels to protect aquatic species) violations increasing once Oldman Reservoir storage empties (Figure 30). Measured at several reaches of the Oldman River (downstream of Lethbridge, Fort MacLeod and Rocky Coulee confluence to the Belly River confluence, and downstream of LNID weir), this suggests possible ecological consequences of maintaining that steady flow as shown in Figure 30. Maintaining higher flows downstream of the Oldman Reservoir past Lethbridge would likely increase fish habitat and increase the length of cold-water habitat downstream from the dam (more volume takes longer to warm up in the summer). This could potentially benefit Lake Sturgeon, which is a Species at Risk, except when Oldman Reservoir storage empties.

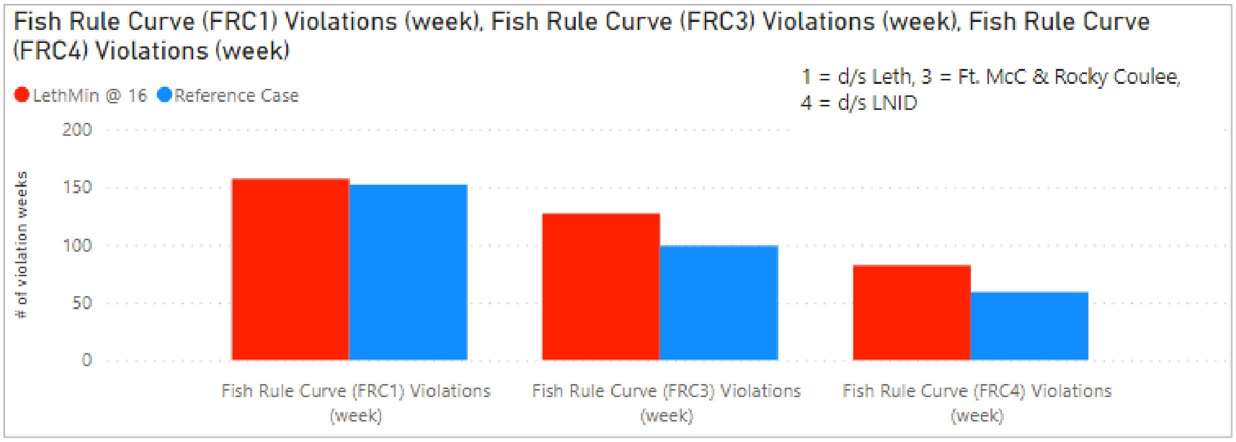


**Figure 30. Increased minimum flows past Lethbridge for improved effluent dilution (red) compared to the Reference Case (blue) showing the Fish Rule Curve violations.**

As the only irrigation district Oldman Reservoir can directly impact, the Lethbridge Northern Irrigation District (LNID) also shows impacts from the reservoir's reduced storage. Although the differential in shortages is not inconsequential, it is worth noting that the impacts are largely limited to already existing drought years (Figure 31). Challenging years would likely become more challenging for the district under this alternative, but most years would remain unaffected.

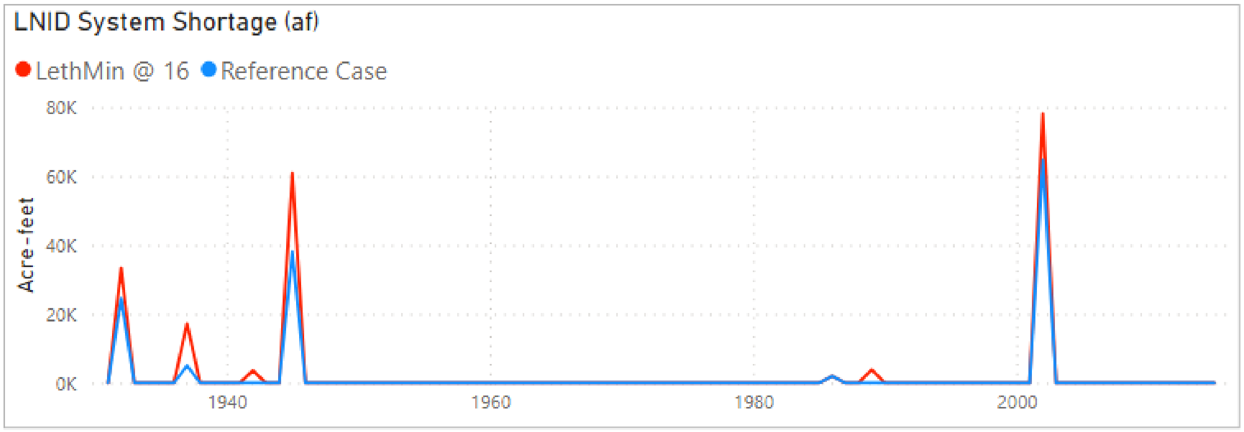


**Figure 31. Increased minimum flows past Lethbridge for improved effluent dilution (red) compared to the Reference Case (blue) showing LNID shortages.**

Although the additional Lethbridge minimum flow has clear consequences, these could be mitigated through additional water management options, such as Eyremore Reservoir (see Section 2.7.5.2). These can be seen only at Medicine Hat; if Lethbridge needs higher dilution flows upstream, Oldman River users will still be impacted.

**Contextualizing the Economic Analysis**

The economic analysis provides a highly conceptual indication of the potential value added and lost from the implementation of a project. Assumptions used in this analysis are influenced by the availability of data and there is room to perform a more granular analysis to refine the net value gained as more information is gathered on the project.

The SSROM modelling shows that increasing the outflow from the Oldman Reservoir releases up to 40,000 dam$^3$ (32,430 acre-feet) of additional water per year flowing past the City of Lethbridge. For the purposes of the economic analysis, this volume was assumed to be split with 50% of the water (20,000 dam$^3$/year) assigned for municipal use and 50% assigned as releases for environmental flows. This is a coarse estimate that aims to provide a high-levels indication of the benefit to both municipal users and the environment.

In Figure 32, the chart representing the recurring outcome categories and potential Year 1 benefit shows that increasing flows past Lethbridge leads to significant benefits to the general public. This includes support for year-on-year projected annual population growth at 1.13% in the Oldman River basin up to a potential maximum of over 147,000 additional people.

The total value created and lost is shown in Figure 33 and shows there is no value lost as a result of increasing flows past Lethbridge. This shows there are no direct negative impacts from increasing minimum flows past Lethbridge, however, it should be noted that occasional economic impacts of severe or multi-year droughts have not been captured in this assessment. The modelling conducted using SSROM notes that in some years the Oldman Reservoir may be drawn down more quickly which may pose some increased economic risk in drought years which has not been assessed in this study. Additionally, changes to hydropower generation capacity and timing were not considered as part of this analysis.

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| 0 | 147,409 | 17,200 | 0 | 0 | 0 | 20,000 | 20,000 |

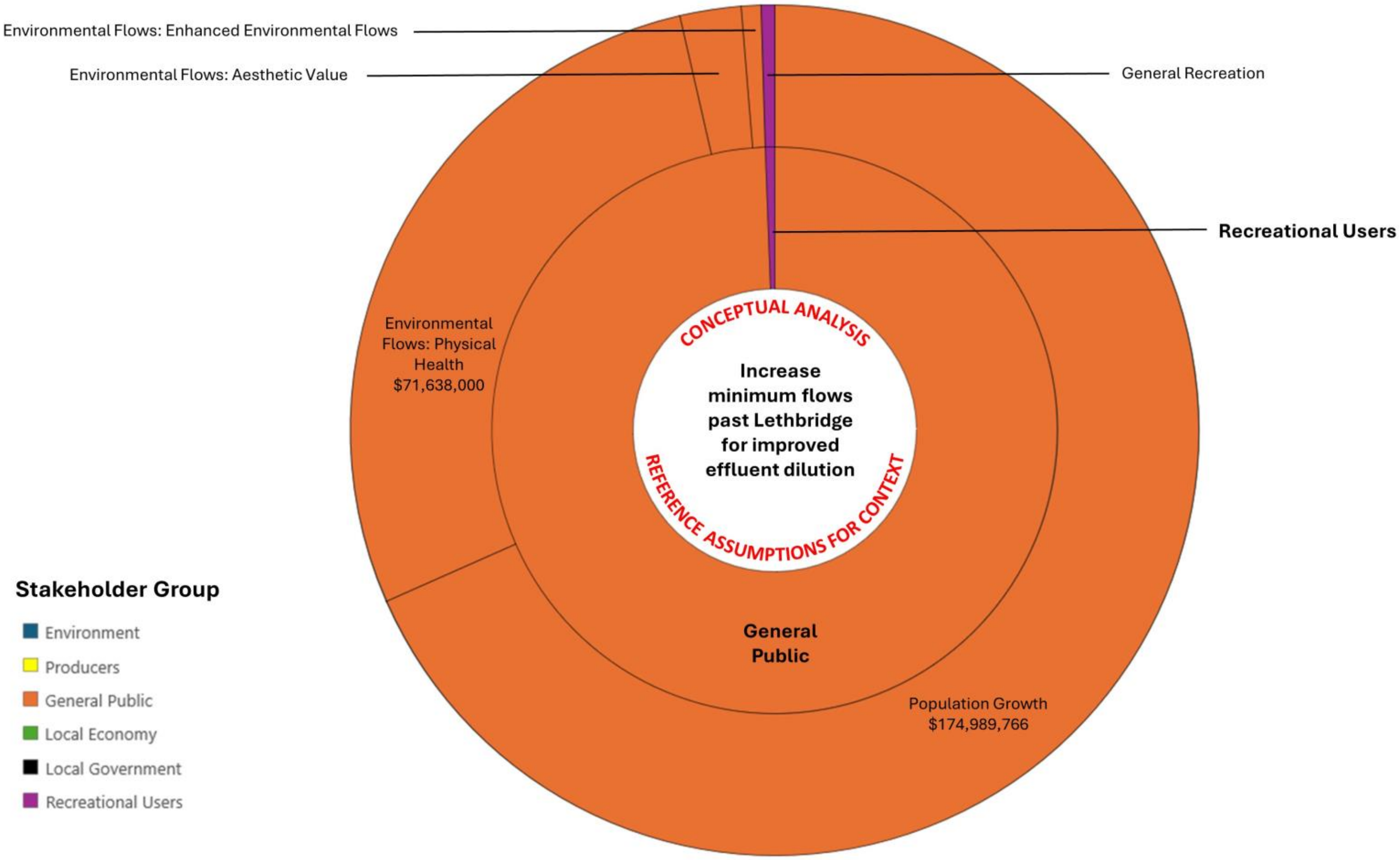


**Figure 32. Annually recurring outcome categories by increasing minimum flows past the City of Lethbridge (with only Year 1 values shown).**

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam$^3$) | Water for Municipal Growth (dam$^3$) | Water for Environmental Flows (dam$^3$) |
|---|---|---|---|---|---|---|---|
| 0 | 147,409 | 17,200 | 0 | 0 | 0 | 20,000 | 20,000 |

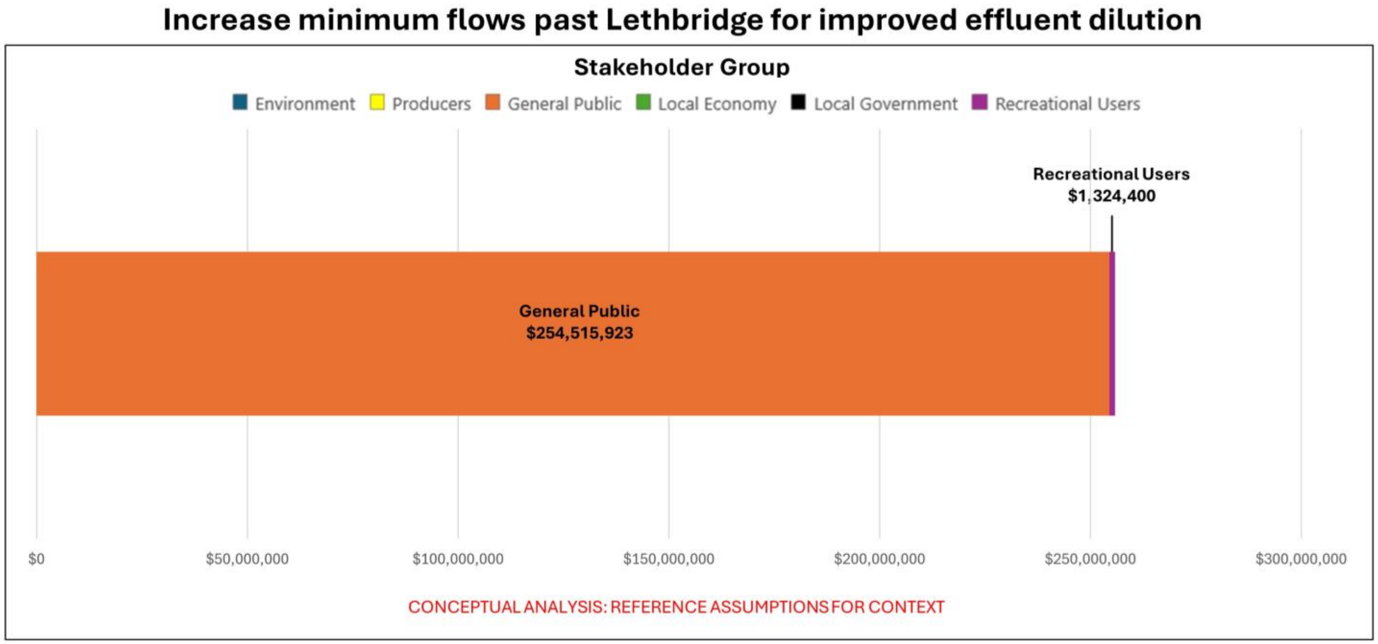


**Figure 33. Annually recurring outcome categories by increasing minimum flows past the City of Lethbridge (with gained value shown only for Year 1; no lost value estimated)**

### 2.7.4 Adaptation Roadmap for the SSRB strategies: Level 2

Projects identified in Level 2 of the SSRB Adaptation Roadmap for the SSRB consist mostly of infrastructure projects which require some form of conceptual, engineering, and construction timeline up to ten years. A map of the projects outlined in Level 2 are found in Figure 34 below.

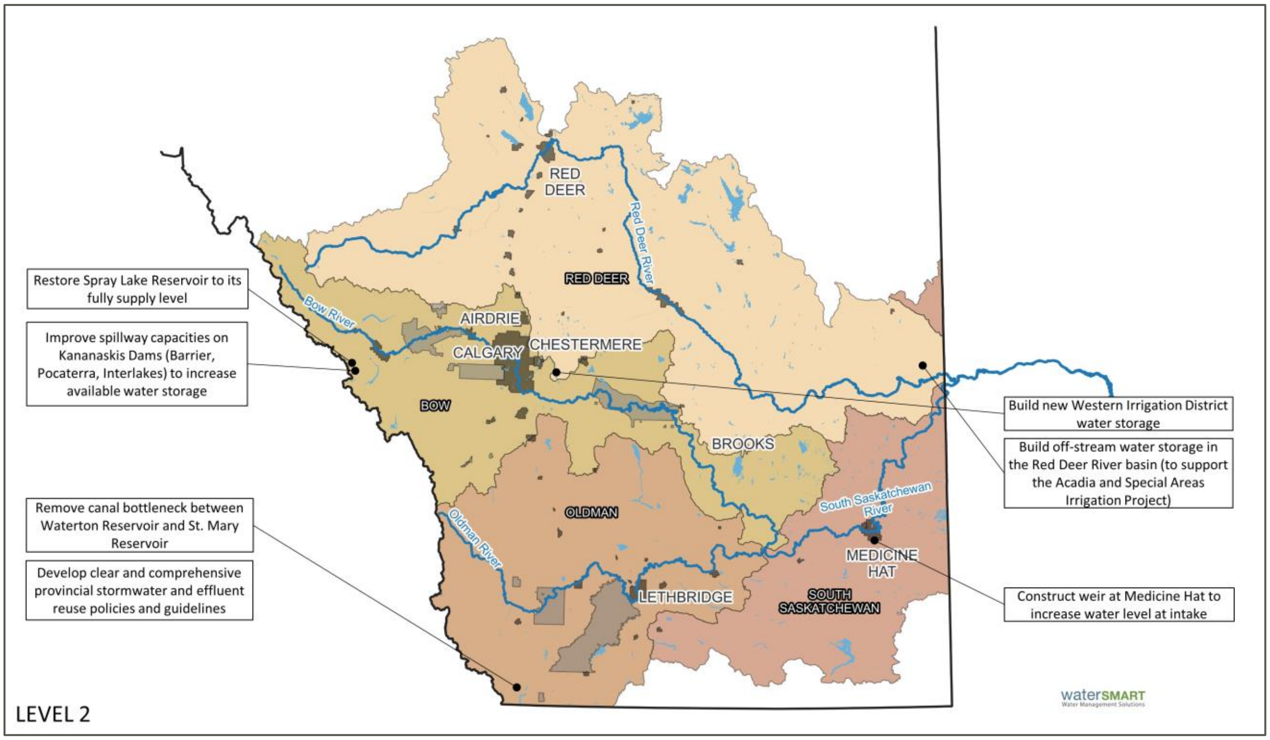


**Figure 34. Identified options in Level 2 across the SSRB.**

#### 2.7.4.1 Develop clear and comprehensive provincial stormwater and effluent reuse policies and guidelines

**Description**

High quality potable water is not an infinite resource, and overuse of potable water for purposes where a high-quality water source is not needed (e.g. irrigation) leads to reduced water security due to lack of source water availability and increased treatment costs. As populations grow, there is a global need to be more efficient with water use. The use of stormwater and reuse of effluent is an approach where poor quality water can be treated to a quality level appropriate for its intended end use.

Water reuse and stormwater use in Alberta has lagged behind other jurisdictions, partly due to a lack of policy direction and guidance in addition to regulatory restriction on suitable end uses for stormwater and recycled effluent. More recently, the GoA has begun to develop water reuse guidance, which enables the use of stormwater and recycled effluent under certain conditions.

The need for further guidance, a clear application process, and appropriate permitting for water reuse and stormwater use was identified by the WG as a key requirement for comprehensive water security planning in the face of a changing climate.

**Modelling assumptions**

Modelling for this option was not undertaken, as the SSROM is unable to quantify additional benefits associated with this option.

**Contextualizing the Economic Analysis**

Economic analysis of this option was not undertaken, as the economic outcomes are highly dependent on the regulatory approach taken to implement stormwater use and water reuse more broadly. Specifically, the outcomes would depend on permitted end uses and water quality requirements.

#### 2.7.4.2 Improve spillway capacities on Kananaskis Dams (Barrier, Pocaterra, Interlakes) to increase available water storage

**Description:**

This option explores the improvement of the spillway capacity in the Kananaskis system. Currently, the GoA has an agreement with TransAlta to implement modified operations on the Kananaskis reservoir system for drought mitigation. Since spillway capacity is currently limiting, the reservoir must be kept low during the freshet season to accommodate high flow events, since if an incoming flow is larger than the spillway capacity, the reservoir must have storage available to capture the extra or risk overtopping. By expanding the spillway capacity, the reservoir can be filled and can maintain higher storage in the freshet season, potentially providing additional releases during drought periods. As an alternative, additional storage could be used for flood mitigation, and a more detailed investigation would be needed to fully estimate additional storage.

**Modelling assumptions**

Modelling for this option was not undertaken due to uncertainty around how the province would choose to operate the storage in a drought condition. It remains an excellent candidate for follow-up study, which should incorporate environmental impact considerations in the Kananaskis River.

**Contextualizing the Economic Analysis**

The economic analysis provides a highly conceptual indication of the potential value added and lost from the implementation of a project. Assumptions used in this analysis are influenced by the availability of data and there is room to perform a more granular analysis to refine the net value gained as more information is gathered on the project.

SSROM modelling was not performed for this option. Discussions with the WG indicated the upgrades to the spillways of the Kananaskis reservoirs will result in an additional storage capacity of 74,000 dam$^3$ (60,000 acre-feet). For the economic analysis it was assumed that half the additional capacity (37,000 dam$^3$) would be used to support environmental flows and half would be used to support municipal growth. The economic analysis assumes that through agreement with the GoA TransAlta would not use the additional reservoir storage to operate for hydropower generation.

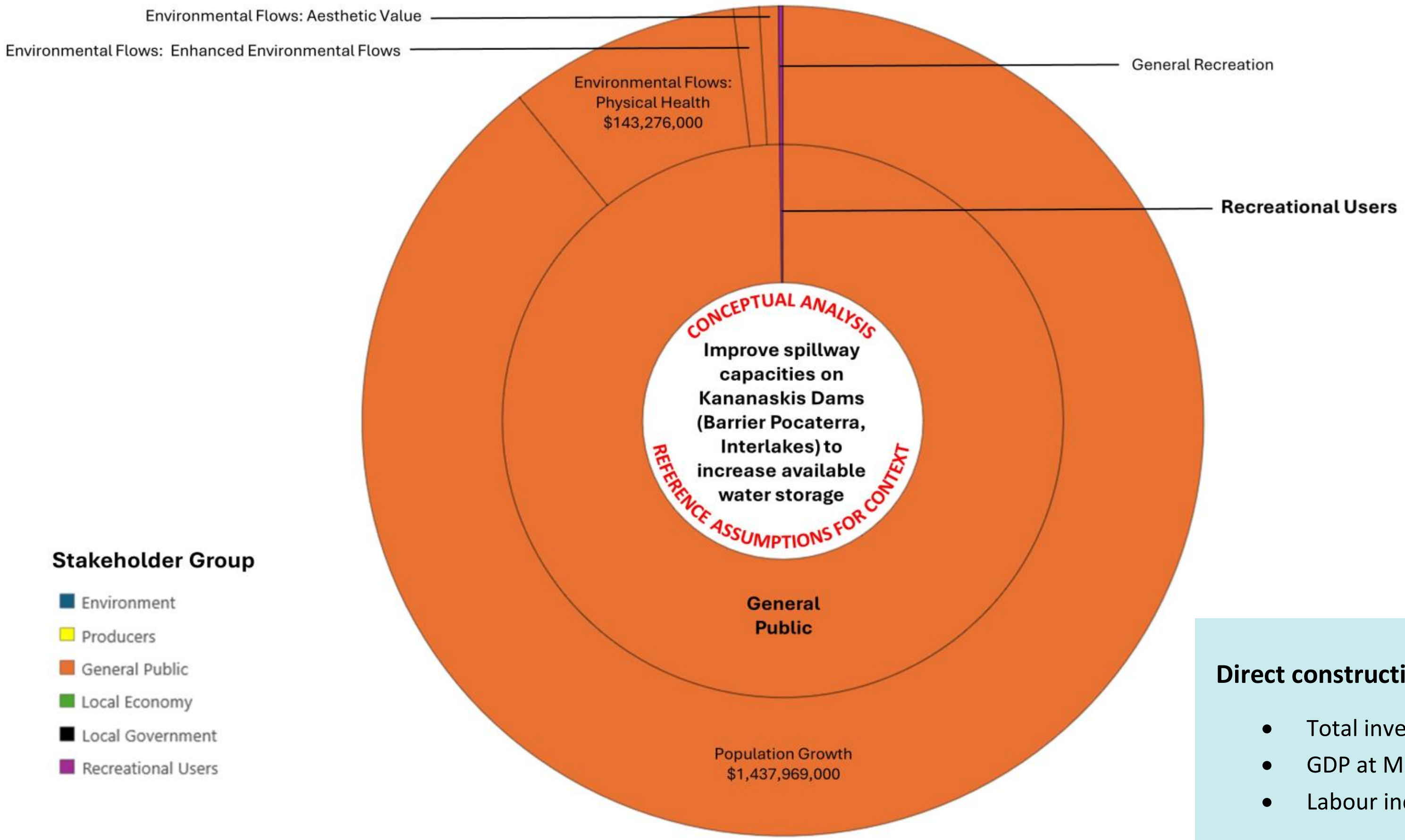
It should be noted that the economic analysis of this project aligns closely with the valuation of the restoration of Spray Lake to Full Supply Level (Section 2.7.4.3). For both projects the assumptions made for the volume of water captured and how that water will be used are similar. These assumptions could be refined for future projects.

In Figure 35, the chart representing the recurring outcome categories and potential Year 1 benefit shows that improvements to storage within the TransAlta system provides significant benefits to the general public. This includes support for year-on-year projected annual population growth at 1.5% in the Bow River basin up to a potential maximum of over 272,000 additional people.

In addition to this population growth, the reservoir storage can potentially provide additional river flows supporting recreational opportunities and improvements to the physical health of basin residents through improved source water quality.

The total value created and lost is shown in Figure 36 and shows that no value is lost as a result of improving spillway capacity of existing reservoirs. This is because it is not anticipated there would be any additional environmental impact through improving spillway capacity. The economic impact to hydropower generation from adding more storage to the system is not considered as part of the analysis but should be investigated in a future study.

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| no additional | 272,727 | 34,400 | 0 | no additional | 0 | 37,004 | 37,004 |

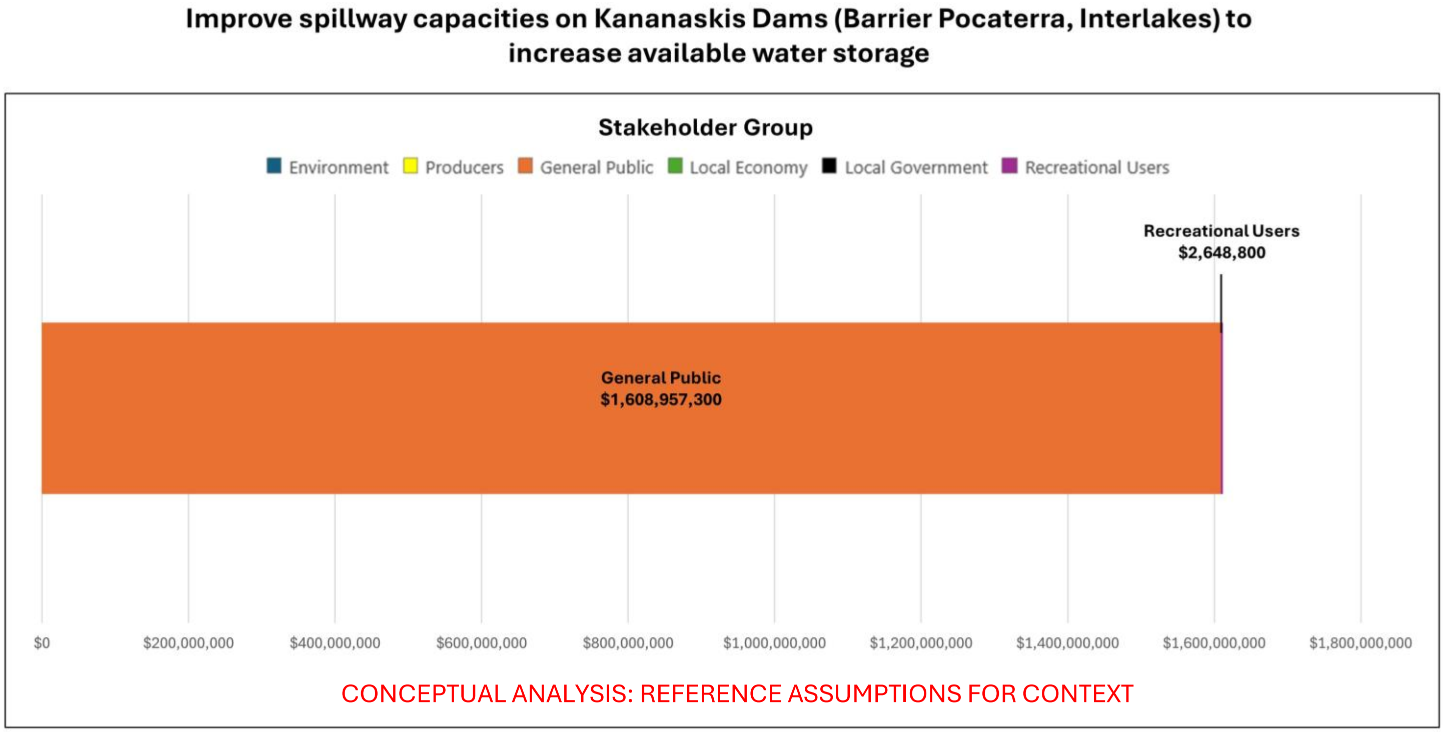


**Direct construction benefits:**

- Total investment costs: $310 million
- GDP at Market Prices: $221 million
- Labour income: $146 million

**Figure 35. Annually recurring outcome categories due to the improvements to spillway capacity in the Kananaskis system (Barrier, Pocaterra, Interlakes, with only Year 1 values shown).**

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| No additional | 272,727 | 34,400 | 0 | No additional | 0 | 37,004 | 37,004 |



Improve spillway capacities on Kananaskis Dams (Barrier Pocaterra, Interlakes) to increase available water storage

CONCEPTUAL ANALYSIS: REFERENCE ASSUMPTIONS FOR CONTEXT

**Figure 36. Annually recurring outcome categories by improving Kananaskis system spillway capacities (with gained value shown only for Year 1; no lost value estimated).**

**Direct construction benefits:**

- Total investment costs: $310 million
- GDP at Market Prices: $221 million
- Labour income: $146 million

### 2.7.4.3 Restore Spray Lake Reservoir to its full supply level

**Description**

The construction of reservoirs can result in seepage as water finds the path of least resistance through the dam and erodes its foundation. At initial construction Spray Lake Reservoir was found to have more seepage than expected when at full supply level (FSL). To mitigate this, the reservoir has historically been kept substantially below full supply level, since less storage reduces pressure experienced at the dam foundation, thus reducing seepage.

It is possible to re-engineer the dam to correct this defect, though this approach was not deemed cost-effective if hydropower generation is the only consideration. Engineered restoration of the reservoir to design FSL would add an additional 74,000 $dam^3$ (60,000 ac-ft) of storage to the reservoir. While TransAlta currently has a five-year agreement with the GoA to provide flood and drought mitigation using TransAlta infrastructure, the drought portion of the 2021 agreement only extends to Barrier and the Kananaskis Lakes. However, if both parties were to agree, this agreement could be extended to include Spray Lake Reservoir. This would allow the additional storage to be used to mitigate drought conditions, making restoration substantially more cost-effective.

**Modelling assumptions**

Storage of the Spray Lakes Reservoir was increased by 74,000 $dam^3$ (60,000 acre-feet).

Original storage continues under hydropower operation; additional storage (74,000 $dam^3$ (60,000 acre-feet)) is used for improved river flows during low flow periods or other uses or both. Releases are purely to improve flows in the river and are not made available for irrigation prior to the Oldman confluence in this run.

When flows at Bassano (or Carseland if Eyremore is engaged) fall below 25 $m^3/s$ (900 cfs), a 11.4 $m^3/s$ (400 cfs) supplementation flow is released from Spray's restored volume. This release continues until flows exceed 28.3 $m^3/s$ (1000 cfs).

> *A Note Regarding TransAlta Operations in SSROM*
>
> TransAlta operations are simplified by converting the last 10 years (shorter for those reservoirs reoperated under the renewed agreement with the GoA) into daily average elevations. The TransAlta reservoirs try to keep as close to those curves as possible on a daily basis, though they are not allowed to store water called on by senior license-holders (neither are they required to release stored water for downstream use). This approach was developed with assistance from TransAlta staff and agreed upon as being sufficiently representative for our purposes.

**Performance under historical conditions**

As the Spray releases are designated for flow supplementation, not irrigation, it is expected there are effectively no changes to irrigation shortages (Figure 37).

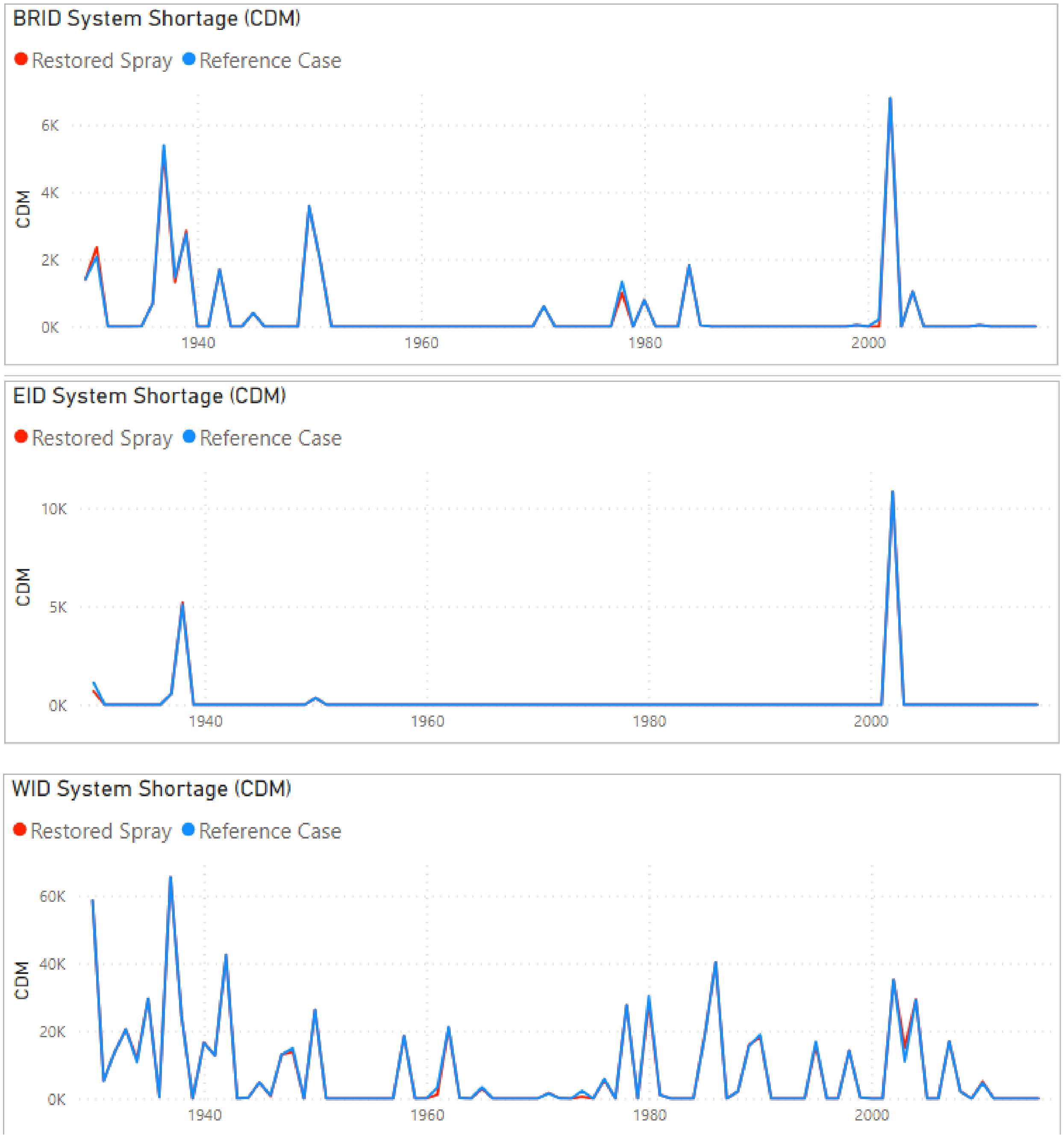


**Figure 37. Restoration of Spray Lakes Reservoir to its full supply level (red) compared to the Reference Case (blue) showing BRID, EID, and WID irrigation shortages.**

The restoration of Spray Lakes Reservoir provides significant environmental benefits, especially in the targeted Bassano reach of the river. Under the historical record, there were 57% fewer days of flow in the low (11-22.6 m$^3$/s (400-800 cfs)) category and 57% more days in the “improved” (22.6-34 m$^3$/s (800-1200 cfs)) flow category (Figure 38).

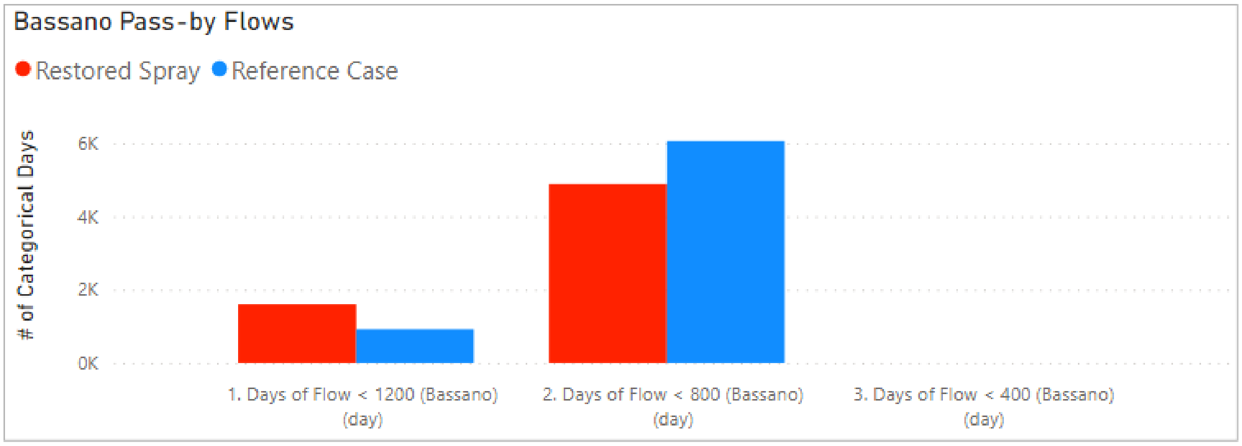


**Figure 38. Restoration of Spray Lakes Reservoir to its full supply level (red) compared to the Reference Case (blue) showing environmental flow past Bassano.**

The restored portion of Spray was modelled as an independent reservoir in SSROM for ease of implementation and operation. However, it is evident that this additional storage is used frequently and aggressively (Figure 39). The main limitation to this alternative seems to be the ability to fill it. Spray Lakes receives a relatively small proportion of the total TransAlta system inflow, and thus is unable to reliably refill the additional storage, given its aggressive use.

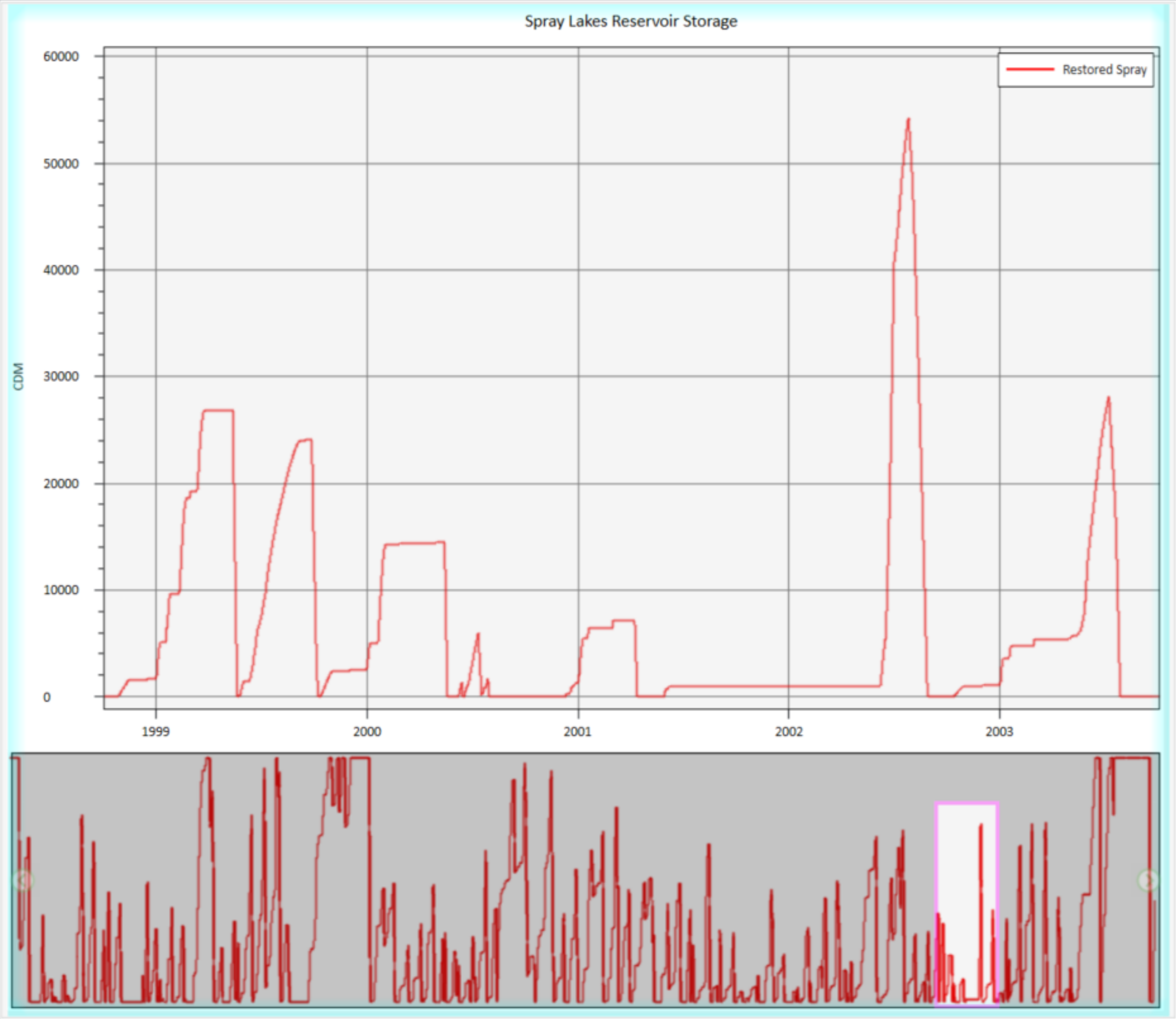


**Figure 39. Restoration of Spray Lakes Reservoir to its full supply level storage.**

**Contextualizing the Economic Analysis**

The economic analysis provides a conceptual indication of the potential value added and lost from the implementation of a project. Assumptions used in this analysis are influenced by the availability of data and there is room to perform a more granular analysis to refine the net value gained as more information is gathered on the project.

The SSROM modelling indicates that allowing Spray Reservoir to reach full supply level will result in an additional storage capacity of 74,000 dam$^3$ (60,000 acre-feet). For the economic analysis it was assumed that half the additional capacity (37,000 dam$^3$) would be used to support environmental flows and half would be used to support municipal growth. The economic analysis assumes that through agreement with the GoA TransAlta would not use the additional reservoir storage to operate for hydropower generation.

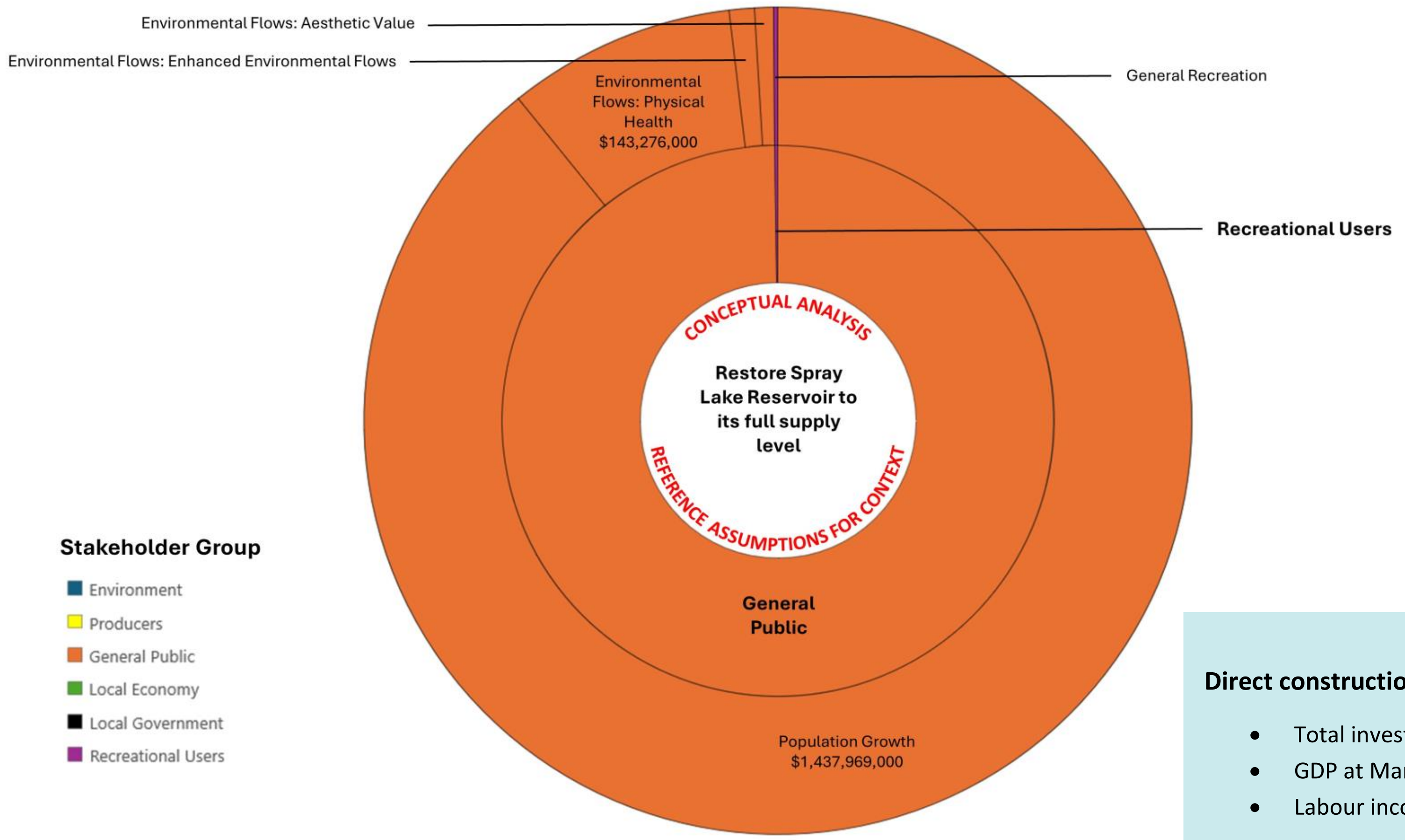
It should be noted that the economic analysis of this project aligns closely with the valuation of the improvements to spillway capacities on the Kananaskis Dam (Section 2.7.4.2). For both projects the assumptions made for the volume of water captured and how that water will be used are similar. These assumptions could be refined for future projects.

In Figure 40, the chart representing the recurring outcome categories and potential Year 1 benefit shows that improvements to storage within the TransAlta system provides significant benefits to the general public. This includes support for year-on-year projected annual population growth at 1.5% in the Bow River basin up to a potential maximum of over 272,000 additional people.

In addition to this population growth, the reservoir storage can potentially provide additional river flows supporting recreational opportunities and improvements to the physical health of basin residents through improved source water quality.

The total value created and lost in Year 1 is shown in Figure 41 and shows that no value is lost as a result of restoring Spray Lakes Reservoir to FSL. This is because it is not anticipated there would be any additional environmental impact through the restoration process and no additional land would be flooded as this restores Spray Lake to its original design capacity. Hydropower generation capacity and timing has not been considered in this economic analysis and should be assessed in future work to understand economic impact more completely.

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| no additional | 272,727 | 34,400 | 0 | no additional | 0 | 37,004 | 37,004 |



**Direct construction benefits:**

- Total investment costs: $125 million
- GDP at Market Prices: $89 million
- Labour income: $59 million

**Figure 40 Annually recurring outcome categories through the restoration of Spray Lakes to FSL (with only Year 1 values shown).**

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| no additional | 272,727 | 34,400 | 0 | no additional | 0 | 37,004 | 37,004 |

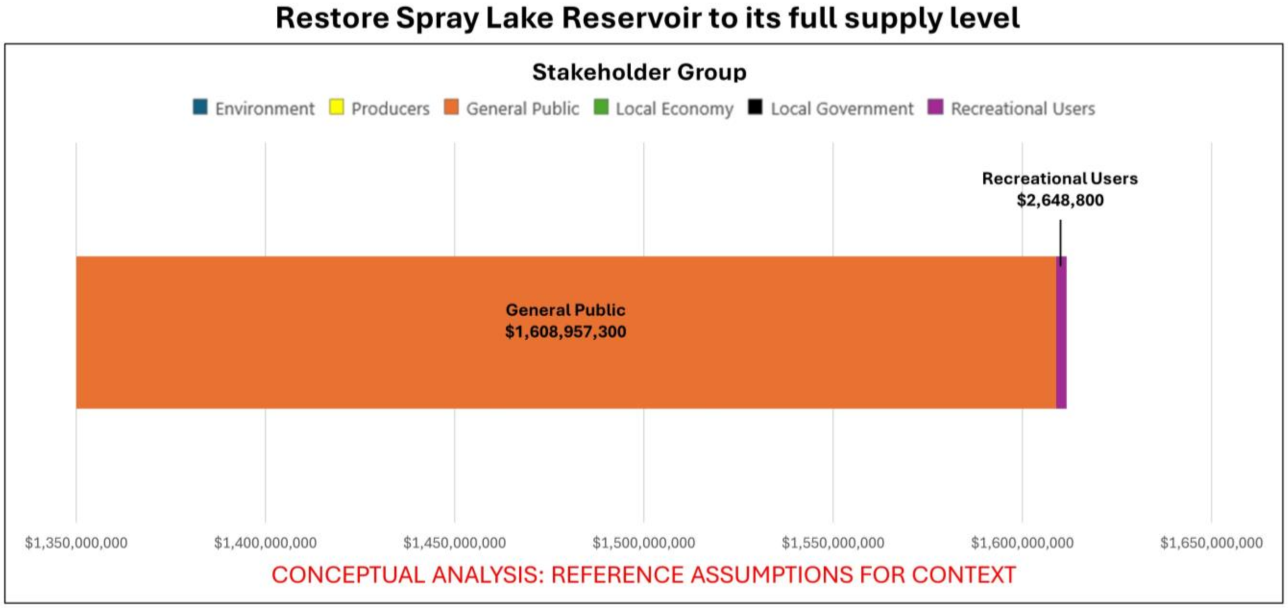


**Figure 41. Annually recurring outcome categories through the restoration of Spray Lakes to FSL (with gained value shown for Year 1; no lost value estimated).**

**Direct construction benefits:**

- Total investment costs: $125 million
- GDP at Market Prices: $89 million
- Labour income: $59 million

### 2.7.4.4 Remove canal bottleneck between Waterton Reservoir and St. Mary Reservoir

**Description**

There is an existing bottleneck in the Waterton Reservoir St. Mary Reservoir canal system, which limits the rate of flow through the canals to 56 $m^3/s$. This option would modify the canal system by reconstructing the portion of the canal limiting the flow as it exits the Waterton Reservoir. This would remove the bottleneck and allow a consistent maximum canal flow rate of 70 $m^3/s$. Increasing the flow rate would allow water to move more rapidly between the Waterton and St. Mary reservoirs, allowing more effective management of the system.

This option provides an incremental benefit to St. Mary River Irrigation District (SMRID) through additional water availability in the St. Mary Reservoir. This option could result in minor flow changes in the Waterton River, which should be considered.

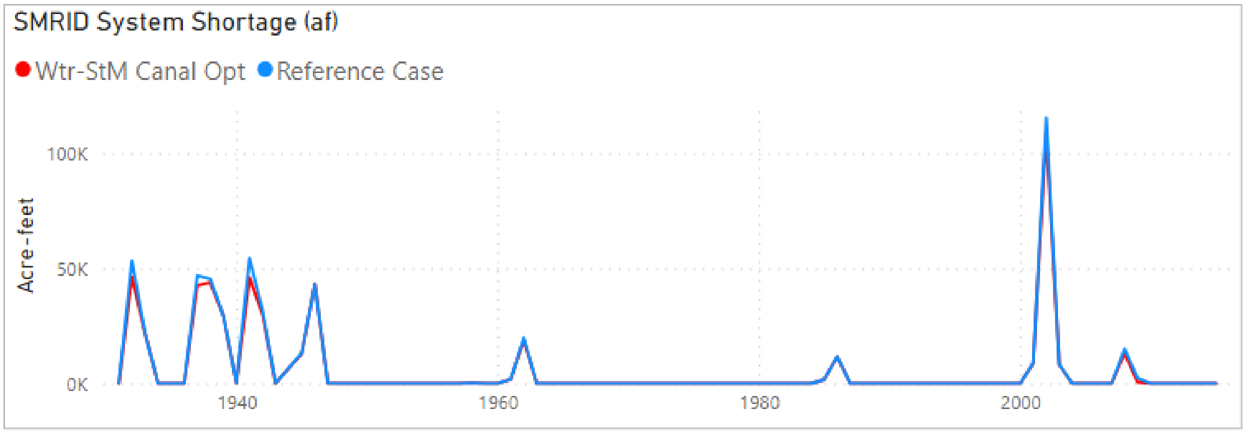
**Modelling assumptions**

Waterton Reservoir would continue to preferentially move water to St. Mary Reservoir during the irrigation season any time St. Mary Reservoir has room to capture it.

**Performance under historical conditions**

By removing the canal bottleneck, water transfer to the SMRID becomes much more efficient. SMRID can divert more water and maintain their internal storage more reliably. This is seen in the reduction of SMRID shortages in Figure 42. The reduction is comparatively small but can be seen in drought years.

Given the benefits of this operation show a preference for one irrigation at direct cost to another, it was not designated as "high performing."



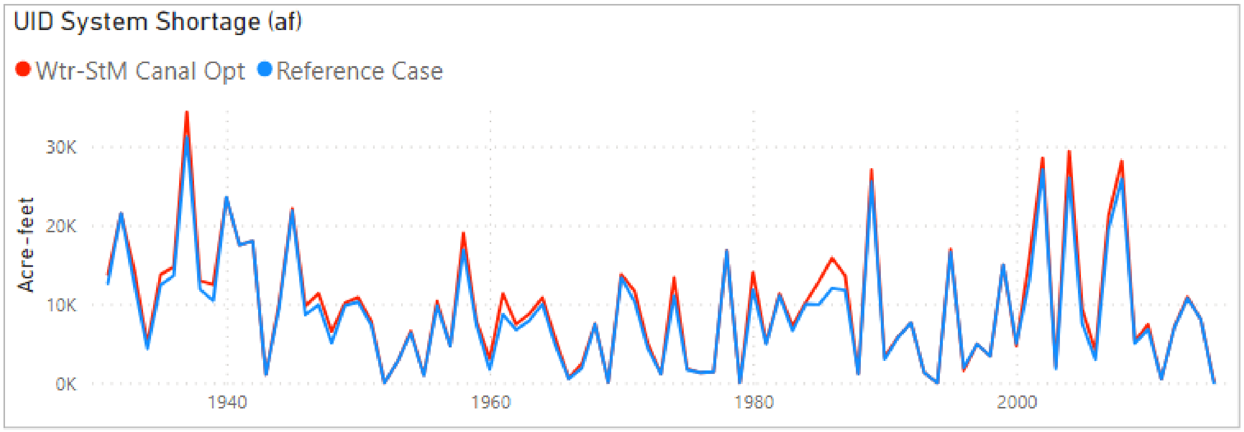


**Figure 42. Removal of the canal bottleneck between Waterton Reservoir and St. Mary Reservoir (red) compared to the Reference Case (blue) showing SMRID and UID irrigation shortages.**

Removing this bottleneck has a secondary effect, as the current canals create some degree of "reservoir balancing" between St. Mary Reservoir and Waterton Reservoir. Without this bottleneck, Waterton Reservoir drains more quickly (Figure 43). This is of particular importance for the United Irrigation District (UID), which withdraws from the canal before it reaches St. Mary Reservoir. When Waterton Reservoir falls below critical thresholds earlier, it is physically not able to access that water. As such, the UID sees irrigation shortages. Given the UID has no internal storage to rely on, these shortages can be seen on a regular basis (Figure 42).

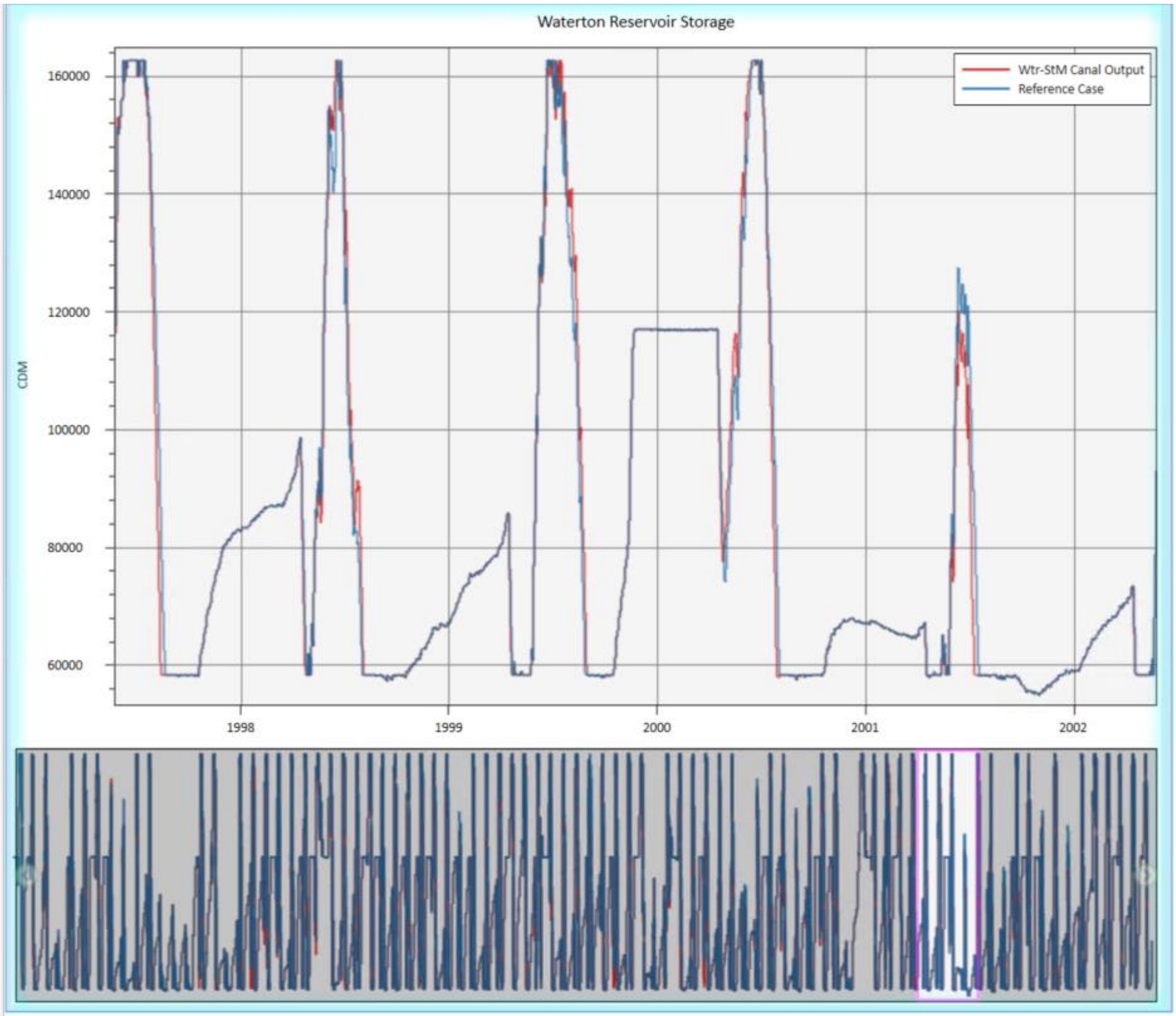


**Figure 43. Removal of the canal bottleneck between the Waterton Reservoir and St. Mary Reservoir (red) compared to the Reference Case (blue) showing Waterton Reservoir storage.**

The results also show an increase in water supply in the St. Mary Reservoir (Figure 44). There could be a potential benefit for fisheries in St. Mary Reservoir if it stabilizes and helps to maintain water levels. St. Mary Reservoir was fully drained in 2022; as such, the impacts to the fisheries of such a severe drawdown are significant. A more stable supply would maintain a better fishery.

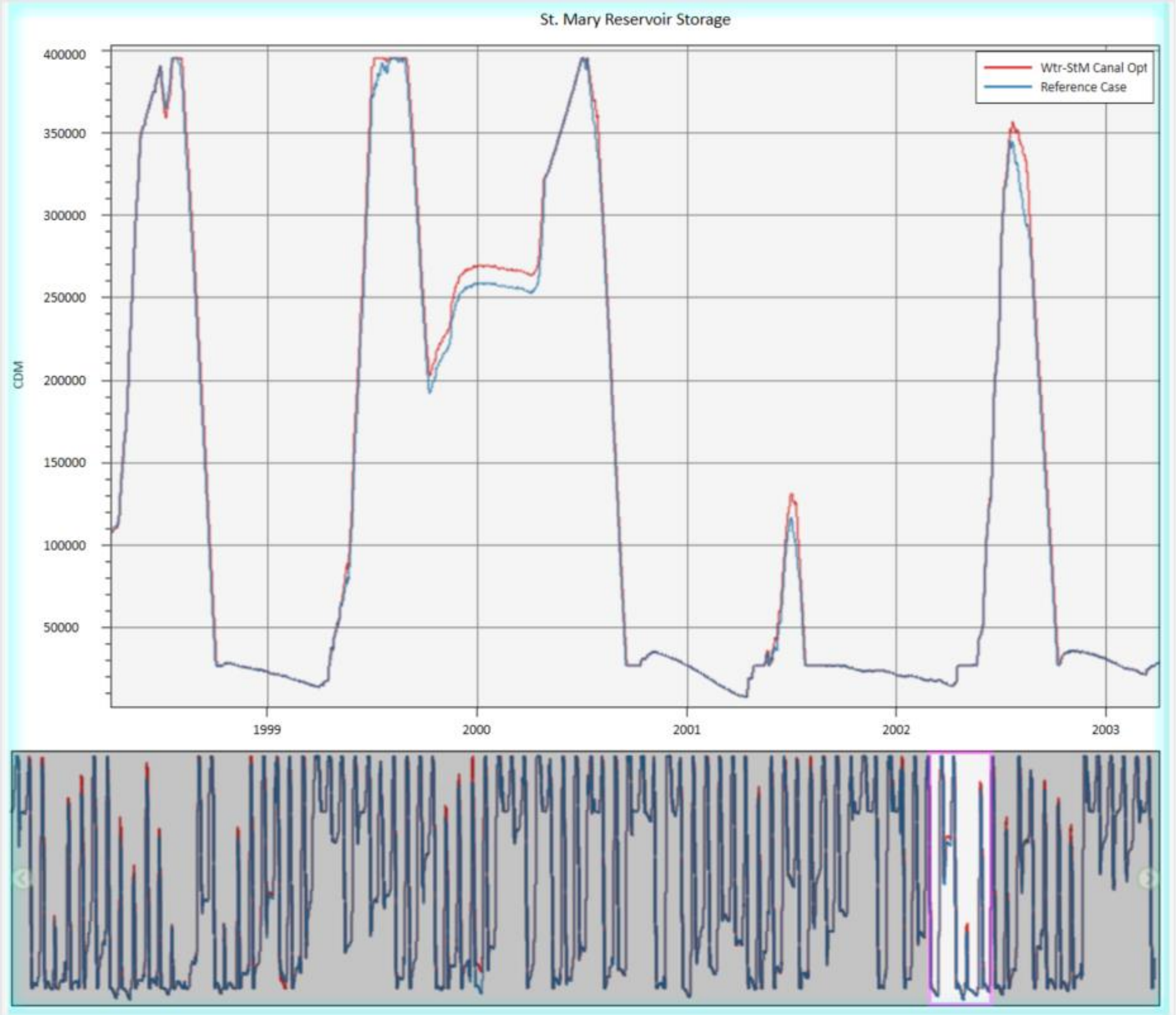


**Figure 44. Removal of the canal bottleneck between the Waterton Reservoir and St. Mary Reservoir (red) compared to the Reference Case (blue) showing St. Mary Reservoir storage.**

### Contextualizing the Economic Analysis

The economic analysis provides a conceptual indication of the potential value added and lost from the implementation of a project. Assumptions used in this analysis are influenced by the availability of data and there is room to perform a more granular analysis to refine the net value gained as more information is gathered on the project.

While not directly providing more water for certain uses, improvements to the canal flow rate allow water to be more easily moved where needed, which allows better utilization of the Waterton and St. Mary reservoirs. The SSROM modelling indicates that upgrading the canal could result in up to an additional 15,000 dam$^3$ (12,150 acre-feet) of water in some years. As the operation of these reservoirs is mainly agriculturally focused, it was assumed that all this water would be used for agriculture in the economic analysis. Although water is focused on agricultural development there is a range of stakeholder benefits as shown by Figure 45. Benefits to the general public are realized from improved security resulting from reduced risk to irrigation districts.

The reduced risk to irrigation districts may in turn lead to development of new irrigation acres. In the economic analysis this is expressed using 15,000 dam$^3$/year of additional water observed in the SSROM model and estimating additional acres of irrigation that could be supported. The analysis identified potentially 10,000 new acres of irrigation which would lead to local economic development as well as some environmental improvements from changes from dryland farming to irrigated acres.

The recurring value created and lost is shown by Figure 46 shows that some value is also lost as a result of the assumed development of new irrigation acres. The value lost relates to reduced phosphorus and nitrogen retention and the assumption that nutrient loading of waterways will increase. The valuation of this impact is around $3 million.

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam$^3$) | Water for Municipal Growth (dam$^3$) | Water for Environmental Flows (dam$^3$) |
|---|---|---|---|---|---|---|---|
| 10,391 | 0 | 0 | 10,391 | 0 | 15,000 | 0 | 0 |

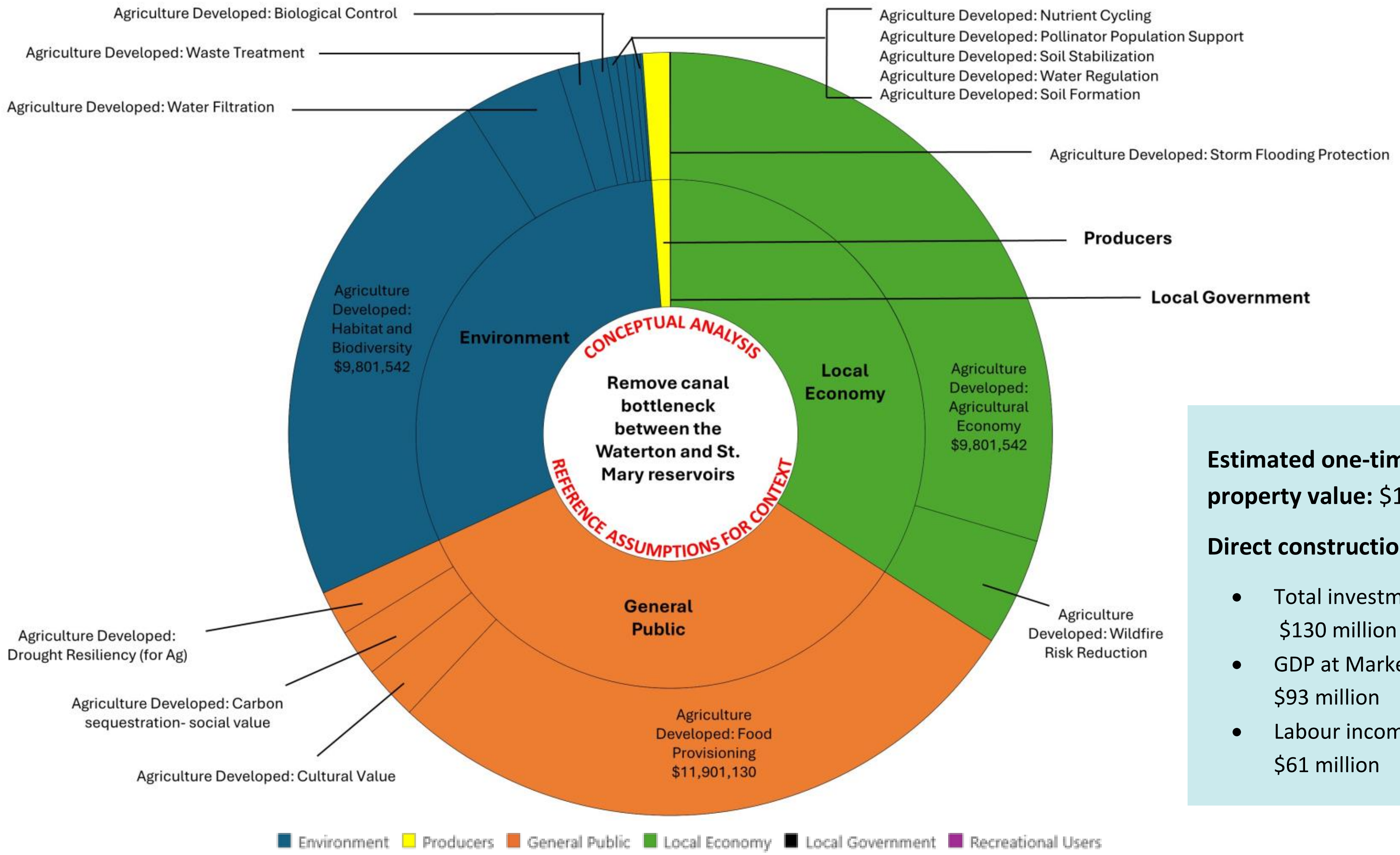


**Figure 45. Annually recurring outcome categories due to canal improvements between the Waterton and St. Mary reservoirs (with only Year 1 values shown).**

**Estimated one-time increase in property value:** $101 million

**Direct construction benefits:**

- Total investment costs: $130 million
- GDP at Market Prices: $93 million
- Labour income: $61 million

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| 10,391 | 0 | 0 | 10,391 | 0 | 15,000 | 0 | 0 |

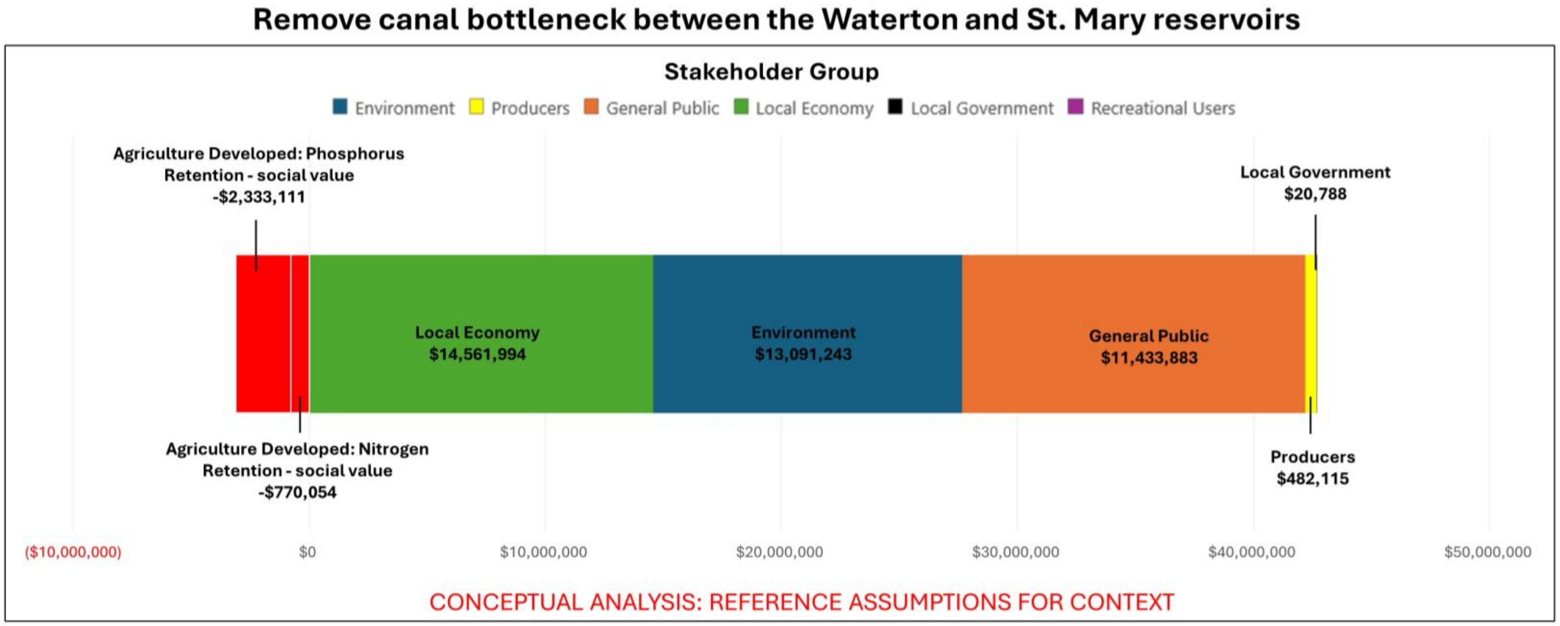


**Figure 46. Annually recurring outcome categories due to canal improvements between the Waterton and St. Mary reservoirs (with gained and lost value shown only for Year 1)**

**Estimated one-time increase in property value:** $101 million

**Direct construction benefits:**

- Total investment costs: $130 million
- GDP at Market Prices: $93 million
- Labour income: $61 million

#### 2.7.4.5 Build off-stream water storage in the Red Deer River basin (to support Acadia and Special Areas Irrigation Project)

**Description**

The Acadia and Special Areas Irrigation Project is located in the Municipal District of Acadia and Special Areas near the Alberta/Saskatchewan border. This option explores additional expected future water demand within the Red Deer River basin. The main purpose of the project is to provide water for irrigation purposes as well as water storage needed for irrigation. A comprehensive assessment of the project is ongoing to assess its feasibility with the GoA, the MD of Acadia, the Special Areas Board, and the Canada Infrastructure Bank.

Development of the irrigation project includes the construction of two off-stream reservoirs, which will provide a live storage volume of 168,000 dam$^3$ (136,200 acre-feet). The Acadia and Special Areas Irrigation project will have a water licence which is bound by the WCO. The off-stream reservoirs are intended to support the irrigated acres when flow in the river is below the WCO threshold.

In the development of the Adaptation Roadmap for the SSRB, the Acadia and Special Areas Irrigation Project was considered part of the Reference Case, and no hydrological or economic analysis of the off-stream storage to support the Acadia and Special Areas Irrigation Project was conducted as part of this project. However, a complete assessment of the storage requirements has been undertaken by the Acadia and Special Areas Project team as part of the ongoing Feasibility assessment of the irrigation project.

**Modelling assumptions:**

Since this option is part of the Reference Case, no hydrological assessments were completed as part of this project. Further ongoing modelling is being done under the feasibility of the Acadia Special Areas Irrigation Project.

**Economic analysis**

Economic analysis for this option was not completed due to the ongoing feasibility study of the Acadia and Special Areas Irrigation Project. An economic analysis will be assessed at a later phase as part of the Acadia and Special Areas Irrigation Project.

#### 2.7.4.6 Build new Western Irrigation District water storage

**Description**

Western Irrigation District (WID) is highly dependent on river flows with limited available off-stream storage. With current infrastructure, the WID is substantially less resilient under drought conditions than other large irrigation districts on the Bow River.

As additional storage is a priority for the WID, the decision was made to explore increasing the available off-stream water storage capacity in the WID through the construction of 37,000 dam$^3$ (30,000 ac-ft) of additional off-stream storage. Since this is only a screening effort at this time, the modelling team chose to optimally locate the storage centrally within the district.

In-district storage significantly reduces the risk to irrigators and minimizes crop losses during periods when Bow River diversions are unavailable.

Lower diversion rates from the Bow River would likely benefit the Bow River system, particularly during the summer months, as this would reduce the water withdrawn during the summer, resulting in more water for the environment and other downstream users.

### Modelling assumptions

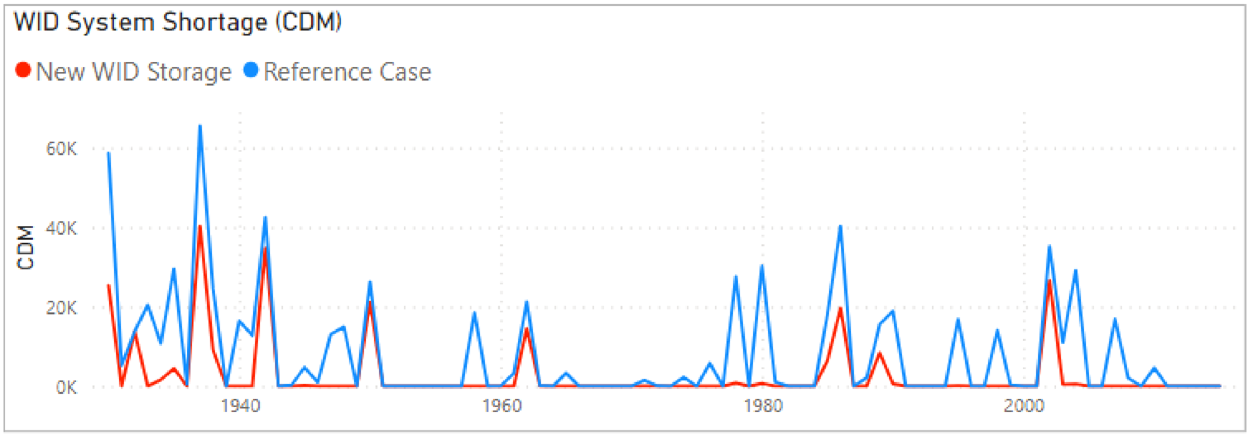
An additional 37,000 dam$^3$ (30,000 ac-ft) of storage in the WID operated as typical irrigation storage.

Storage is located so it can feed all WID canals and acres which provides maximum potential benefits.

### Performance under historical conditions

As expected, the new water storage provides significant benefit to WID. Shortages are almost eliminated in most dry years (e.g. 1980) as seen in Figure 47. Even in many of the most severe droughts, including the multi-year droughts of the 1930's, shortages are dramatically reduced. At 37,000 dam$^3$ (30,000 ac-ft), however, the additional storage is not a panacea. In the worst droughts (e.g. 2001) there will continue to be a need for demand management.

Thanks to the informal agreements between the EID, BRID, and WID, this off-stream storage also provides some small secondary benefits to BRID. When WID is able to rely on storage, BRID's river-dependent acres are granted additional water since WID will use stored water rather than cause BRID's river-dependent acres to go dry. Figure 47 also shows the small reduction in BRID shortages during severe droughts. Note that these shortages are almost entirely confined to the irrigated acres which are not supported by district shortage and require a substantial carriage flow.



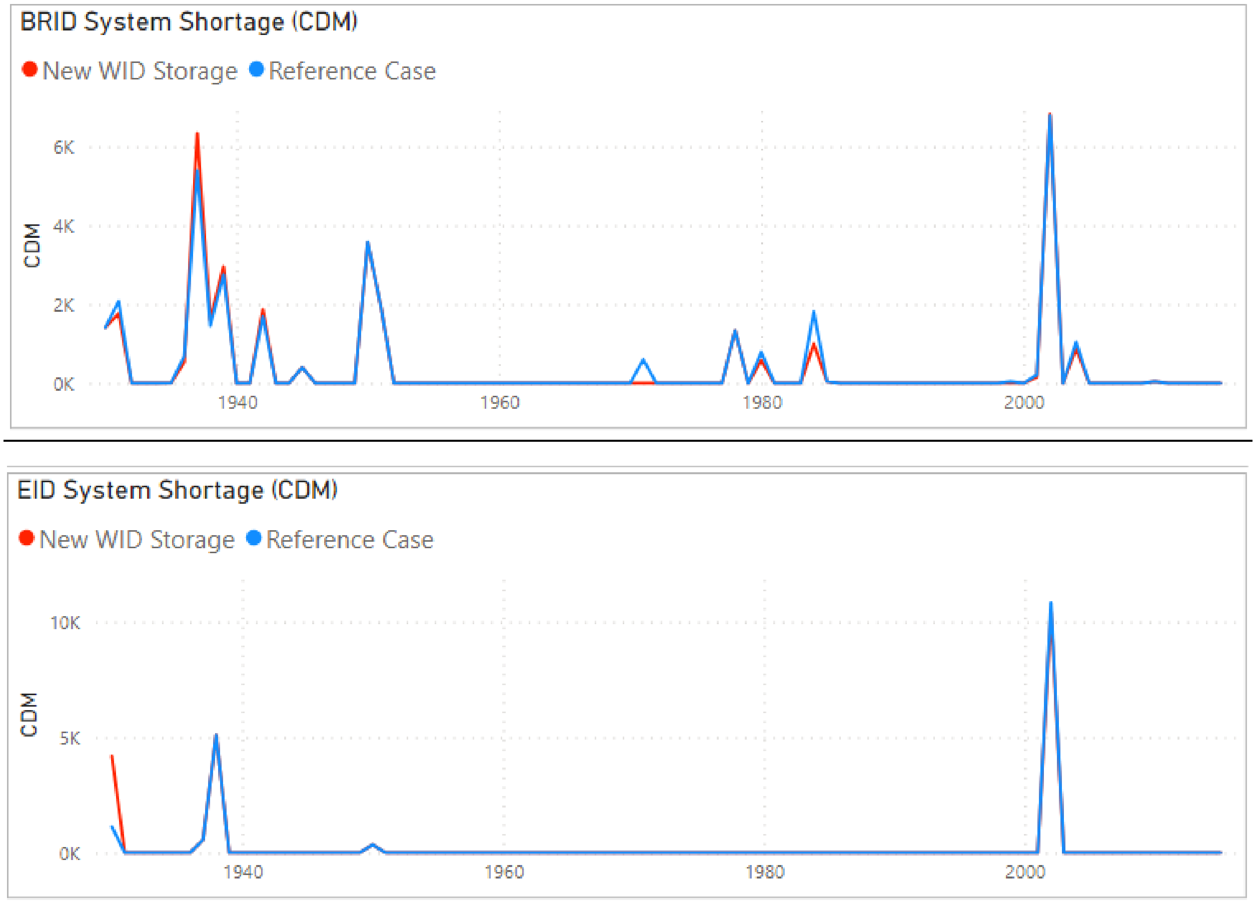


**Figure 47. New water storage in the WID (red) compared to the Reference Case showing the WID, BRID, and EID irrigation shortages.**

### Contextualizing the Economic Analysis

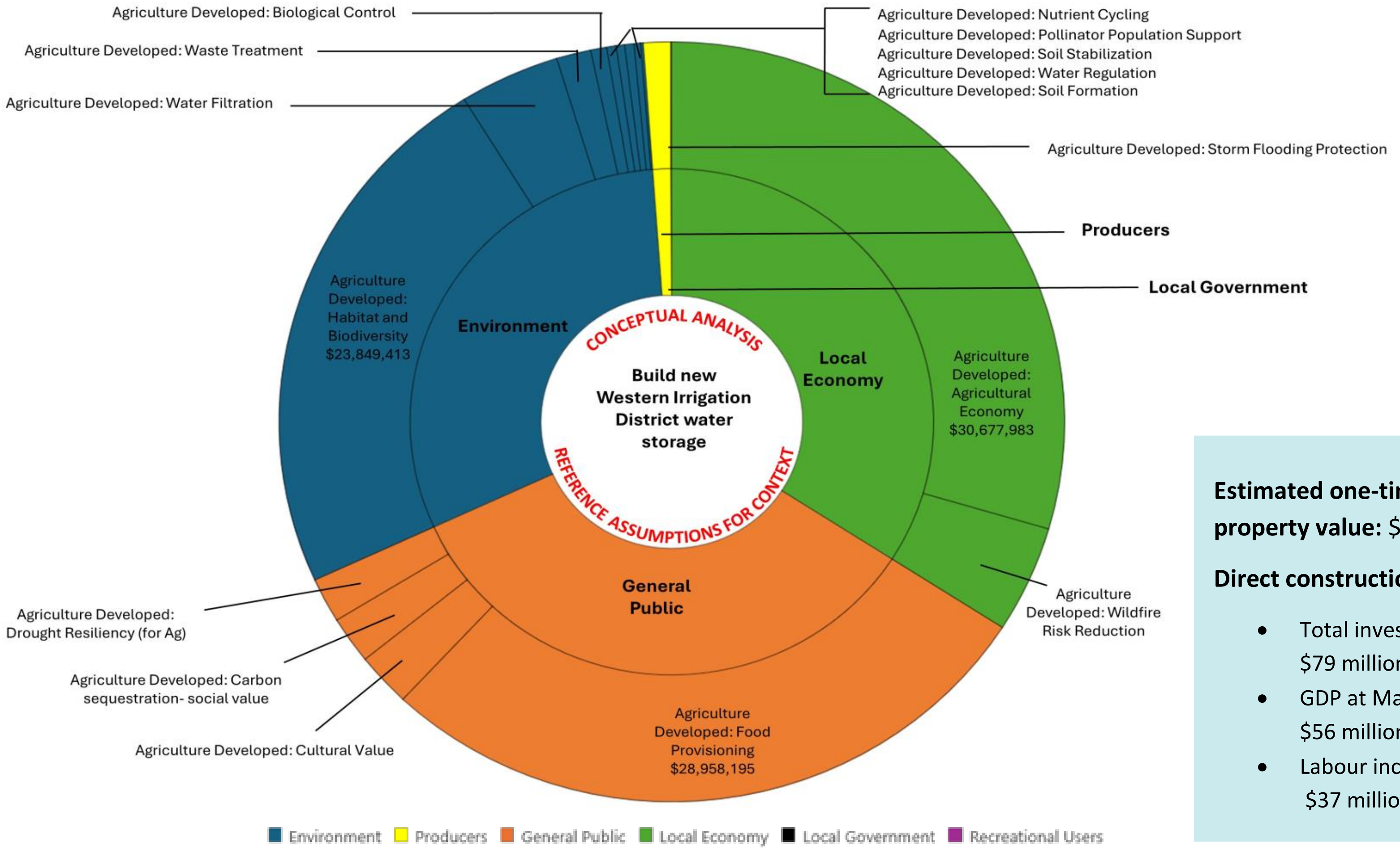
The economic analysis provides a conceptual indication of the potential value added and lost from the implementation of a project. Assumptions used in this analysis are influenced by the availability of data and there is room to perform a more granular analysis to refine the net value gained as more information is gathered on the project.

As many storage options and approaches are under consideration, it was assumed new off-stream storage in the WID would comprise a total live storage volume of 37,000 $dam^3$ (30,000 acre-feet). Since this would be wholly operated for the benefit of the WID, and all storage was assumed to be for agriculture as part of the economic analysis. The resulting storage would lead to reduced risk to the irrigation district or lead to the development of around 26,000 additional irrigation acres leading to improvements in the local economy.

Although wholly operated for agricultural purposes the agricultural sector is not the only beneficiary of new irrigation storage. The development of new acres would lead to a direct improvement in food security for all Albertans which directly benefits the general public as shown by Figure 48. The development of new irrigation acres would also improve environmental outcomes in the form of improved biodiversity compared to dryland farms.

The total value created and lost in Year 1 is shown in Figure 49 and shows that some value is also lost as a result of the assumed development of new irrigation acres. The value lost relates to reduced phosphorus and nitrogen retention and the assumption that nutrient loading of waterways will increase. The valuation of this impact is around $7.5 million.

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| 25,991 | 0 | 0 | 25,291 | 754 | 37,004 | 0 | 0 |



**Estimated one-time increase in property value:** $247 million

**Direct construction benefits:**

- Total investment costs: $79 million
- GDP at Market Prices: $56 million
- Labour income: $37 million

**Figure 48. Annually recurring outcome categories due to new off-stream storage in the WID (with only Year 1 values shown).**

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| 25,991 | 0 | 0 | 25,291 | 754 | 37,004 | 0 | 0 |

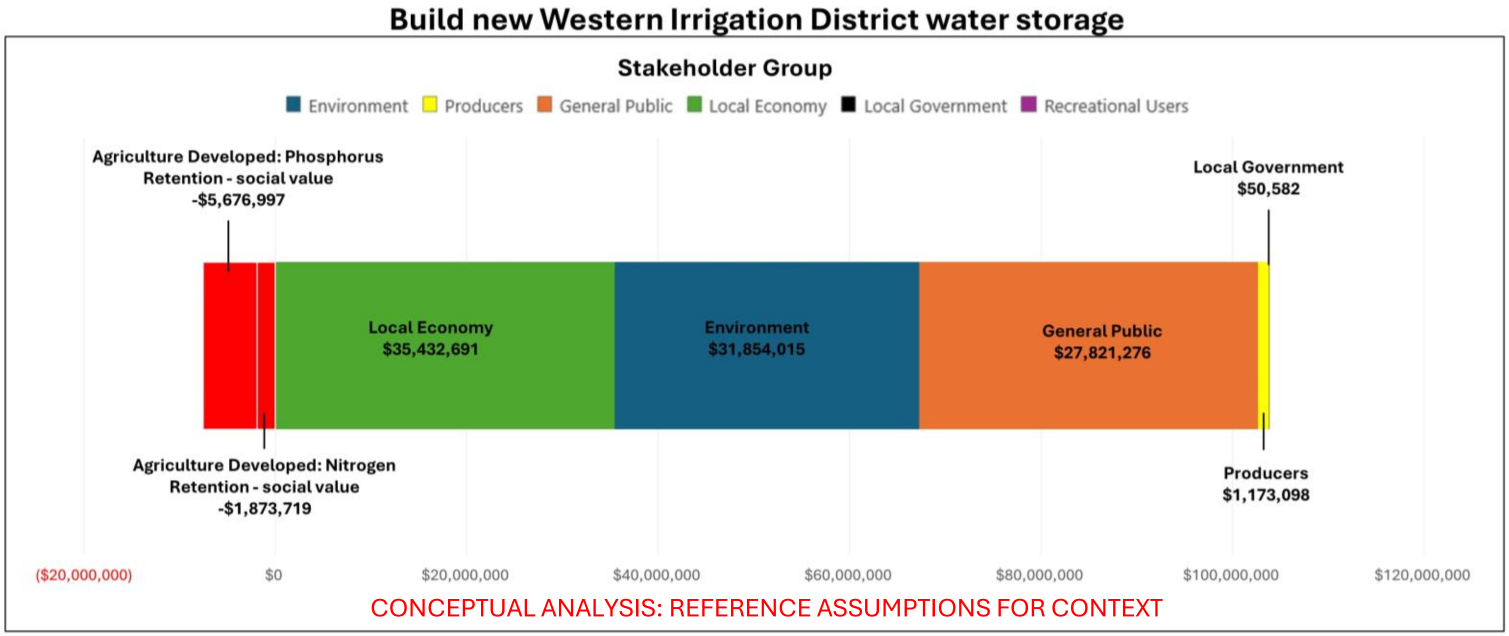


**Figure 49. Annually recurring outcome categories due new off-stream storage in the WID (with gained and lost value shown only for Year 1).**

**Estimated one-time increase in property value:** $247 million

**Direct construction benefits:**

- Total investment costs: $79 million
- GDP at Market Prices: $56 million
- Labour income: $37 million

#### 2.7.4.7 Construct weir at Medicine Hat to increase water level at intake

**Description**

The Oldman Reservoir, the Oldman River, and its tributaries are operated to maintain a flow of 42.5 $m^3/s$ past the City of Medicine Hat. One purpose of this is to maintain adequate river depth for the water treatment plant intakes. The reliance on river flows poses a risk to the City of Medicine Hat in times of drought, as it becomes more difficult to maintain this level.

As part of their water management strategy, the City of Medicine Hat could explore the construction of a weir located within the city. A weir can be used to control water levels within the city and maintain an appropriate depth for the water treatment intakes. In addition, it could provide secondary benefits, which would need to be identified.

This option was identified as one with high potential by the WG; however, it was not modelled due to project time constraints. It is suggested that this option be explored independently to fully assess the water security and economic potential for the City of Medicine Hat.

**Modelling assumptions**

This option was not modelled in SSROM as part of this project due to time constraints and the need for additional detail. It is recommended that a future modelling study fully assess the hydrological benefits of this option and identify suitable weir design approaches.

**Contextualizing the Economic Analysis**

This option was not considered as part of the economic analysis. It is suggested that a future study fully explores the economic opportunities and environmental impacts associated with this option.

### 2.7.5 Adaptation Roadmap for the SSRB strategies: Level 3

The Adaptation Roadmap for the SSRB options explored in Level 3 consist of large infrastructure projects, which may require 20 years or more for impact to be realized. A map of the Level 3 options can be found in Figure 50 below.

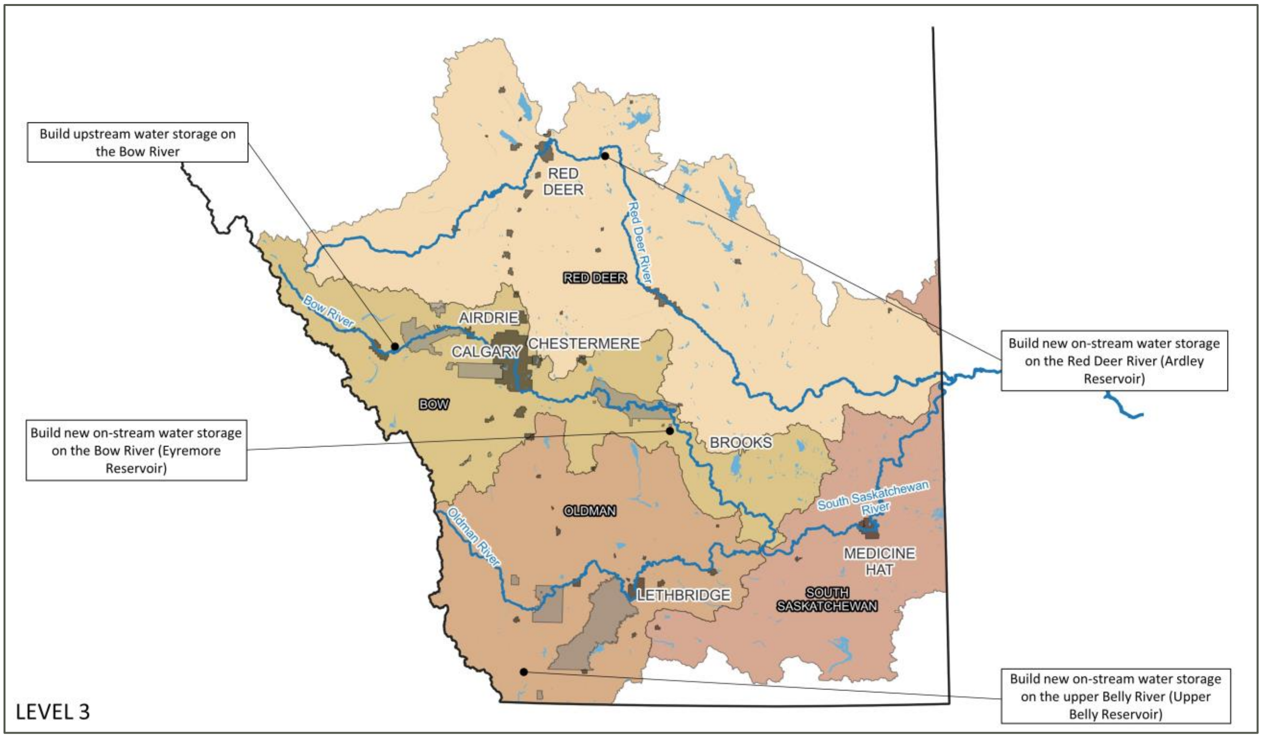


**Figure 50. Identified options in Level 3 across the SSRB.**

### 2.7.5.1 Build upstream water storage on the Bow River

**Description**

Storage on the Bow River, regardless of location, showed substantial promise during modelling, improving overall water security in the SSRB. Upstream water storage on the Bow River and Eyremore Reservoir storage can work in conjunction with each other to provide flood protection during high flow events by passing water from the upstream Bow water storage to be captured in Eyremore Reservoir. This effort allows for lower flows later in the year to be supported by Eyremore. In addition, these operations in the Bow sub-basin support flows in the Oldman and decrease overall shortages in the SSRB.

Although Eyremore Reservoir (Section 2.7.5.2) showed substantial cross-basin benefit, storage, and flood mitigation in the headwaters of the Bow offers the advantage of already undergoing feasibility analysis. This option, without the combined benefit from Eyremore Reservoir, explores construction of additional storage in the upper Bow River sub-basin. The usage and operation of this storage is yet to be finalized; modelling for this effort found it supports flood protection, while also supporting irrigation shortage reduction and environmental low flow augmentation.

Storage in the upper Bow basin is the subject an ongoing study as part of the Government of Alberta's Bow River Reservoir Options (BRRO) project. Phase 1 of the study was completed in 2020 (Wood Environment and Infrastructure Solutions, 2020). Although that report identified several potential locations for additional upstream storage, the WG chose to only consider the "Relocated Ghost Dam" site as part of this assessment. Flood mitigation was not a focus of this assessment, as the specific location of the reservoir was less critical, so the Relocated Ghost Dam site was selected as a representation of storage in the Upstream Bow. Any site selection would require engagement with First Nations rightsholders. It is recognized that the benefits may be increased or reduced depending on the final location and live storage for the chosen reservoir option.

**Modelling assumptions**

The Upstream Bow reservoir is modelled using the following assumptions for the Relocated Ghost Dam option from the BRRO Phase 1: Conceptual assessment:

- A new dam is located approximately 3 km downstream of the existing Ghost Dam.
- Total reservoir storage is 175,100 $dam^3$ (141,950 acre-feet).
- Live reservoir storage is 152,100 $dam^3$ (123,300 acre-feet).
- Maximum reservoir level is 1191.77 m.

Since there are several options being assessed by the BRRO project, the WG suggested using the modelling assumptions for the Relocated Ghost Dam option as a surrogate as part of this assessment, knowing that at least one of the options will likely go forward. In this scenario, modelling assumes:

- The full volume of a new Ghost Reservoir is available for flood/drought operation (i.e. hydropower generation from this dam is incidental and does not drive releases).
- The WID license is amended to allow the uptake of supplemental releases from relocated Ghost Reservoir, even when in “low flow” conditions.
    - WID is allowed to take all of the supplemental release above natural flow up to their current canal capacity 28.3 $m^3/s$ (1,000 cfs) in addition to their existing licensed diversion.
- Operations of new storage follow one of two coarse rulesets:
    - Irrigation use operations: When irrigators place a “call” on the river (i.e., call on their senior license and disallow additional TransAlta storage), an additional 19.8 $m^3/s$ (700 cfs) are released from Ghost Reservoir storage. The irrigation use operations rule curve of the upstream water storage on the Bow River reservoir can be seen in Figure 51.
    - Mixed-use operations: Relocated Ghost makes releases for both irrigation and low flow augmentation. Irrigation release follows the same rules as “Irrigation operations” but only releases a 300 cfs supplementation flow. Low flow augmentation releases an additional 11.3 $m^3/s$ (400 cfs) which *are not allowed to be diverted by irrigators* when Carseland flows drop below 42.5 $m^3/s$ (1500 cfs) and continue until the 7-day average flow exceeds 52.4 $m^3/s$ (1850 cfs) (inclusive of augmentation release). The mixed-use operations of the upstream water storage on the Bow River reservoir can be seen in Figure 52.

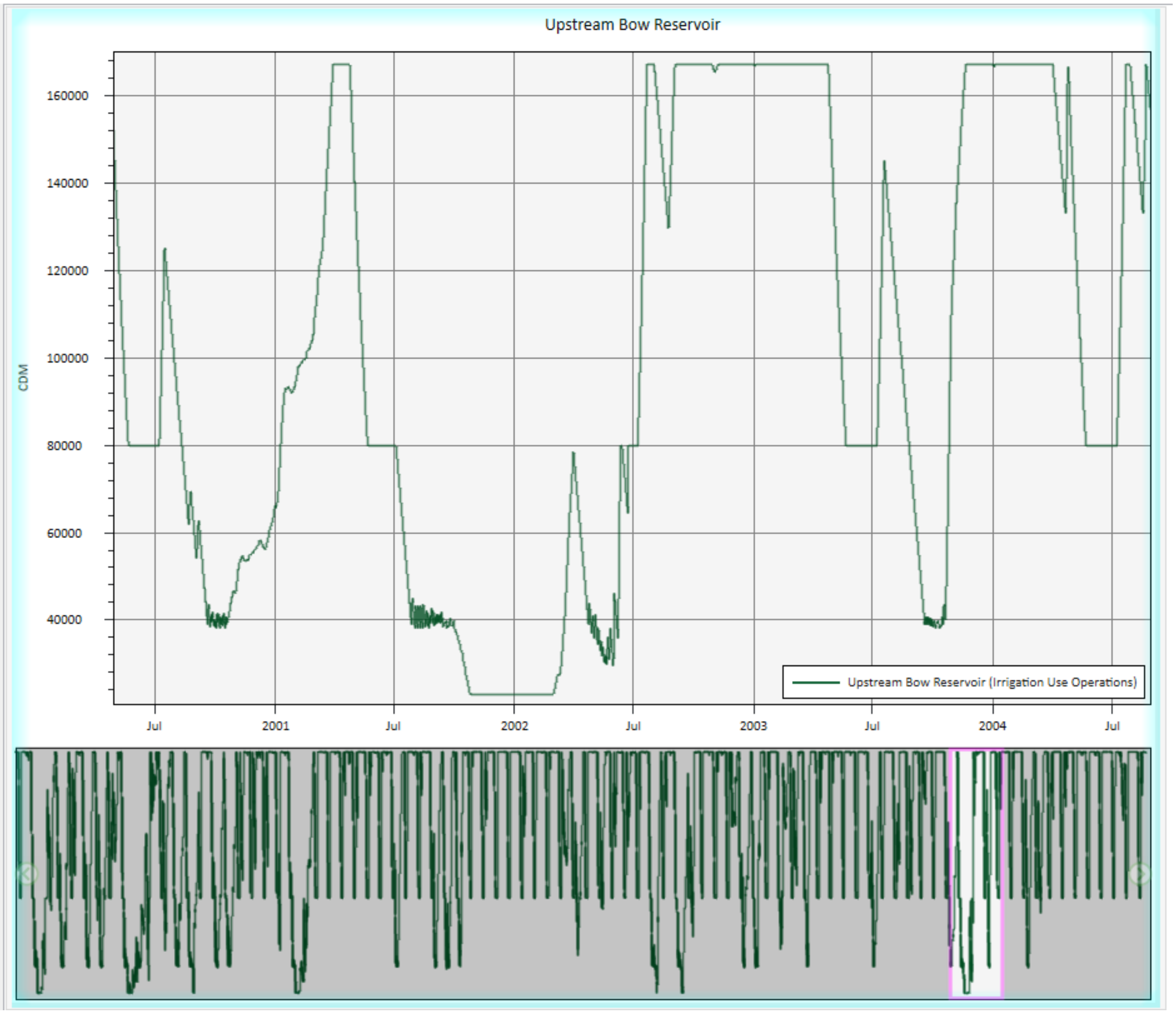


Figure 51. New upstream water storage on the Bow River with irrigation operations rule curve.

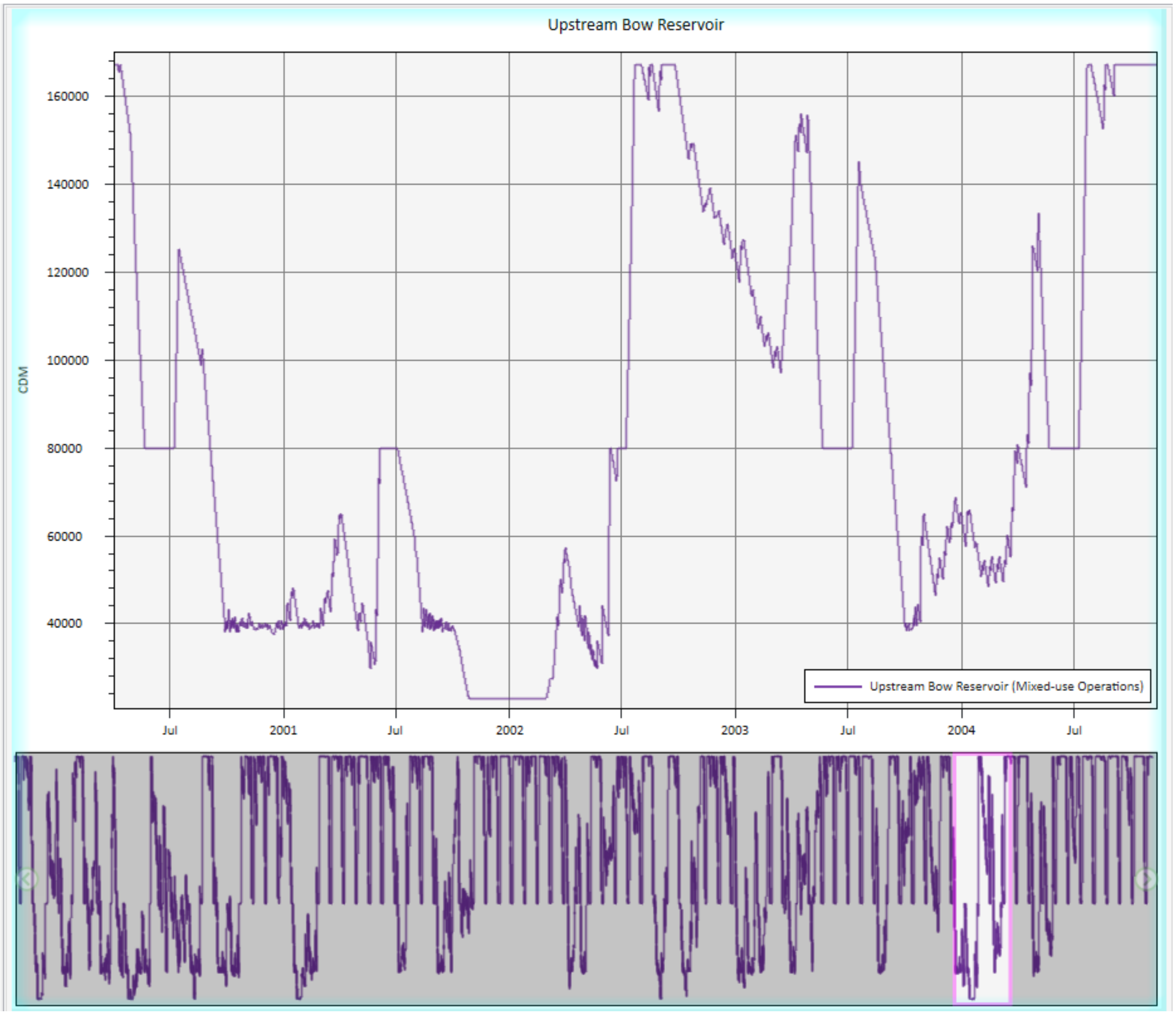


**Figure 52. New upstream water storage on the Bow River with mixed-use operations rule curve.**

### Performance under historical conditions

The initial focus of upstream Bow storage was identifying the maximum shortage mitigation potential of a new reservoir (i.e., irrigation use operations). Since the WID is the most exposed to shortages under historical conditions and infrastructure, new operations and license modification were designed to allow the WID to capture benefit from any new structure. The 19.8 $m^3/s$ (700 cfs) supplemental release was hand-tuned by the Project Teams' modellers to achieve a "reasonable" level of storage utilization (reservoir is used regularly, but not persistently zero as seen in Figure 53). The benefits to the WID are obvious (Figure 54), with shortages almost entirely eliminated. Note that this operation is quite different from the historical Ghost operations. The changes in flow regime which result from this operation could put the BRID headworks at increased risk of shortages relative to historical operations, as they are dependent on river flows. These shortages are generally small, and the WG believes that thoughtful operations could be designed to avoid them.

Prior modelling efforts (Wood Environment and Infrastructure Solutions, 2020) have suggested additional upstream storage (like that proposed here) could also be used for low flow augmentation. This is considered the mixed-use operations model run. As they encompassed a diverse set of perspectives, the group decided to refine these operations and create an alternative set which attempted to improve both economic and environmental conditions in the basin. Under these operations (described in Modeling Assumptions, above) the shortage reductions were less complete, but still substantial (Figure 54). Days of low flows at Carseland (Figure 55) similarly saw performance improvement beyond historical. Thoughtful operations could almost certainly improve these gains and balance uses further. At the screening level, the WG agreed this analysis showed how new upstream storage can and should be operated to meet both economic and environmental objectives.

The mixed-use operations resulted in drawdowns during 2001. It is suggested that further refinement of the operations be done in a later study.

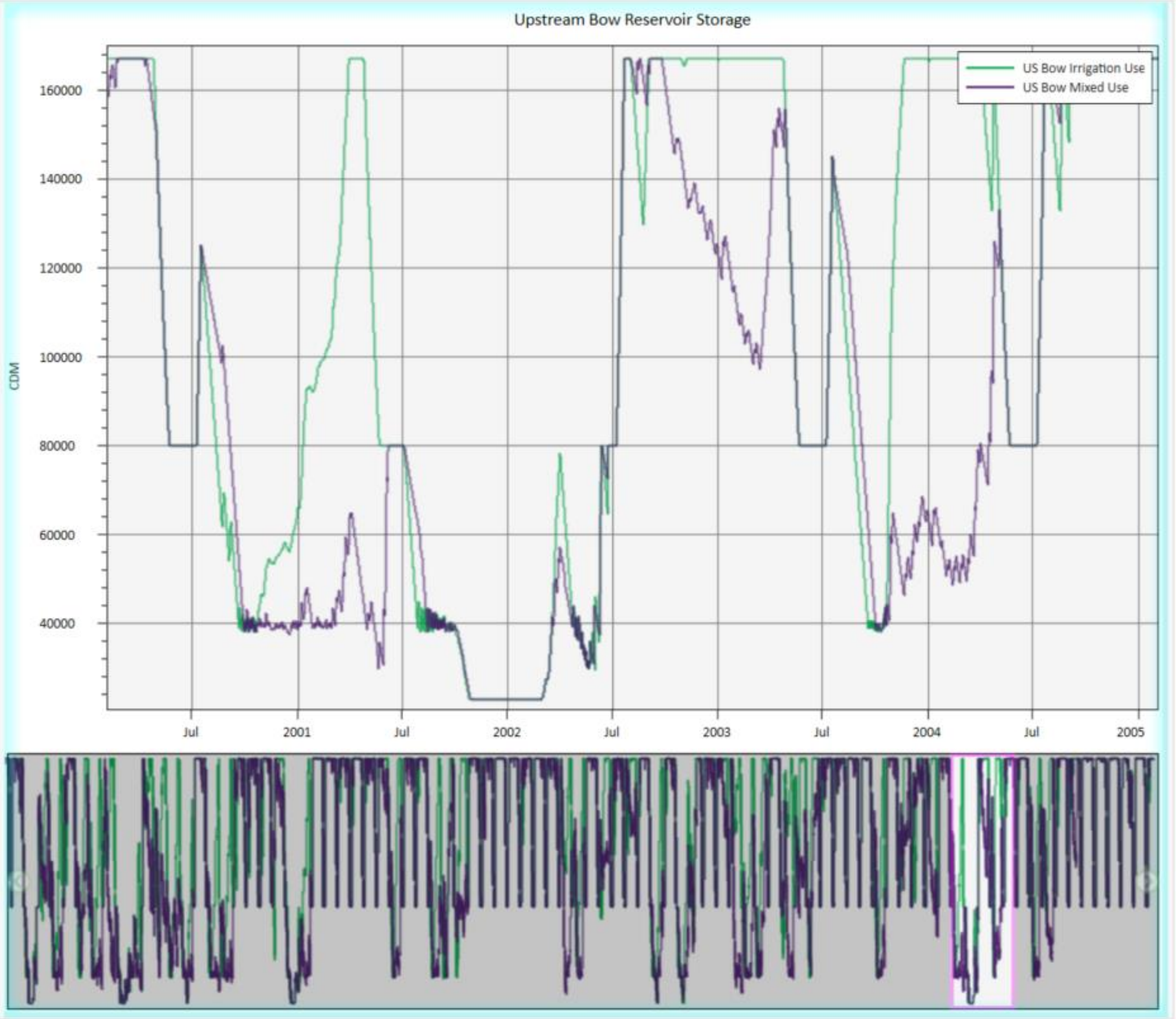


**Figure 53. New upstream water storage on the Bow River with irrigation operations (green) compared to the new upstream water storage on the Bow River with mixed use operations (purple) outlining the new upstream water storage on the Bow River.**

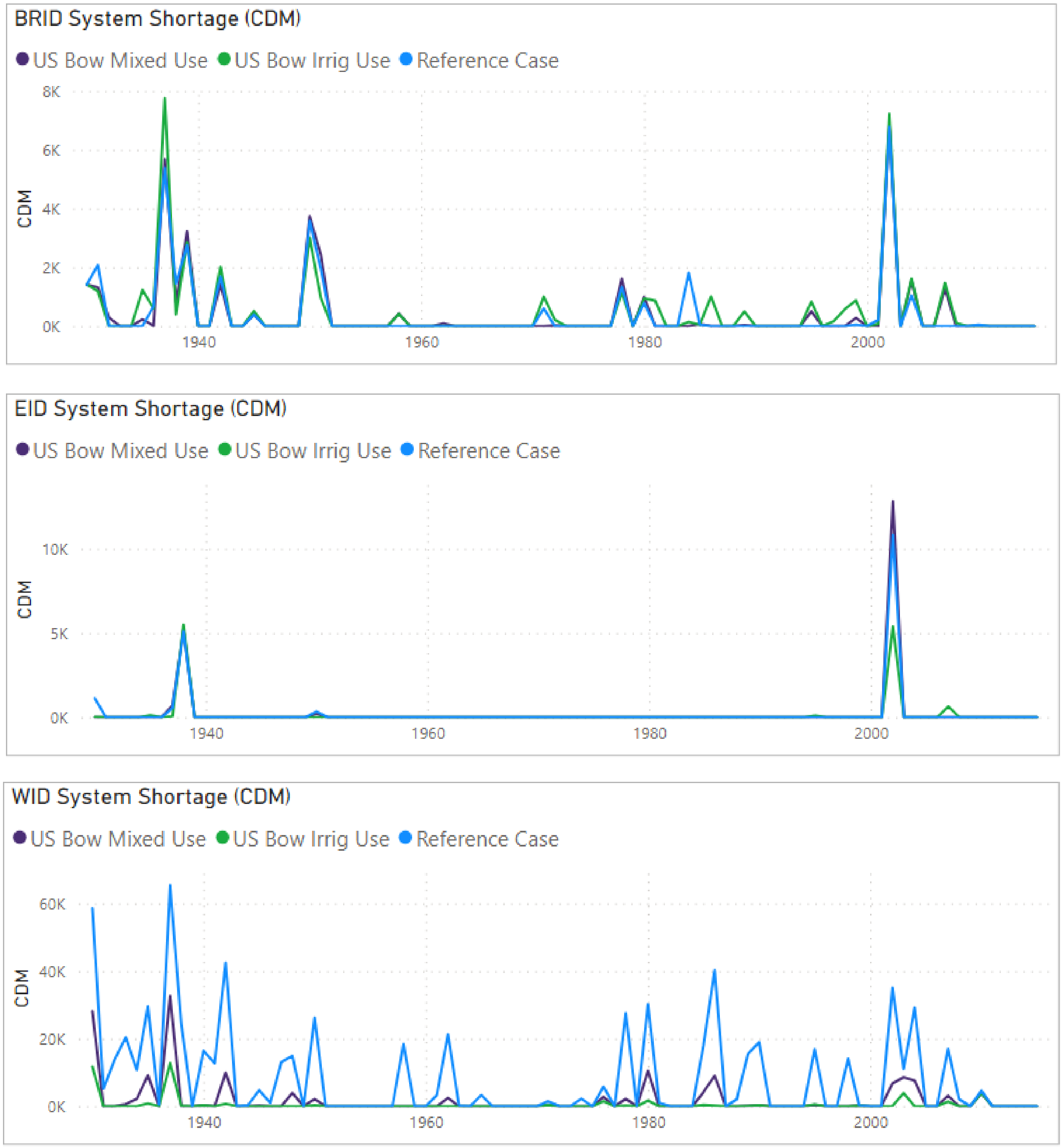


**Figure 54. New upstream water storage on the Bow River with mixed use (purple) and irrigation use (green) operations compared to the Reference Case (blue) outlining the BRID, EID, and WID irrigation shortages.**

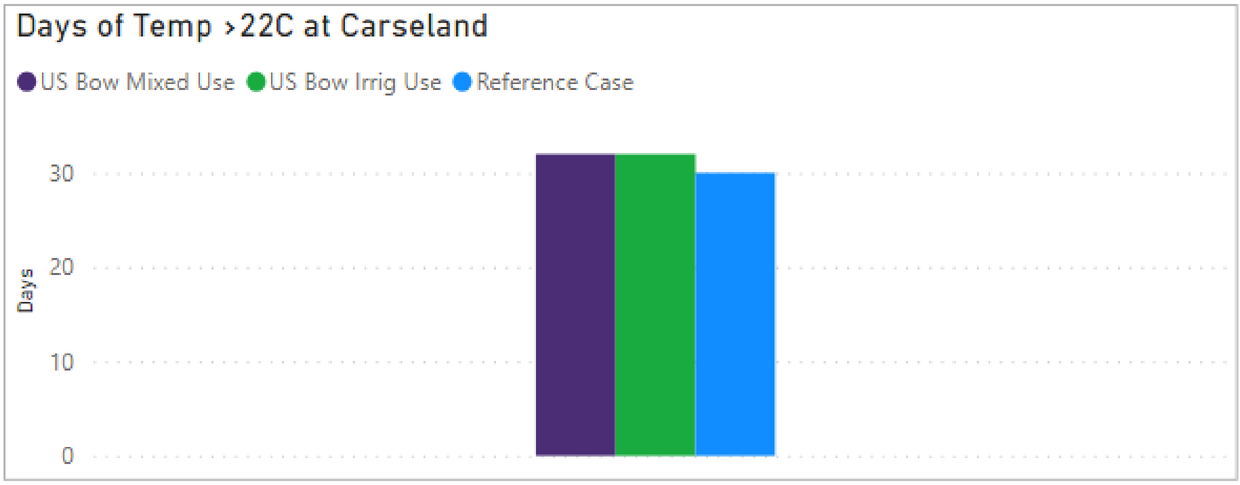


**Figure 55. New upstream water storage on the Bow River with irrigation use and mixed-use operations compared to the Reference Case (blue) outlining the number of stream temperate is 22°C at Carseland.**

## Contextualizing the Economic Analysis

The economic analysis provides a conceptual indication of the potential value added and lost from the implementation of a project. Assumptions used in this analysis are influenced by the availability of data and there is room to perform a more granular analysis to refine the net value gained as more information is gathered on the project.

It was assumed that the development of upstream storage on the Bow River would result in an additional 152,100 dam$^3$ (123,300 acre-feet) of live storage. For the purposes of the economic analysis, it was assumed that one third of this volume of water (50,700 dam$^3$) would be assigned for agricultural development, one third for municipal growth, and one third for environmental flow. The volume split assumes the water will be available for the assigned use when that water use needs it.

In Figure 56, the chart representing the recurring outcome categories and potential Year 1 benefit shows how the development of upstream storage leads to significant benefits for the general public through improved physical health that results from increased flow in the river as well as improved food security for all Albertans as a result of additional food production from irrigation.

The additional water assigned to the agricultural sector could be used to decrease drought risk for the irrigation districts in the Bow basin or facilitate the development of new irrigated acres. For the purposes of the economic analysis, it is assumed that the water would be used for district expansion. The analysis shows that new storage in the Bow River upstream of Calgary could facilitate the development of over 35,000 new irrigated acres. While this results in significant improvement to the local economy which is a direct benefit to the agricultural sector there are also environmental benefits that occur as a result of conversion from dry land to irrigated acres including improvements to habitat and biodiversity.

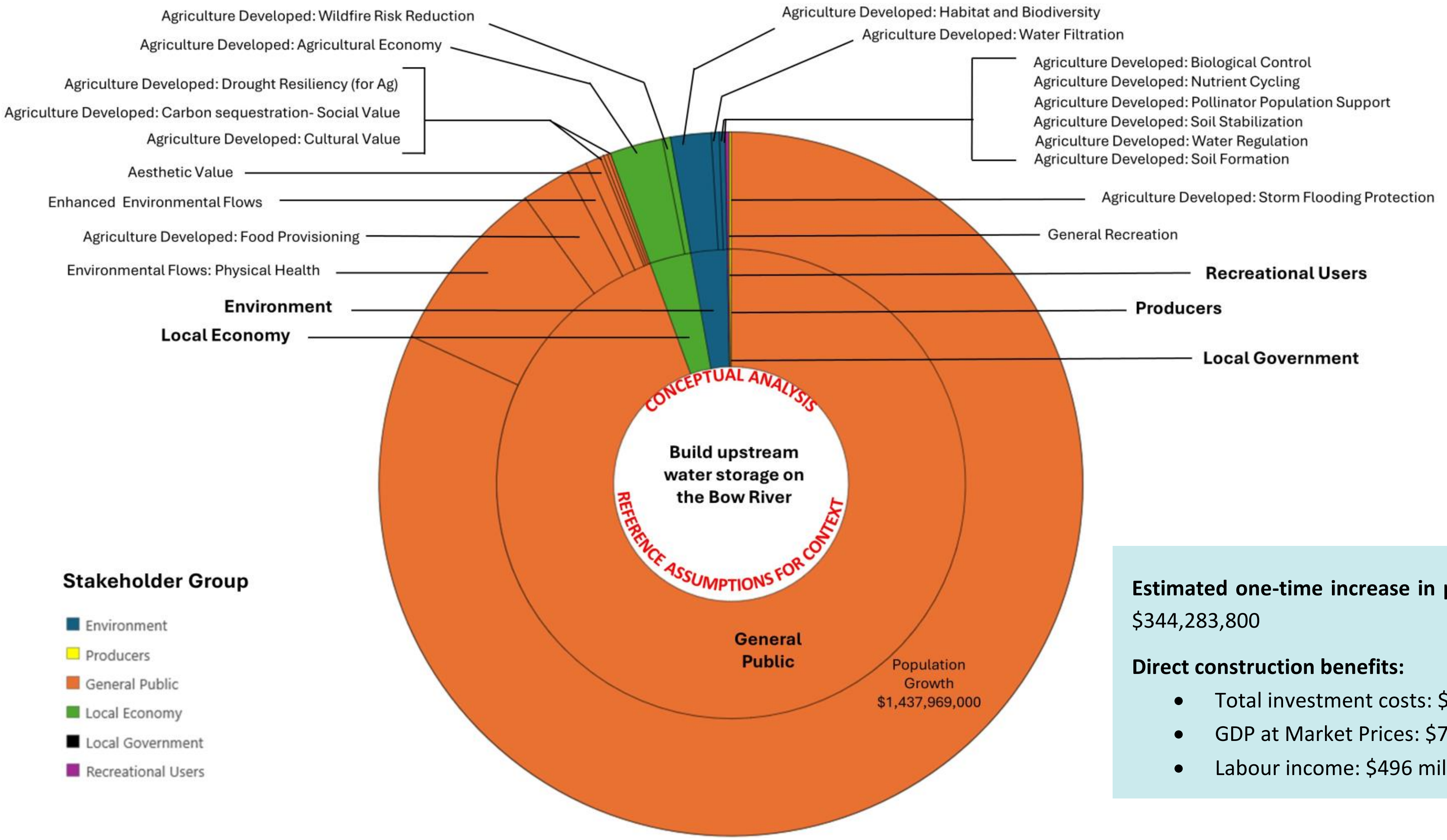
The municipal growth category is an aggregated metric of additional GDP per capita. The water assigned to municipal growth can support long-term population growth in the region. Figure 56 shows that the reservoir can support the projected 1.5% year-on-year growth in the Bow River Basin up to a maximum population increase of over 373,000 new residents based on a per capita demand of 375 L/day.

The development of a new upstream reservoir that partially serves agriculture, municipal needs and the environment could also result in some lost value. Figure 57 shows the annual recurring outcome categories with the value created and lost for Year 1 as a result of the storage. The total value lost is shown to be approximately $10.5 million mainly due to decreased phosphorus and nitrogen retention from f increased agricultural activity and the risk of the resultant runoff accumulating in local watersheds.

The economic assessment did not consider the economic outcomes of flood mitigation that could be significant due to the location of the reservoir upstream of a major city. The economic benefit of flood defence can be quantified in terms of avoided cost and should be considered as part of a more detailed economic assessment.

Additionally, this economic analysis does not consider economic outcomes from potential hydropower generation which should be considered to provide a detailed understanding of economic outcomes.

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| 35,699 | 373,664 | 34,400 | 35,131 | 568 | 50,700 | 50,700 | 50,700 |



**Estimated one-time increase in property value:** $344,283,800

**Direct construction benefits:**

- Total investment costs: $1,052 million
- GDP at Market Prices: $749 million
- Labour income: $496 million

**Figure 56. Annually recurring outcome categories due to new upstream water storage on the Bow River (with only Year 1 values shown).**

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Additional Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| 35,699 | 373,664 | 34,400 | 35,131 | 568 | 50,700 | 50,700 | 50,700 |

Build upstream water storage on the Bow River

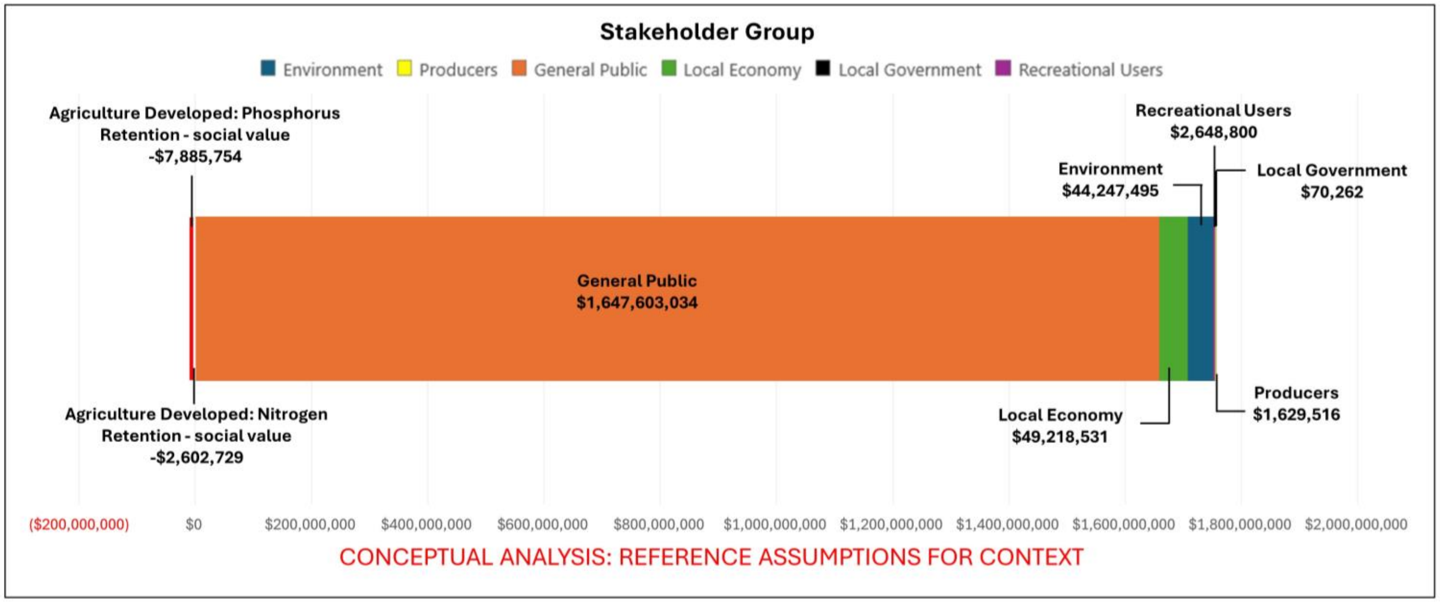


**Figure 57. Annually recurring outcome categories due to new upstream water storage on the Bow River (with gained and lost value shown only for Year 1).**

**Estimated one-time increase in property value:** $344,283,800

**Direct construction benefits:**

- Total investment costs: $1,052 million
- GDP at Market Prices: $749 million
- Labour income: $496 million

#### 2.7.5.2 Build new on-stream water storage on the Bow River (Eyremore Reservoir)

**Description**

This large storage was first studied at a conceptual level in 1977, and the most promising site was identified as Eyremore (located approximately 30 km below Bassano Dam).

The Eyremore Reservoir is intended to significantly improve water security for not only the Bow sub-basin, but also the Oldman sub-basin, due to its strategic location. As this water storage is large, it can be operated to meet multiple objectives. As part of this assessment, the following objectives were identified:

- Support demands in the lower Bow River basin.
- Supplement environmental flows in the Bow River basin.
- Supplement apportionment flows as needed.
- Relieve pressure on the Oldman Reservoir by making releases for the needs downstream of the Bow confluence. Most notably, this includes the 28.3 $m^3/s$ (31,000 cfs) daily target at Medicine Hat for both waste diffusion and apportionment.

As a large storage facility, Eyremore Reservoir provides multiple opportunities. The above objectives were identified as operational priorities for this assessment; however, there may be additional operational targets and priorities which could be explored.

This would be a significant infrastructure undertaking with a large associated cost. Any new structure associated with new storage would need a thorough engineering and environmental evaluation, which is anticipated to commence in Q1 2024. The potential benefits are explored in detail below.

**Modelling assumptions**

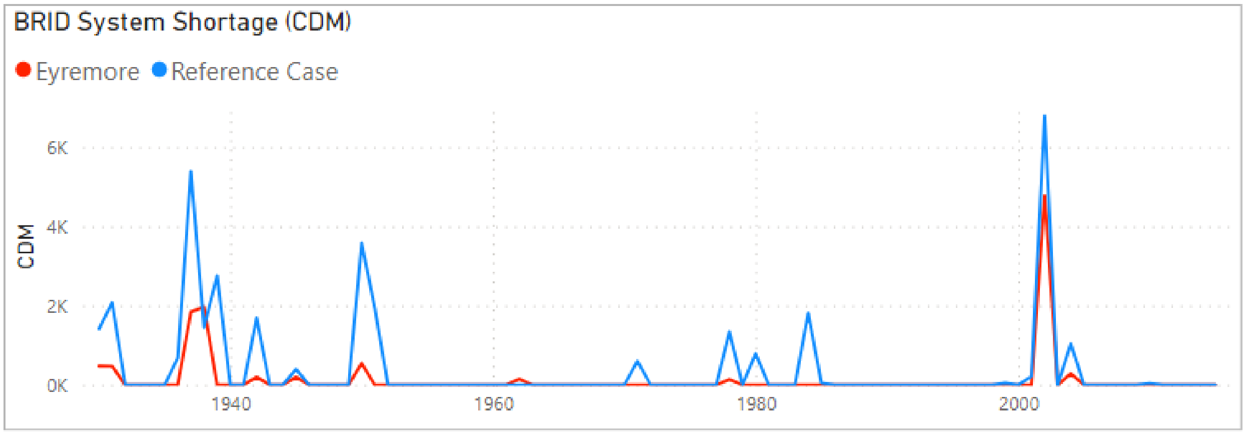
Modelling assumed Eyremore Reservoir would be a large storage facility, up to an approximate live storage capacity of 616,740 $dam^3$ (500,000 ac-ft) based on the 1977 study published by the Prairie Farm Rehabilitation Administration (PFRA). Additional options have been assessed in historical work, including options from the Bow River Working Group (BRWG). As it was modelled in this project, this option provides additional water security within the Bow River sub-basin (and Oldman sub-basin) and provides an opportunity to aid in supplementing downstream flows and meeting apportionment requirements.

**Performance under historical conditions**

The Eyremore Reservoir is a particularly interesting option, as it has unexpected opportunities to benefit throughout the system. Within the Bow sub-basin, the most obvious beneficiary is EID. With a massive new reservoir at the site of their diversion, the EID effectively no longer suffers much in the way of water insecurity, seen here as the near total elimination of shortages to the district (Figure 58). For those not intimately familiar with irrigation on the Bow, the reduction in shortages at the BRID (Figure 58) comes as a surprise. These shortage reductions come primarily from two sources:

1) The informal water-sharing in which the three major Bow districts engage (EID's water security makes them not need to rely on river flows, and allowing BRID to withdraw additional flows); and
2) BRID, which at present ensures that the 11.3 $m^3/s$ (400 cfs) minimum license flow passes to the

EID, no longer needs to do so. This 11.3 m$^3$/s (400 cfs) is "freed up" for use by the BRID.



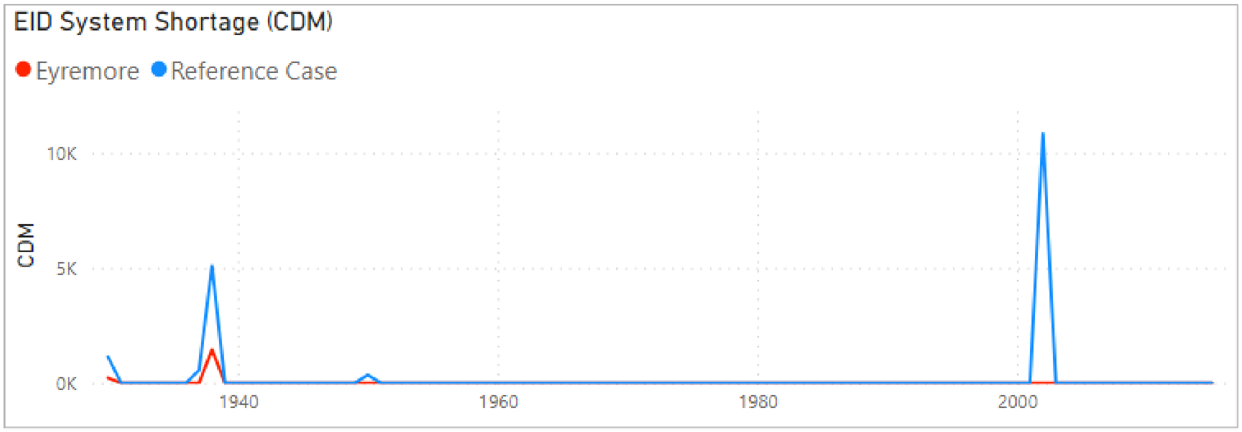


**Figure 58. New on-stream water storage on the Bow River (Eyremore Reservoir) (red) compared to the Reference case (blue) outlining the BRID and EID irrigation shortages.**

The next unexpected opportunity with the Eyremore Reservoir lies in its ability to ease pressure on Oldman Reservoir. Though the Bow River confluence occurs downstream of most Oldman Reservoir water use (i.e., downstream of the southern tributaries, LNID, and City of Lethbridge), the remaining downstream users remain substantial during times of drought. By balancing storage between Eyremore and Oldman (as best one can), Eyremore Reservoir can take over the provisioning of some downstream flows when Oldman Reservoir falls low. Notably, this includes the 1,000 cfs daily minimum at Medicine Hat for return flow diffusion and, informally, apportionment. Figure 59 shows the preservation of storage in Oldman Reservoir possible under an Eyremore Reservoir scenario. Note that not only is the reservoir's storage consistently higher, but also its typical drawdown across the entire historical period is less. This additional storage could be used for several purposes, including river flows (like the 16 m$^3$/s year-round minimum at Lethbridge, Section 2.7.3.5) or additional security for irrigators (see reductions in shortages at LNID in Figure 60).

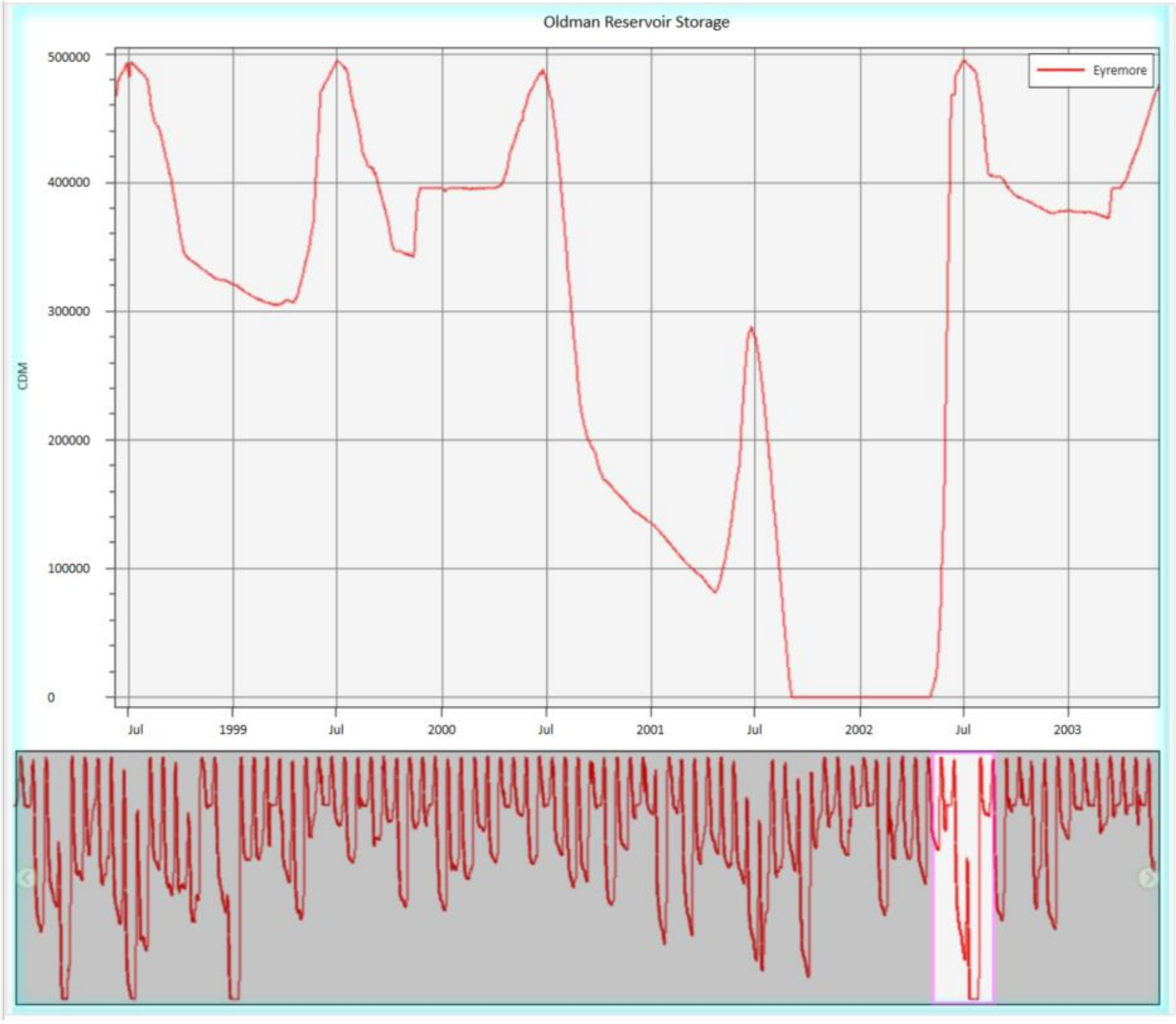


**Figure 59. New on-stream storage on the Bow River (Eyremore Reservoir) (red) model run showing the effect of on the storage of the Oldman Reservoir.**

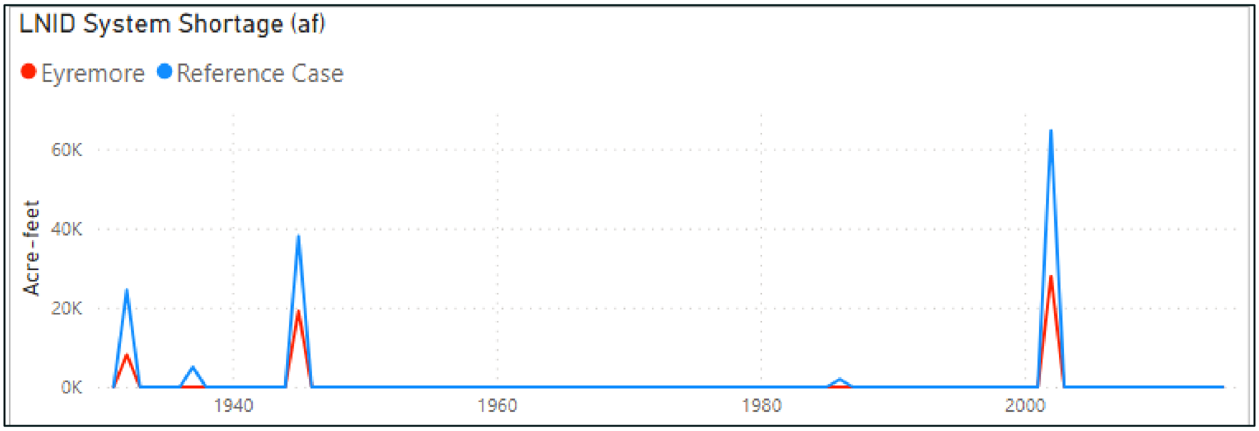


**Figure 60. New on-stream storage on the Bow River (Eyremore Reservoir) (red) compared to the Reference Case (blue) showing LNID shortages.**

Note in Figure 61, Eyremore Reservoir sees considerable use under this operations scheme and is drawn down to empty in the worst drought. This indicates that opportunities for shared responsibility/operations are surprisingly common. However, this shared operation is not without consequence. By reducing outflows from Oldman (and increasing outflows from Eyremore Reservoir/the Bow) there sometimes are reduced instream flows in the Oldman River (Figure 62).

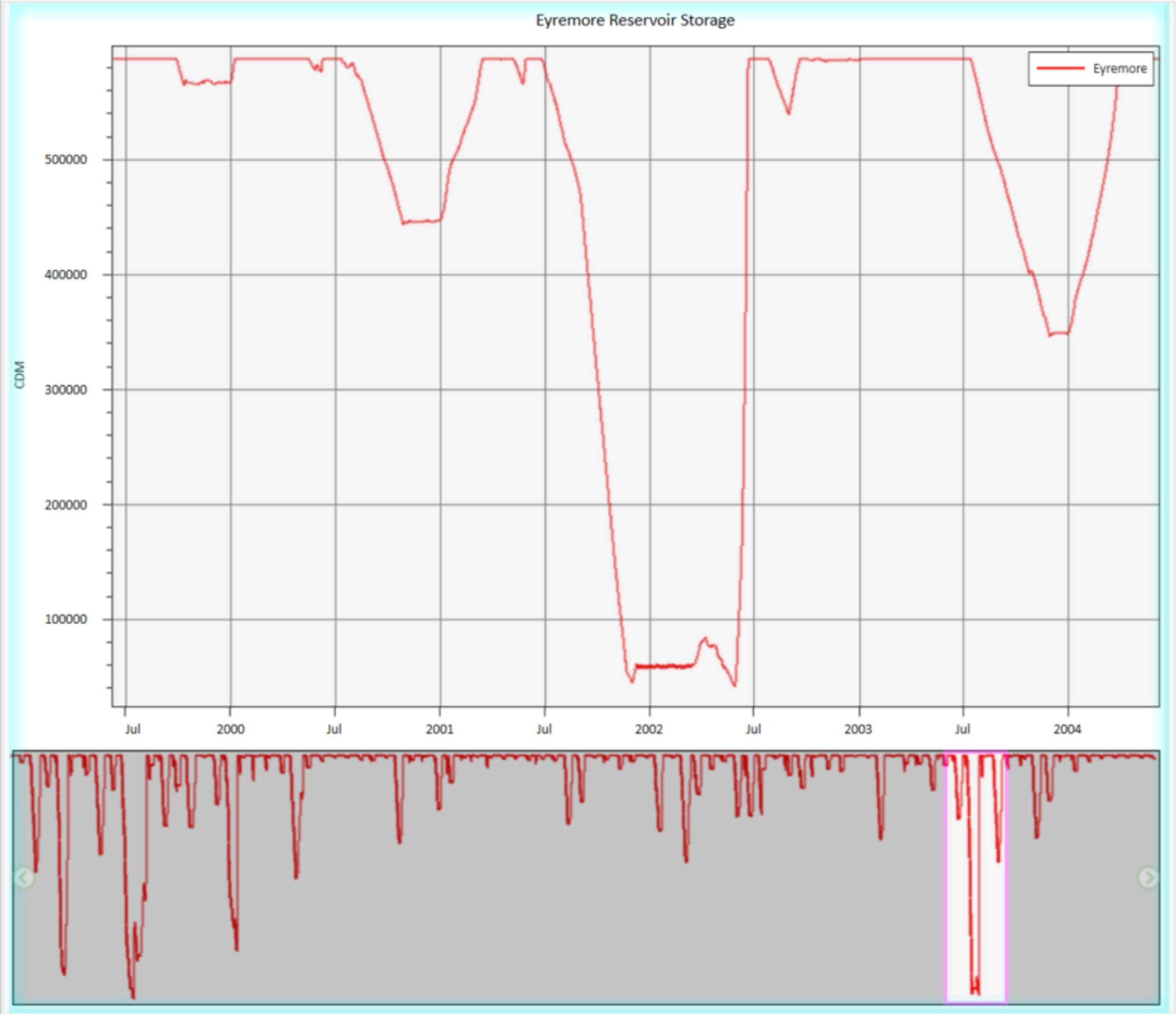


**Figure 61. New on-stream storage on the Bow River (Eyremore Reservoir) (red) showing the Eyremore Reservoir storage.**

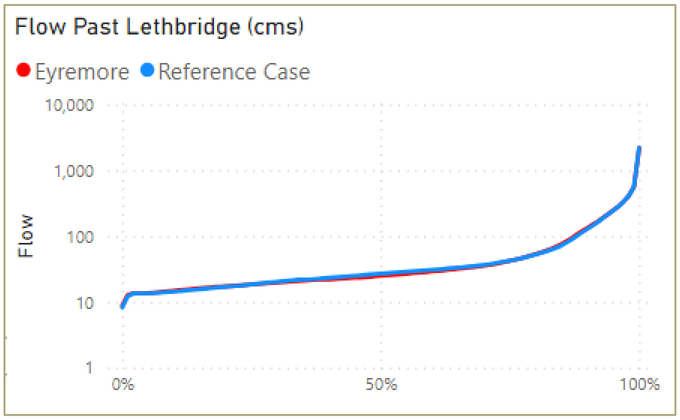


**Figure 62. New on-stream storage on the Bow River (Eyremore Reservoir) (red) compared to the Reference Case (blue) showing Lethbridge flows.**

## Contextualizing the Economic Analysis

The economic analysis provides a conceptual indication of the potential value added and lost from the implementation of a project. Assumptions used in this analysis are influenced by the availability of data and there is room to perform a more granular analysis to refine the net value gained as more information is gathered on the project.

It was assumed that the development of additional on-stream storage on the Bow River at Eyremore would result in an additional 616,738 dam$^3$ (500,000 acre-feet) of live storage. For the purposes of the economic analysis, it was assumed that of this volume of water, one third (205,579 dam$^3$) would be used for agricultural development, one third for environmental flow and one third for municipal growth. Note that only the potential maximum population represents the full use of the municipal portion of the water. The volume split assumes the water will be available for the assigned use when that water user needs it.

In Figure 63, the chart representing the recurring outcome categories and potential Year 1 benefit shows that the development of upstream storage leads to significant benefits to the general public. This includes support for year-on-year projected annual population growth at 1.5% in the Bow River basin up to a potential maximum of over 1.5 million additional people.

In addition to this population growth, the reservoir storage can potentially support almost 137,000 new irrigated acres which provides benefit to the general public by the additional provision to grow food leading to increased food security in the province. The new agriculture will also provide local economic benefits due to the increased agricultural activity which could include the development of food processing plants in the region.

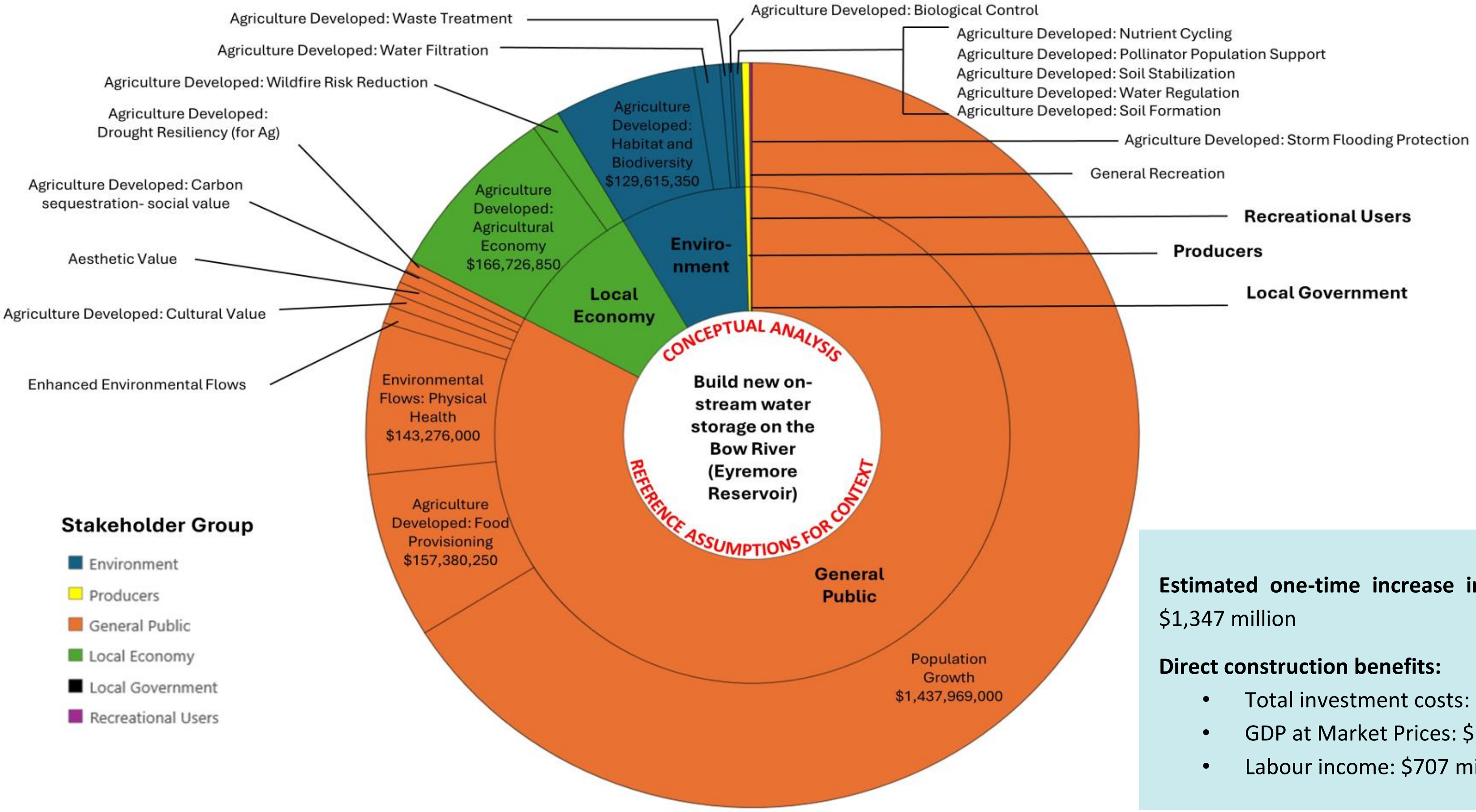
Environmental flows also benefit. The quantified benefits mostly relate to improvements to the physical health of residents and improvements to recreational opportunities. Note that there are additional benefits, including benefits to aquatic ecosystem health resulting from increased river flows.

The total value created and lost in Year 1 is shown in Figure 64 and shows that some value is lost as a result of the reduced phosphorus and nitrogen retention resulting from increased agricultural activity. The reduced ability to retain nutrients results in a loss of value of approximately $41 million.

It is not known if this project will also be operated for flood mitigation. Economic outcomes of flood mitigation have not been considered in this analysis, however, the avoided cost of flooding should be quantified in a future study.

Additionally, this economic analysis does not consider economic outcomes from potential hydropower generation which should be considered to provide a detailed understanding of economic outcomes.

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| 141,450 | 1,515,145 | 34,400 | 137,450 | 5,000 | 205,579 | 205,579 | 205,579 |



**Estimated one-time increase in property value:** $1,347 million

**Direct construction benefits:**

- Total investment costs: $1,500 million
- GDP at Market Prices: $1,068 million
- Labour income: $707 million

**Figure 63. Annually recurring outcome categories due to new on-stream storage on the Bow River (Eyremore Reservoir) (with only Year 1 values shown). implementation.**

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| 141,450 | 1,515,145 | 34,400 | 137,450 | 5,000 | 205,579 | 205,579 | 205,579 |

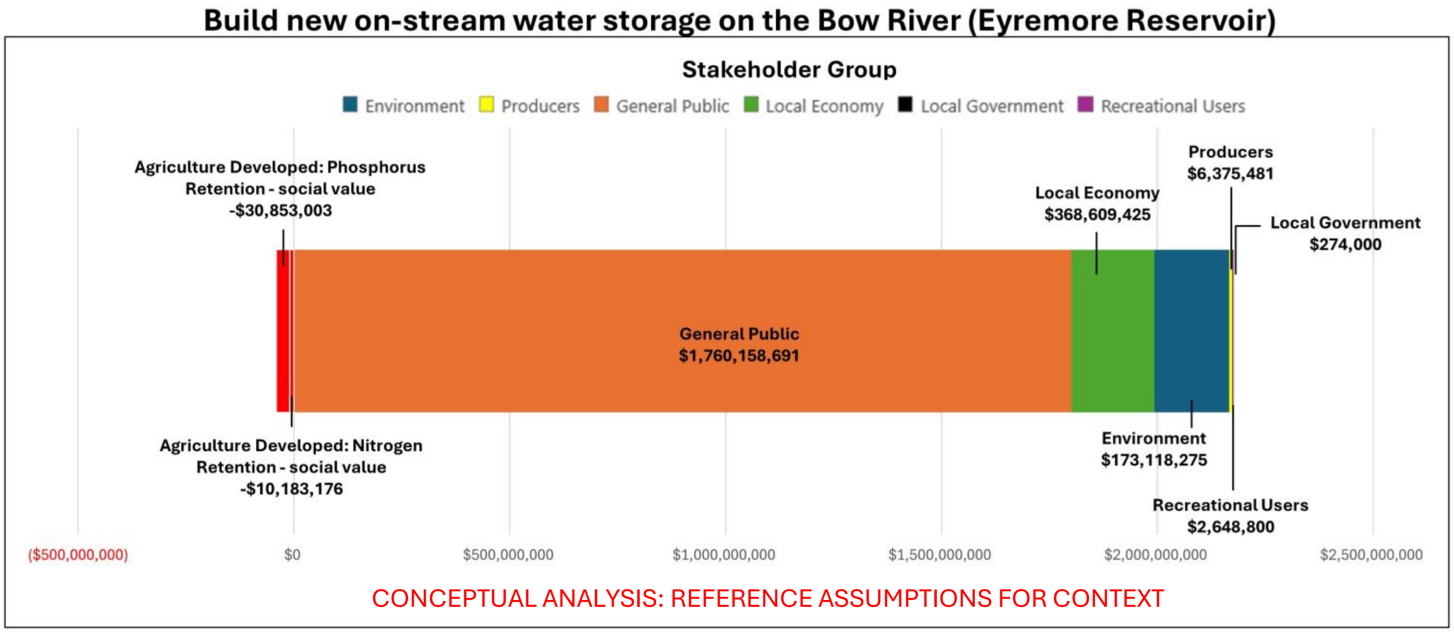


**Figure 64. Annually recurring outcome categories due to new on-stream storage on the Bow River (Eyremore Reservoir) (with gained and lost value shown only for Year 1).**

**Estimated one-time increase in property value:** $1,347 million

**Direct construction benefits:**

- Total investment costs: $1,500 million
- GDP at Market Prices: $1,069 million
- Labour income: $707 million

### 2.7.5.3 Build new on-stream water storage on the Red Deer River

**Description**

As the Red Deer River basin continues to grow economically, the demand for water is increasing. While the basin is not yet fully allocated, there is an opportunity to implement strategic water management projects to facilitate growth in the basin. Growth in water demand brings higher risk of water insecurity during droughts. While the Bow and Oldman sub-basins have effective infrastructure and operations in place to manage extreme events, there is little infrastructure in the Red Deer sub-basin, leaving water users potentially vulnerable. Drought simulation exercises, such as the one undertaken by the Alberta Water Council in 2022, highlight the risk that in a severe multi-year drought, water managers in the Red Deer have few levers to pull (Alberta Water Council, 2022).

On-stream storage on the Red Deer River has the potential to significantly reduce the risk posed by severe and multi-year droughts by providing a secure source of water to existing water users. A larger reservoir could potentially facilitate economic growth by providing water supply for agriculture, industry, and municipalities, and could simultaneously supplement river flows for environmental benefits and to meet apportionment requirements.

For modelling purposes, a site was chosen east of the City of Red Deer, near Ardley, to explore the potential benefits of on-stream storage in the Red Deer sub-basin. There are potentially multiple sites for new water storage on the reservoir. For the purposes of this assessment, Ardley Reservoir was selected as a reference, as there was existing information available from the Saskatchewan Nelson Basin Board Study, originally published in 1968 (Goodwin, 1981). The main purpose of this water storage is to supplement flows in the Red Deer River, especially during low flow periods, and to supply anticipated future demand within the sub-basin.

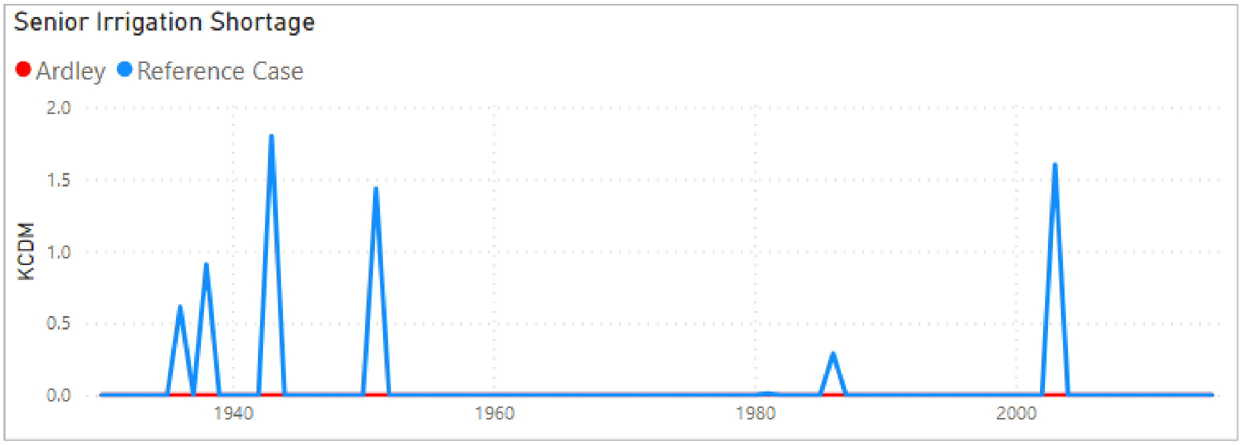
**Modelling assumptions**

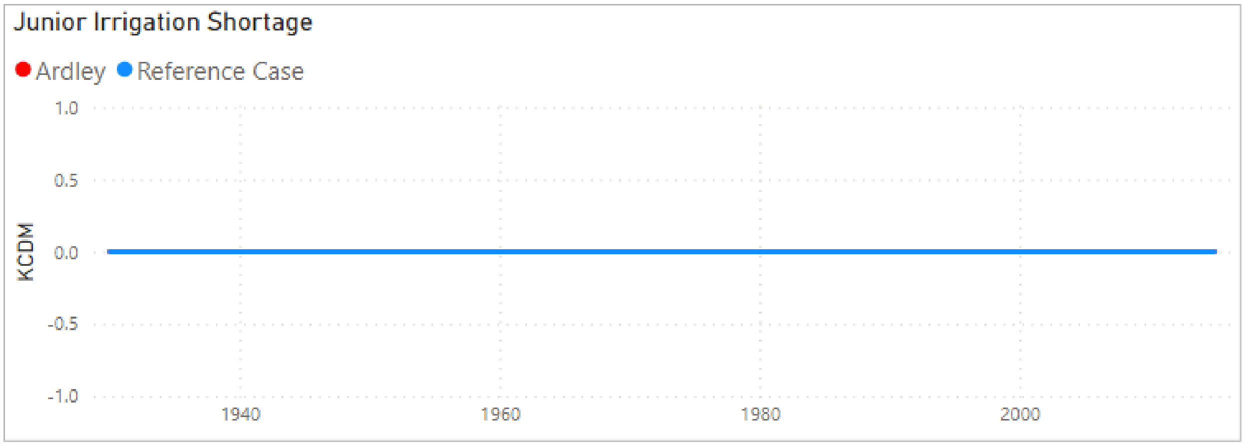
Live storage is assumed to be at the Ardley Reservoir site, at 571,102 dam$^3$ (463,000 ac-ft) in size (Goodwin, 1981).

The new reservoir takes on the downstream looking operations of Dickson Dam. Gleniffer Reservoir reverts back to current operations, which meets the WCO requirements.

**Performance under historical conditions**

Unsurprisingly, the addition of major storage in the Red Deer sub-basin shows substantial benefit. Shortages to all users (including junior irrigators representing build out to full basin allocation) are reduced to zero, with the singular exception of some Temporary Diversion License (TDL) shortages, which are upstream of all system storage (Figure 65). This raises the question of whether some of the TDLs in this basin could be converted to term licenses in this scenario. It should be noted that the conversion of TDLs to full licences in this scenario has a time restriction and is subject to closure at any time.


Senior Irrigation Shortage
● Ardley ● Reference Case
KCDM
2.0
1.5
1.0
0.5
0.0
1940
1960
1980
2000


Junior Irrigation Shortage
● Ardley ● Reference Case
KCDM
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-0.5
-1.0
1940
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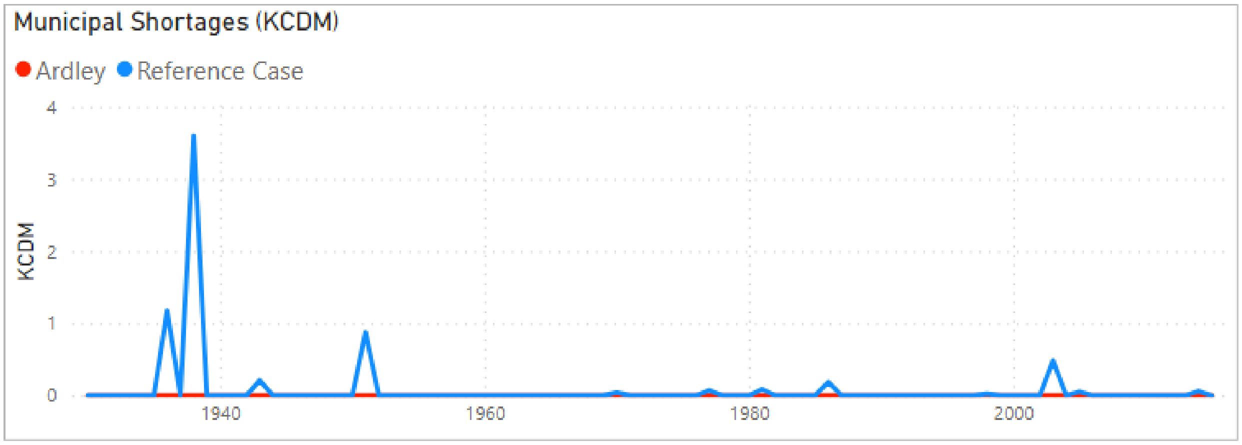
1980
2000


Municipal Shortages (KCDM)
● Ardley ● Reference Case
KCDM
4
3
2
1
0
1940
1960
1980
2000

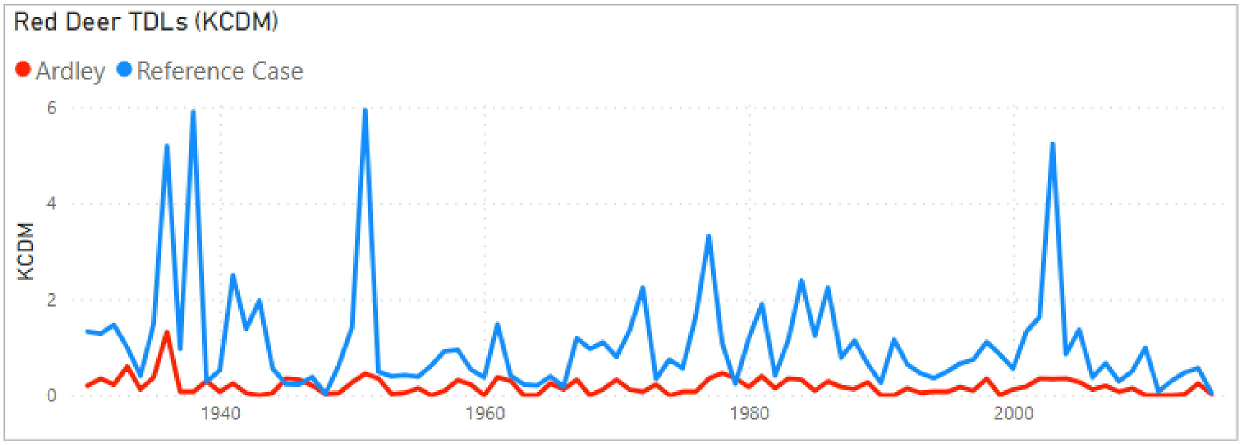


**Figure 65. On-stream water storage on the Red Deer River (Ardley Reservoir) (red) compared to the Reference Case (blue) showing senior irrigation shortages, junior irrigation shortages, municipal shortages, and TDL shortages.**

WCOs also show substantial improvement (Figure 66), as does storage in Gleniffer Reservoir (Figure 67), which no longer drains as completely or as often since the pressure to meet downstream needs is lessened.

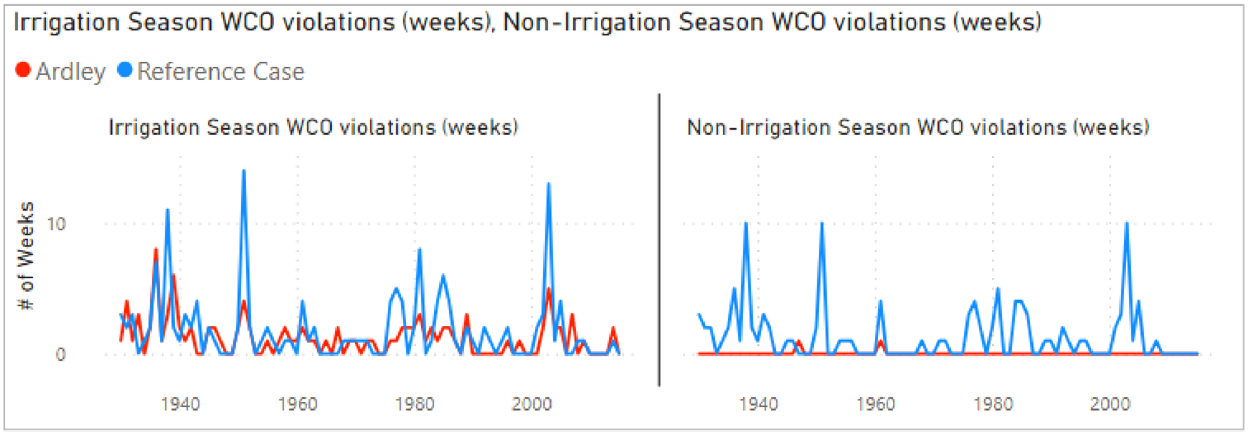


**Figure 66. On-stream water storage on the Red Deer River (Ardley Reservoir) (red) compared to the Reference Case (blue) showing the number of WCO violations (weeks).**

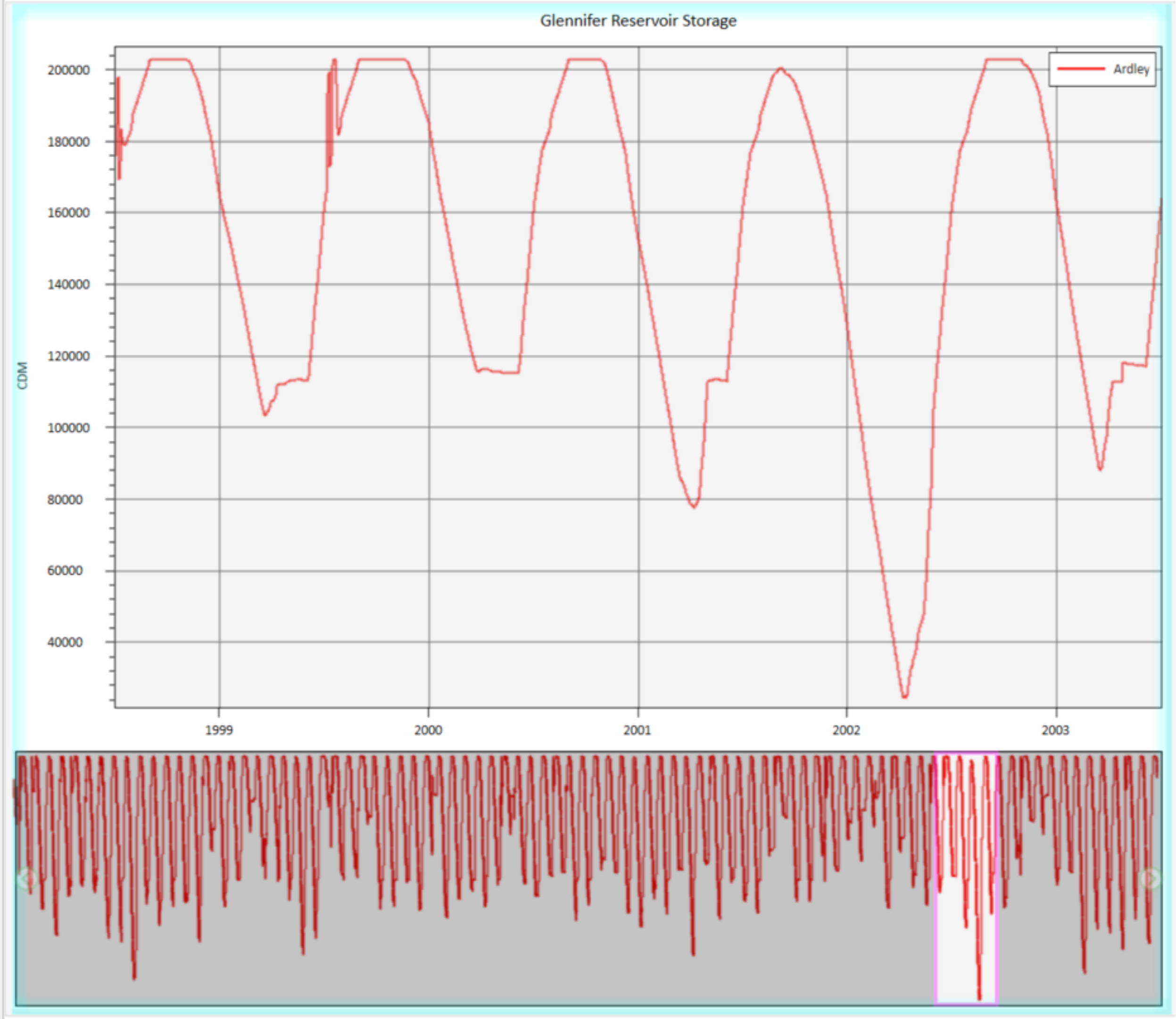


**Figure 67. On-stream water storage on the Red Deer River (Ardley Reservoir) (red) model run showing the storage of Gleniffer Reservoir.**

Ardley Reservoir provides substantial leverage in the Red Deer River basin to mitigate drought and floods to meet current and future demand in the basin. In fact, the reservoir achieves all goals set to it without even draining completely. Under historical hydrology, Ardley Reservoir never draws below 25,277 dam$^3$ (Figure 68). This suggests either the reservoir could be built to a smaller capacity, or with support from Ardley Reservoir, the basin could support demand in excess of current maximum basin allocation limits. Further analysis is recommended for both cases.

A new reservoir would provide additional recreational (i.e. boating) opportunities in an area that values this, minimize risks of not meeting WCO in extreme and consecutive drought years, open the possibility to increase minimum flow at key times of the year for environmental and fisheries habitat benefits, and even provide more flow for apportionment to offset overuse in other South Saskatchewan River tributaries.

**Figure 68. On-stream water storage on the Red Deer River (Ardley Reservoir) storage.**

The obstruction of fish migration, particularly that of Walleye, Goldeye, and Mooneye, is one of the difficulties facing this on-stream reservoir. For breeding and raising their young, Goldeye/Mooneye use the lower parts of the Red Deer and South Saskatchewan River. However, during the summer, adults migrate up the Red Deer to forage; as a result, this migration is more restricted and could have an impact on the population in the Red Deer River.

**Contextualizing the Economic Analysis**

The economic analysis provides a conceptual indication of the potential value added and lost from the implementation of a project. Assumptions used in this analysis are influenced by the availability of data and there is room to perform a more granular analysis to refine the net value gained as more information is gathered on the project.

It was assumed that the development of additional on-stream storage on the Red Deer River would result in an additional 571,102 dam$^3$ (463,000 acre-feet) of live storage. For the purposes of the economic analysis, it was assumed that of this volume of water, one third (190,367 dam$^3$) would be used for agricultural development, one third for environmental flow and one third for municipal growth. Note that only the potential maximum population represents the full use of the municipal portion of the water. The volume split assumes the water will be available for the assigned use when that water user needs it.

In Figure 69, the chart representing the recurring outcome categories and potential Year 1 benefit shows that the development of upstream storage leads to significant benefits to the general public. This includes support for year-on-year projected annual population growth at 1.4% up to a potential maximum of over 1.4 million additional people.

In addition to this population growth, the reservoir storage can potentially support almost 127,000 new irrigated acres which provides benefit to the general public by the additional provision to grow food leading to increased food security in the province. The new agriculture will also provide local economic benefits due to the increased agricultural activity which could include the development of food processing plants in the region.

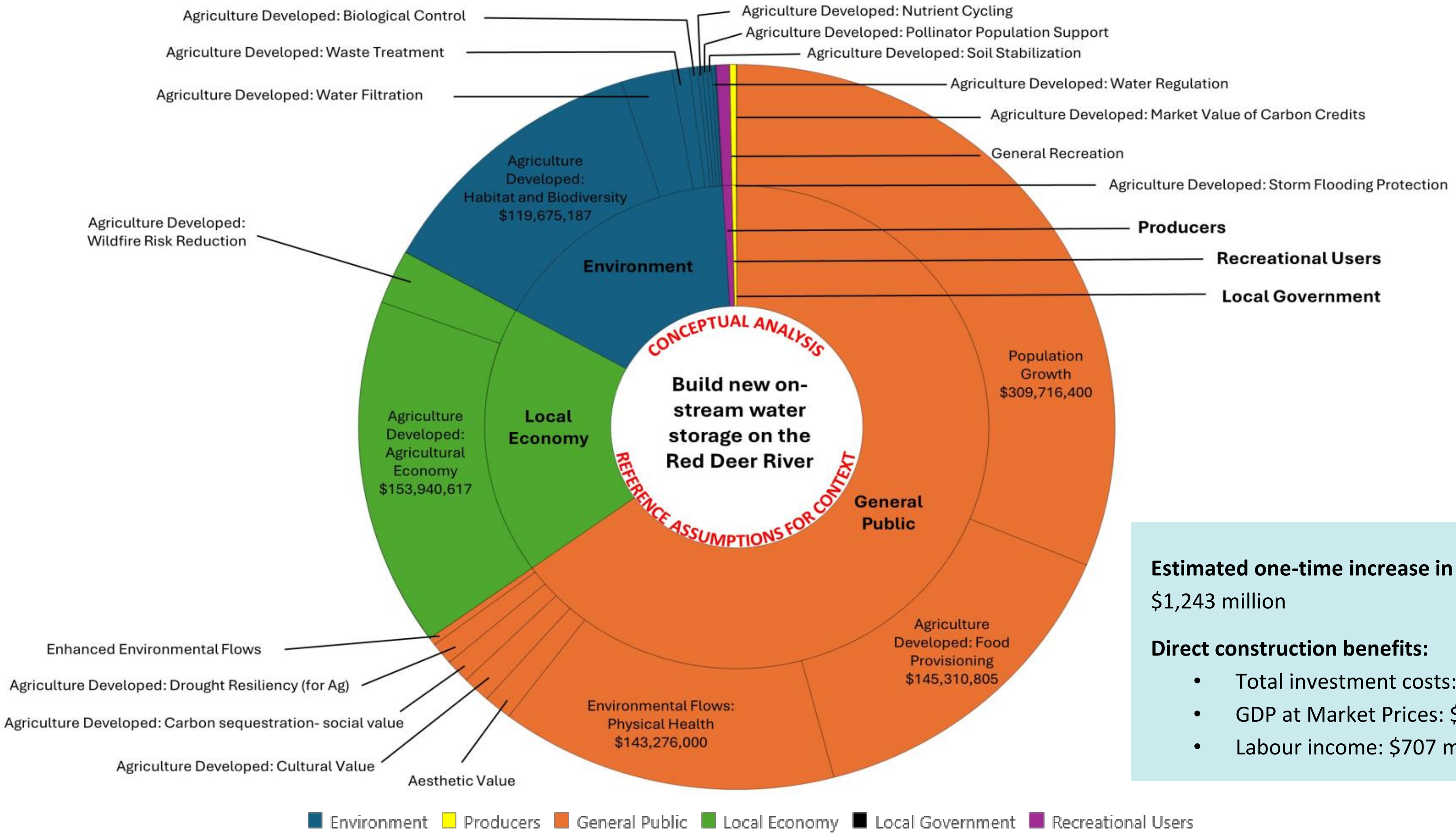
Environmental flows also benefit. The quantified benefits mostly relate to improvements to the physical health of residents and improvements to recreational opportunities. Note that there are additional benefits, including benefits to aquatic ecosystem health resulting from increased river flows.

The total value created and lost in Year 1 is shown in Figure 70 and shows that some value is lost as a result of the reduced phosphorus and nitrogen retention resulting from increased agricultural activity. The reduced ability to retain nutrients results in a loss of value of approximately $37 million.

It is not known if this project will also be operated for flood mitigation. Economic outcomes of flood mitigation have not been considered in this analysis, however, the avoided cost of flooding should be quantified in a future study.

Additionally, this economic analysis does not consider economic outcomes from potential hydropower generation which should be considered to provide a detailed understanding of economic outcomes.

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam$^3$) | Water for Municipal Growth (dam$^3$) | Water for Environmental Flows (dam$^3$) |
|---|---|---|---|---|---|---|---|
| 131,909 | 1,403,027 | 34,400 | 126,909 | 5,000 | 190,367 | 190,367 | 190,367 |



**Estimated one-time increase in property value:** $1,243 million

**Direct construction benefits:**

- Total investment costs: $1,500 million
- GDP at Market Prices: $1,068 million
- Labour income: $707 million

**Figure 69. Annually recurring outcome categories due to new on-stream storage on the Red Deer River (with only Year 1 values shown).**

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| 131,909 | 1,403,027 | 34,400 | 126,909 | 5,000 | 190,367 | 190,367 | 190,367 |

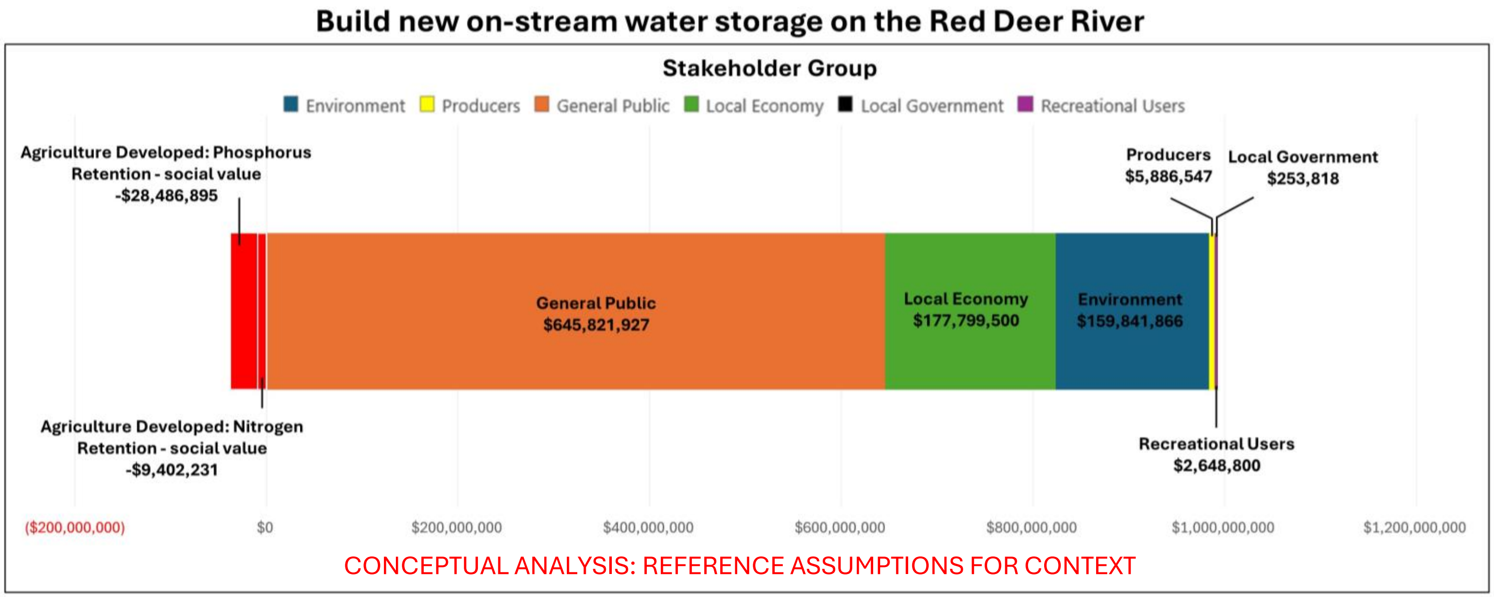


**Figure 70. Annually recurring outcome categories due to new on-stream storage on the Red Deer River (with gained and lost value shown only for Year 1).**

**Estimated one-time increase in property value: $**1,243 million

**Direct construction benefits:**

- Total investment costs: $1,500 million
- GDP at Market Prices: $1,068 million
- Labour income: $707 million

### 2.7.5.4 Build new on-stream water storage on the upper Belly River (Upper Belly River Reservoir)

**Description**

UID is located on the Belly River, a tributary of the Oldman River. Currently, the district relies on river flows to meet demand, which results in frequent irrigation shortages and potential crop losses during drought periods for farmers. A more secure water supply for the district would provide significant economic benefit to the region.

This option explored a water storage solution to support irrigation and maintain environmental flows in the area. The storage option is estimated at 67,841 dam$^3$ (55,000 ac-ft) in storage and is built on existing agricultural land. An on-stream reservoir can also provide additional environmental benefits, such as meeting the instream objective (IO) in the Belly River.

This would be a significant infrastructure undertaking with a large associated cost. Any new structure would need thorough engineering and environmental evaluation. Potential benefits are explored in detail below.

**Modelling assumptions**

The size of the reservoir is 67,841 dam$^3$ (55,000 ac-ft) in storage.

To preserve the Belly River ecology, UID voluntarily limits their diversion to flows over 2.0 m$^3$/s (about 240% of the current IO).

**Performance under historical conditions**

As a District without storage and entirely dependent on Waterton Reservoir releases and Belly River flows, the addition of a new reservoir is very consequential. Although shortages are not reduced entirely, their pattern of small to moderate shortages every year is reduced to zero in all but dry years (Figure 71). Interestingly, this ability to bank water also improves the reliability of other districts in the area, though not to the same degree. The ability of the UID to use stored water allows additional flow into St. Mary where previously it would have been taken straight into the UID (Figure 71). With the voluntary increase in Belly River pass-by flows, the impacts to low flows at the mouth of the Belly River do not appear to be significant (Figure 72).

Note that this reservoir would see substantial use with it filling and emptying almost every year. This behavior is the hallmark of well-utilized irrigation storage (see Figure 73).

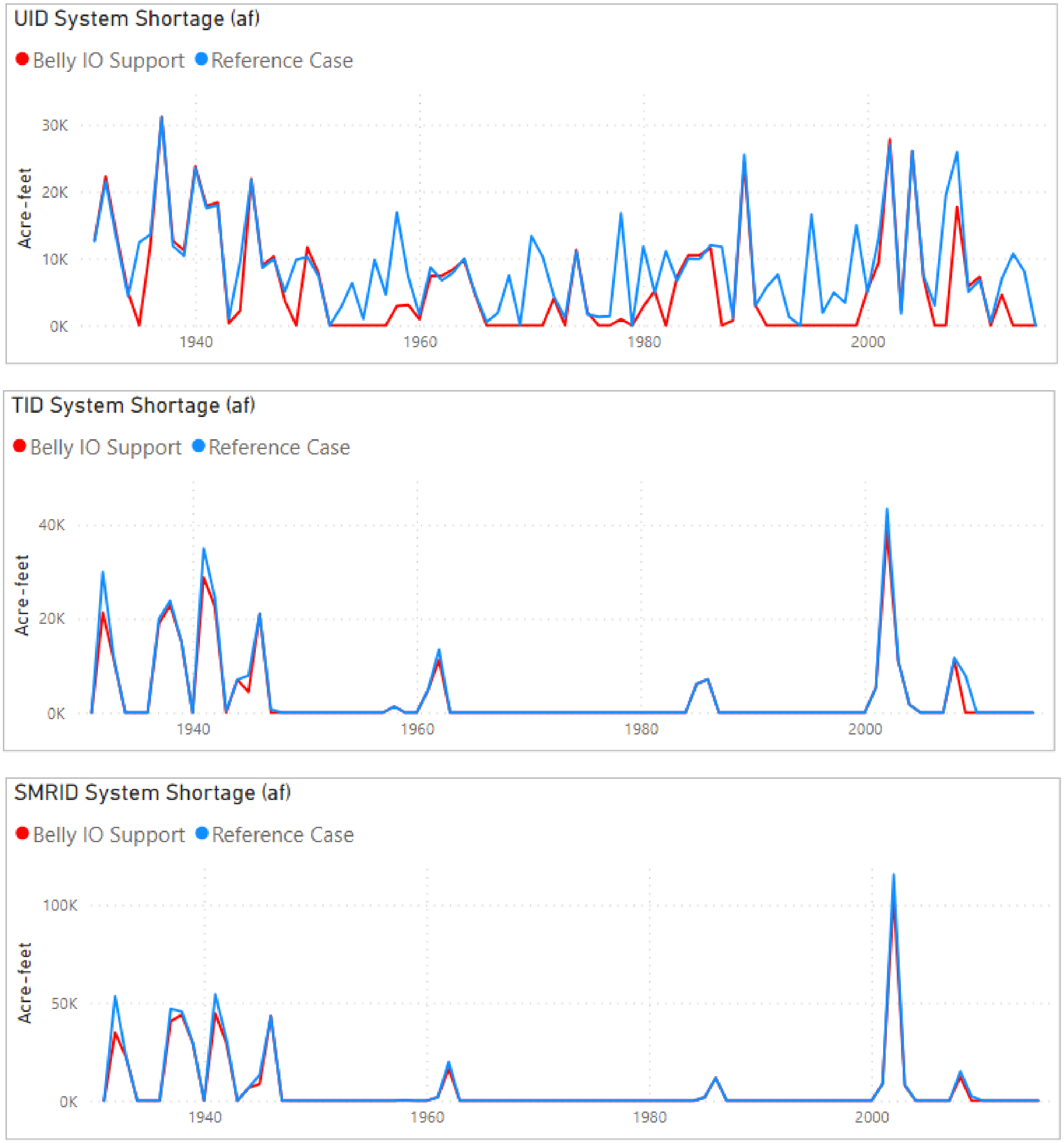


**Figure 71. On-stream water storage on the upper Belly River (Upper Belly Reservoir) (red) compared to the Reference Case (blue) showing the UID, TID, SMRID irrigation shortage. Note that the SSROM model update in 2021/2022 was completed before the amalgamation of TID into SMRID, and therefore these are separated in the results.**

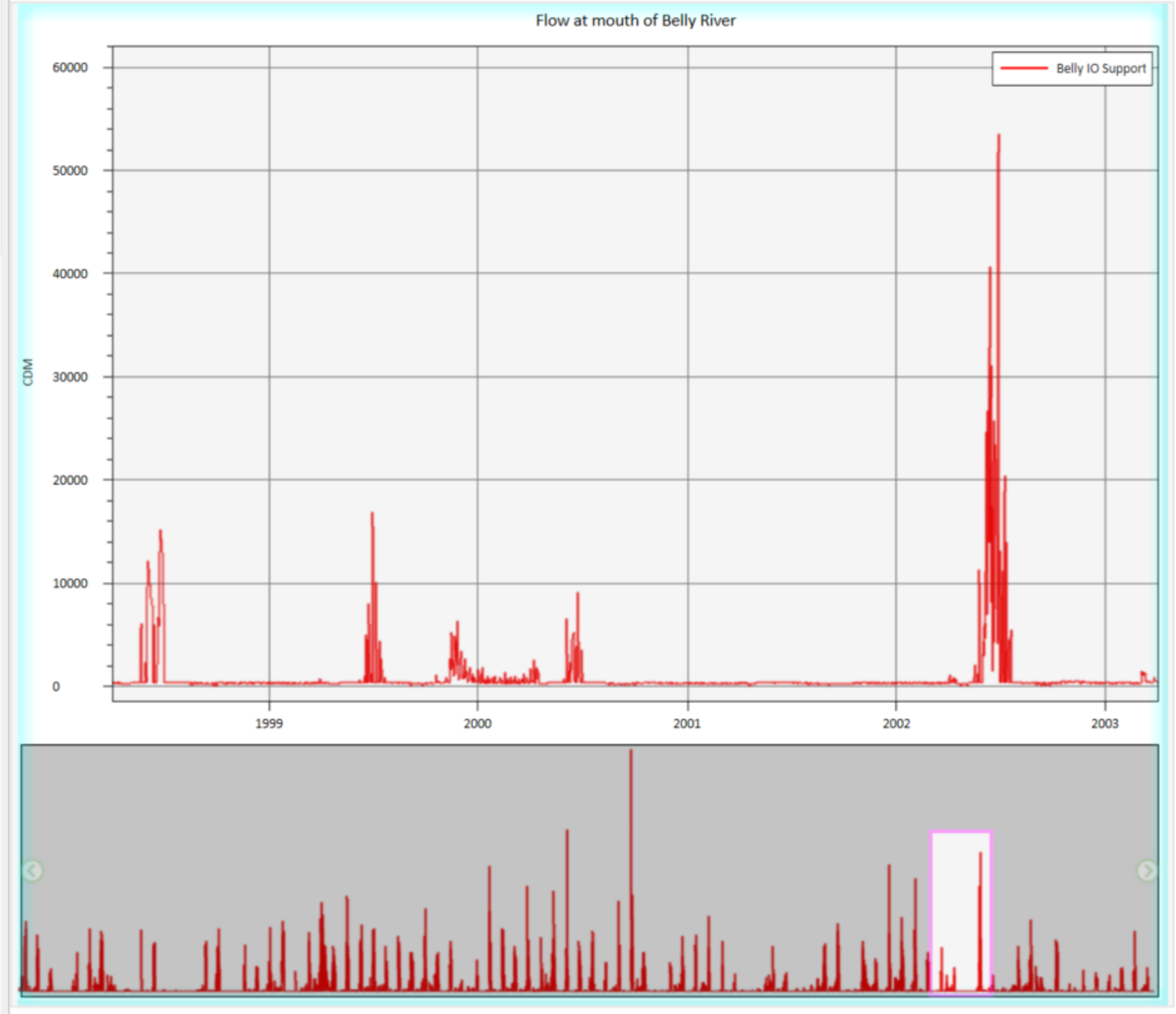


**Figure 72. On-stream water storage on the upper Belly River (Upper Belly Reservoir) (red) showing the flow at the mouth of the Belly River.**

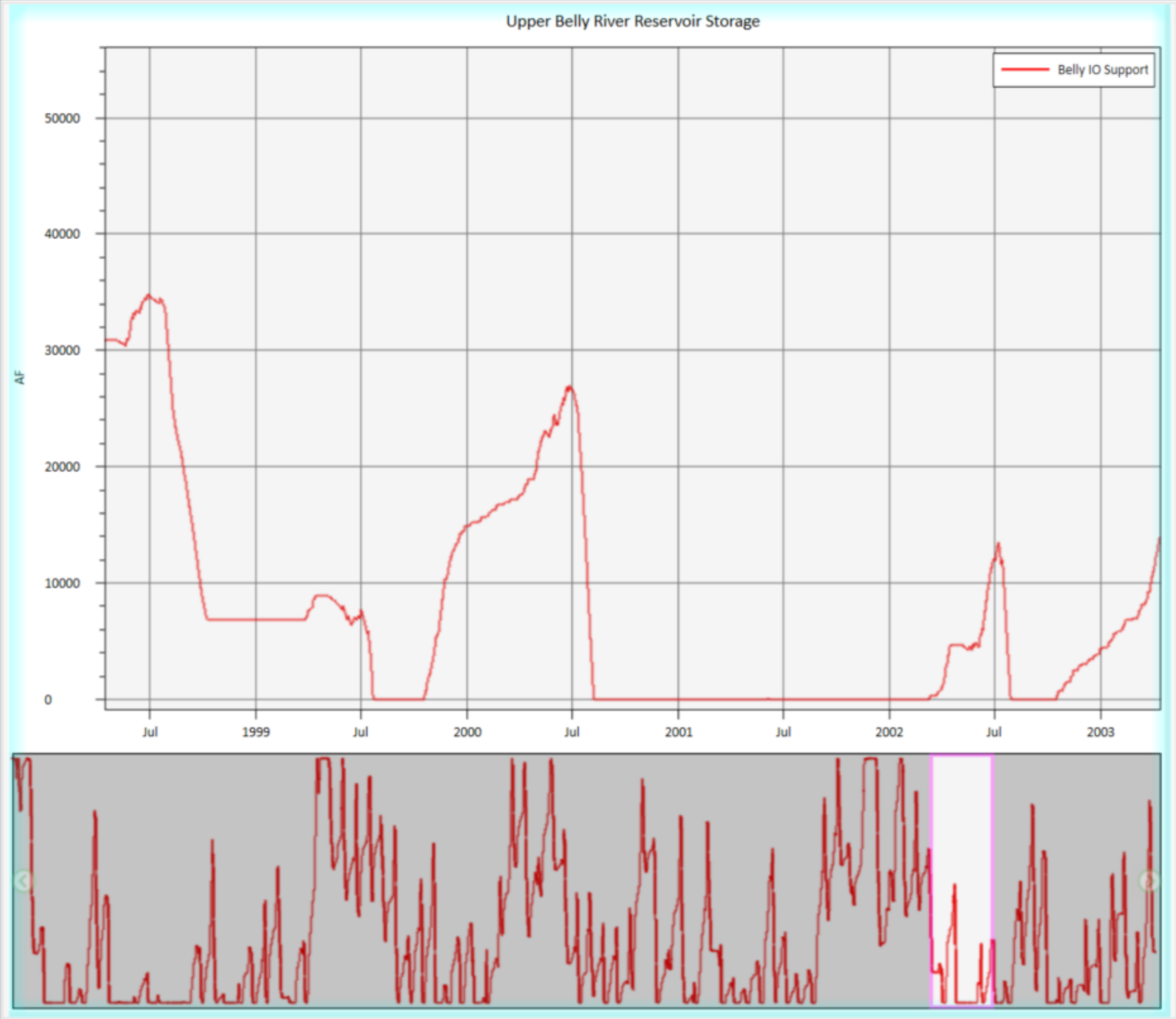


**Figure 73. On-stream water storage on the upper Belly River (Upper Belly Reservoir) (red) showing the upper Belly River Reservoir storage.**

Additionally, this would help the Mountain View Irrigation District (MVID) and Southwest Irrigation District (SID), allowing the two irrigation districts to take more water upstream at the Payne Lake diversion operated by the GoA.

## Contextualizing the Economic Analysis

The economic analysis provides a conceptual indication of the potential value added and lost from the implementation of a project. Assumptions used in this analysis are influenced by the availability of data and there is room to perform a more granular analysis to refine the net value gained as more information is gathered on the project.

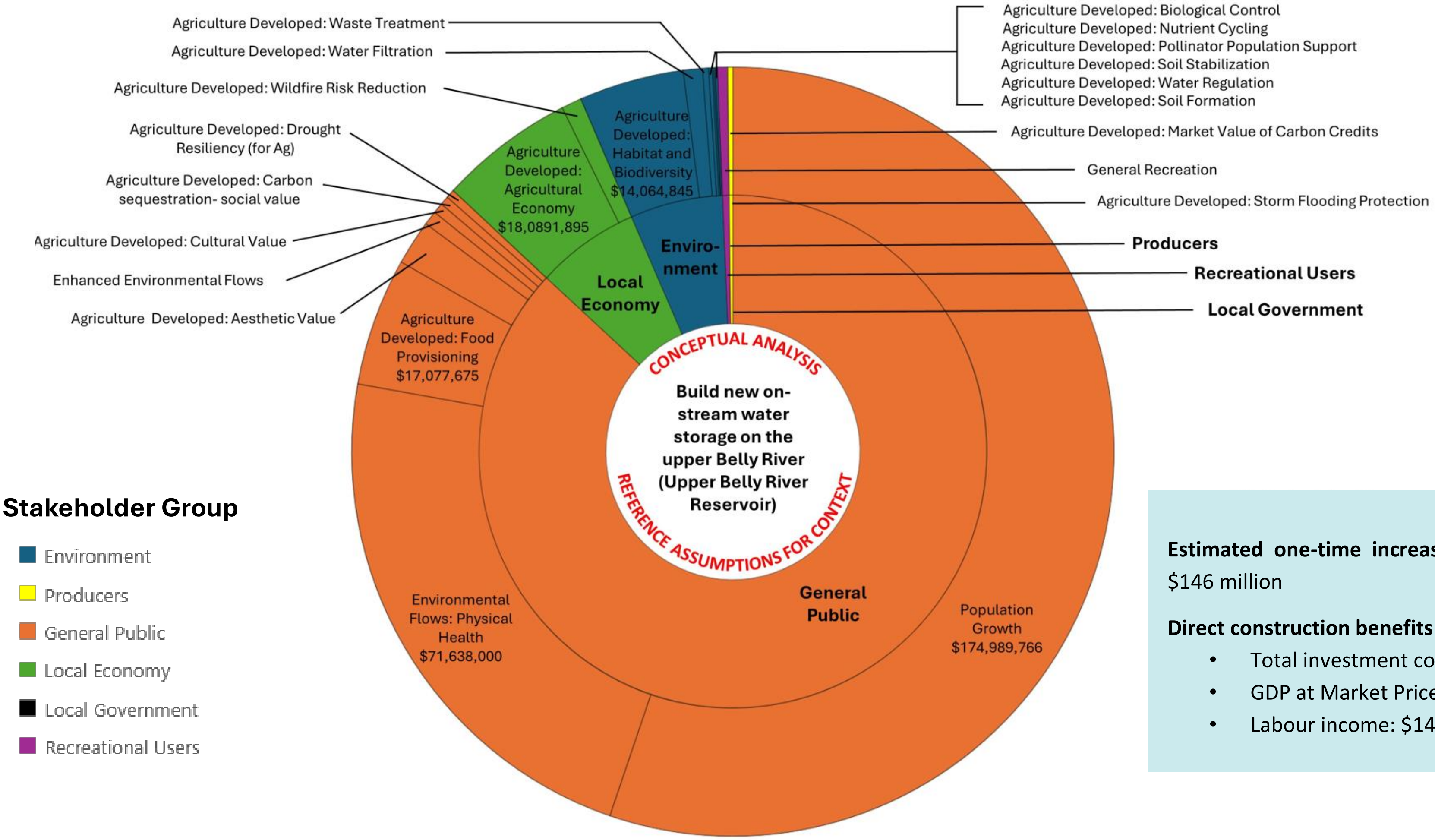
It was assumed that the development of the Belly River Reservoir would result in an additional 67,841 dam$^3$ (55,000 acre-feet) of live storage. For the purposes of the economic analysis, it was assumed that of this volume of water, one third would be used for agricultural development, one third for municipal growth, and one third for environmental flow. The volume split assumes the water will be available for the assigned use when that water use needs it.

In Figure 74, the chart representing the recurring outcome categories and potential Year 1 benefit shows that the development of upstream storage leads to significant benefits to the general public. Most significantly this includes improvements to the physical health of residents resulting from the increased flows in the Belly River. The development of on-stream storage on the Belly River also results in the potential to support approximately 15,000 new irrigated acres which results in improved security and additional growth of the local economy.

The economic analysis has assumed some water could be available from the reservoir to support growth of rural municipalities. As long term growth potential in the region was not known the economic analysis was assumed that one third of the live storage volume (18,333 dam$^3$) of water would be available to support population growth in the region. Figure 74 shows that the assigned volume of water can support the projected annual population growth of 1.13% in the region up to a maximum of over 166,000 additional residents. Future analysis could refine the portion attributed to municipal growth to further refine the benefit valuation.

The total value created and lost is shown in Figure 75 and shows that some value is lost as a result of the reduced phosphorus and nitrogen retention resulting from increased agricultural activity. The reduced ability to retain nutrients results in a loss of value of approximately $2.7 million.

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| 16,423 | 166,664 | 17,200 | 14,915 | 754 | 22,613 | 22,613 | 22,613 |



**Estimated one-time increase in property value:** $146 million

**Direct construction benefits:**

- Total investment costs: $300 million
- GDP at Market Prices: $214 million
- Labour income: $141 million

**Figure 74. Annually recurring outcome categories by the development of the Belly Reservoir (with only Year 1 values shown).**

| Total Project Area (acres) | Potential Maximum population supported | Visitors Added | Ag Acres | Reservoir Acres | Water for Ag (dam³) | Water for Municipal Growth (dam³) | Water for Environmental Flows (dam³) |
|---|---|---|---|---|---|---|---|
| 16,423 | 166,664 | 17,200 | 14,915 | 754 | 22,613 | 22,613 | 22,613 |

**Build new on-stream water storage on the upper Belly River (Upper Belly River Reservoir)**

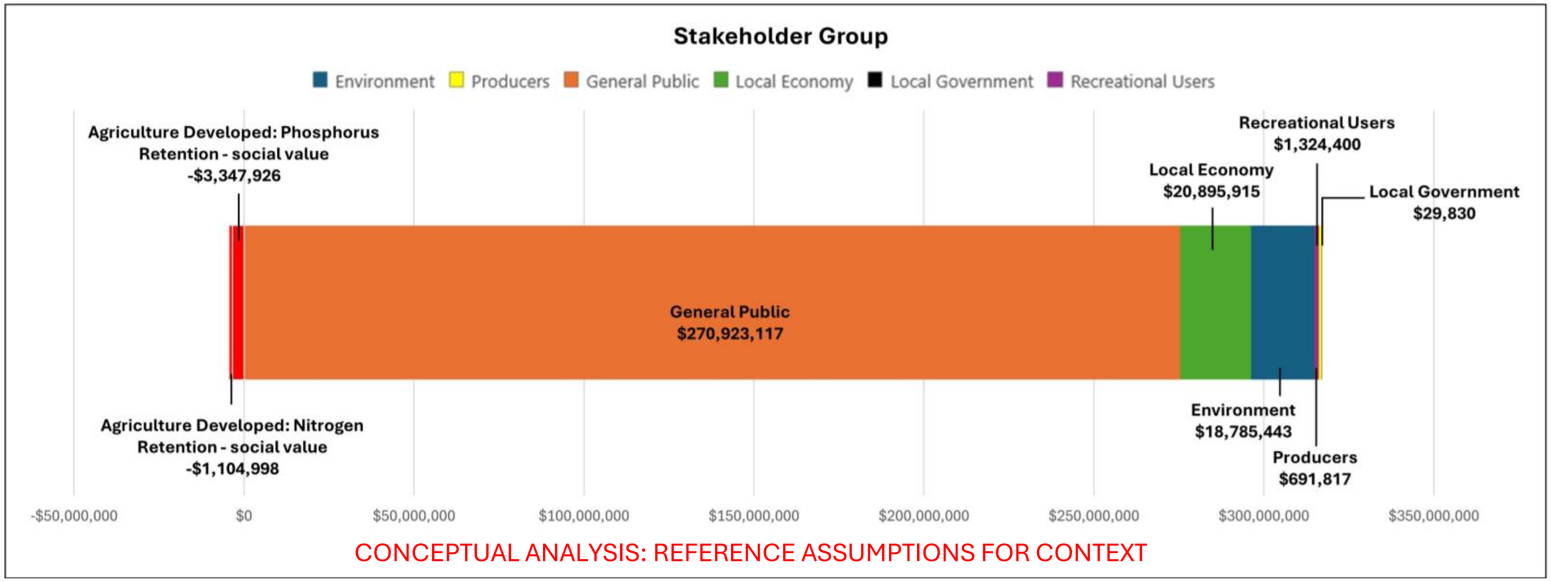


**Figure 75. Annually recurring outcome categories by the development of the Belly River Reservoir (with gained and lost value shown only for Year 1).**

**Estimated one-time increase in property value:** $146 million

**Direct construction benefits:**

- Total investment costs: $300 million
- GDP at Market Prices: $214 million
- Labour income: $141 million

# 3.0 Water availability under a multi-option build out scenario

Understanding potential water availability and future demands is critical to identifying the projects which facilitate future growth within the SSRB while improving environmental outcomes.

Two future growth scenarios were modelled in the SSROM to assess the performance of the options under stressful conditions. These include:

- A scenario modelled under future climate conditions and present-day demands.
- A stress test of future municipal growth and irrigation expansion demands to stress the multi-option buildout scenario under historical conditions.

## 3.1 Multi-option buildout scenario

The multi-option buildout scenario was developed to understand how potential projects within the Adaptation Roadmap for the SSRB would perform under potential future climate scenarios, with particular focus on which options would complement one another. Within the WG, this SSROM run was colloquially known as the “Kitchen Sink” run, as it includes many of the Adaptation Roadmap for the SSRB projects.

Table 12 shows the projects which were included in the multi-option buildout scenario. These projects were selected as the highest-performing options identified when run under historical flow conditions in SSROM.

**Table 12. Adaptation Roadmap for the SSRB projects modelled as part of the multi-option buildout scenario.**

| Option name | Sub-basin |
|---|---|
| Build new on-stream water storage on the Red Deer River (Ardley Reservoir) | Red Deer |
| Build upstream water storage on the Bow River (mixed operations) | Bow |
| Build new on-stream water storage on the Bow River (Eyremore Reservoir) | Bow |
| Restore Spray Lake Reservoir to its full supply level | Bow |
| Build new Western Irrigation District water storage | Bow |
| Increased minimum flow past Lethbridge for additional dilution | Oldman |
| Remove canal bottleneck between Waterton Reservoir and St. Mary Reservoir | Oldman |
| Build new on-stream water storage on the upper Belly River (Upper Belly River Reservoir) | Oldman |

## 3.2 Growth under the multi-option buildout scenario

The multi-option buildout scenario and the Reference Case were run under stressful basin growth conditions. The basin growth scenario was layered on the growth of municipalities and irrigation expansion. This scenario was run under the historical flow conditions in SSROM.

**Municipal growth assumptions**

The municipal growth focussed on demand increases from the major municipalities within the SSRB. Population growth estimates for Red Deer, Lethbridge, and Medicine Hat are based on the Population Projections: Alberta Census Divisions 2021 – 2046 report published by the GoA (Alberta Treasury Board and Finance, 2021). For these municipalities, the 2046 population was used. Growth projections for Calgary were taken from the 2022 CMRB Growth Plan, and the 2048 population was used for Calgary and its regional customers (Rennie Intelligence, 2018). For all municipalities, it was estimated that per capita demand would decrease by 10% from 2023 per capita demand, based on efficiency programs underway in each municipality. Table 13 outlines the municipal growth assumptions.

**Table 13. Municipal growth assumptions to model growth in the SSRB. *Red Deer is already assumed at full license allocation in the Reference Case, so growth is listed as the absolute volume of a new Junior license presumed to be issued.**

| City | YoY growth (%) | Total Annual demand (ML) | Peak Demand per day (ML) | Increase over reference case in SSROM |
|---|---|---|---|---|
| Red Deer | 1.4% (2020 – 2046) | 862 | 31 | +24,120 dam$^3$* |
| Lethbridge | 1.13% (2020 – 2046) | 47,687 | 332 | +33.9% |
| Medicine Hat | 0.94% (2020 – 2046) | 160,299 | 1019 | +27.5% |
| Calgary | 1.5% (2018 – 2048) | 265, 472 | 893 | +54% |

**Irrigation growth assumptions**

Historically, the growth of irrigation districts has been driven by efficiencies programs to reduce water losses and the development of off-stream storage reservoirs, which allow water to be captured and used at times when flow in the river is not enough to allow irrigation. The SSROM Reference Case uses 2018 assumptions for the water demand per acre of irrigated land. However, since 2018 irrigation efficiency programs such as the Alberta Irrigation Modernization program (AIM) have continued to reduce the water demand per acre of irrigated land and the SSROM is likely overestimating actual demand, it is anticipated that future expansions based on efficiency will become smaller and eventually limited as irrigation districts become highly efficient.

Noting expansion may be more limited in the future, the WG performed an additional irrigation stress test, where the 2023 expansion limits were used as the maximum bounds for irrigation expansion. Expansion limit acres represents the maximum number of acres a district is allowed to have on their assessment roll. The expansion limit is normally higher than actual irrigated acres as irrigators want to minimize the risk of shortages.

In SSROM the additional acres added to account for the expansion limit also assume the 2018 per acre water demands, which would model an artificially high demand across the expanded acres. Table 14 shows the 2023 irrigation expansion limits where growth was modelled in SSROM, detailing the maximum number of acres per irrigation district. Note as of April 2023, Aetna Irrigation District and Leavitt Irrigation District amalgamated to form the Southwest Irrigation District (SID). In the SSROM, these two districts are considered separate, as per the update to the SSROM model in 2022 (WaterSMART Solutions Ltd., 2022). Also note the 2022 SSROM model update was completed before the amalgamation of TID into SMRID, and therefore these are separated in the results.

**Table 14. 2023 irrigation district expansion limits which were included in the growth scenario.**

| District | 2023 Current expansion limit (acres) |
|---|---|
| BRID | 295,000 |
| EID | 345,000 |
| LNID | 227,000 |
| MID | 18,300 |
| MVID | 4,240 |
| RID | 58,500 |
| SMRID | 584,200 |
| SID (Aetna and Leavitt irrigation districts) | 13,500 |
| UID | 37,840 |
| WID | 110,000 |
| Total | 1,680,080 |

### 3.2.1 Municipal growth and irrigation expansion stress test performance

**Red Deer Basin**

There was no expansion of irrigation acres assumed in the Red Deer basin because the Reference Case already assumed the Acadia Special Areas Irrigation Project (note: the Acadia and Special Areas Irrigation Project is discussed earlier in this report). As the Reference Case presumes full license allocation for the City of Red Deer, additional expansion requires a new licence junior to the WCO. Under current infrastructure, this license would expect to encounter shortages when the WCO is binding. Figure 76 shows that these municipal shortages occur infrequently and could be managed through demand management. When Ardley Reservoir is introduced, these shortages are eliminated. Ardley Reservoir can meet downstream needs, allowing Gleniffer Reservoir to focus on water users supplied by several municipal, regional commissions, and private water systems along and near 140 km of the Highway 2 growth corridor and municipal demands (Figure 76).

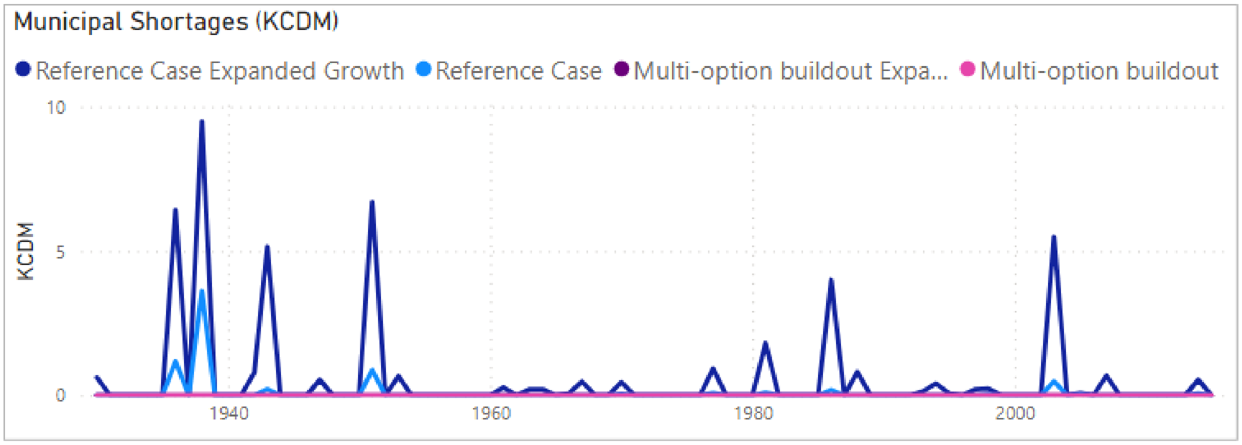
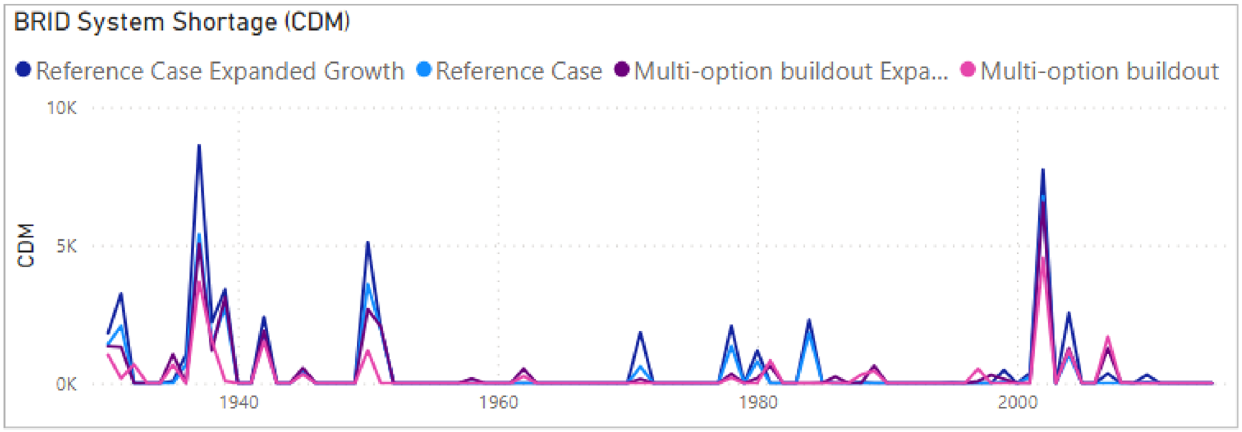


**Figure 76. Comparison of the Reference Case Expanded Growth Scenario (dark blue) compared to the Reference Case (light blue) and the multi-option buildout Expansion compared to the multi-option buildout scenarios showing the Red Deer River basin municipal shortages.**

## Bow River Basin

The Bow River Basin experiences the largest population increase of any SSRB sub-basin, in addition to significant irrigation expansion, under the growth and expansion stress test conditions. In the Reference Case, this increased demand results in an expected increased risk to irrigation districts. Figure 77 shows the relative magnitude of these increased shortages across all IDs. Under the multi-option buildout scenario, shortages within irrigation districts are significantly reduced, as they were in the Reference Case analysis (see Figure 77).



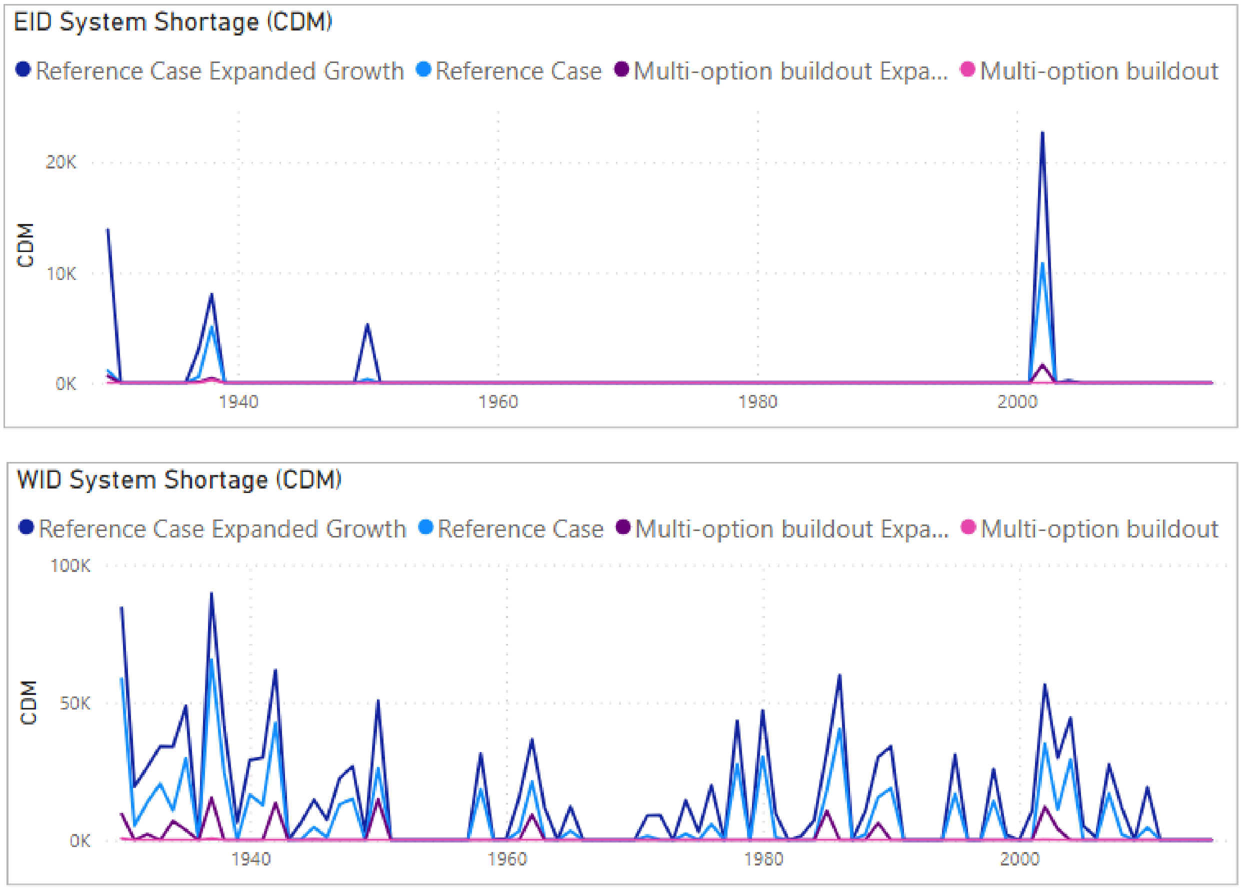


**Figure 77. Comparison of the Reference Case Expanded Growth Scenario (dark blue) compared to the Reference Case (light blue) and the multi-option buildout Expansion compared to the multi-option buildout scenarios showing the BRID, EID, and WID shortages.**

## Oldman River Basin

Compared to other basins in the SSRB, the Oldman River has less margin of error for drought resilience. Conditions worsen when additional growth is applied to this basin drought year. With additional users in the system, the Oldman Reservoir (which already risks emptying) will empty sooner and draw down deeper and more frequently (Figure 78). Once the reservoir is out of water, it can no longer support economic or environmental releases, and such measures suffer (see Figure 79 and Figure 80).

Fortunately, introducing suggested improvements from the Adaptation Roadmap for the SSRB continue to mitigate these risks. Just as with the Reference Case, the “Multi-option buildout” run continues to reduce shortages and improve environmental flows at similar magnitudes as it did in the Reference Case.

Introducing the multi-option buildout scenario significantly reduces the effluent dilution risks at Lethbridge. The introduction of Eyremore Reservoir continues to relieve pressure on the Oldman

Reservoir by making releases to maintain flow past Medicine Hat. Under the growth conditions, the Oldman Reservoir can make releases to maintain 16 m$^3$/s past Lethbridge. Figure 78 shows that under the growth scenario, storage in the Oldman Reservoir is drawn down significantly; however, Figure 81 shows that flow past Lethbridge is kept above the 16 m$^3$/s threshold.

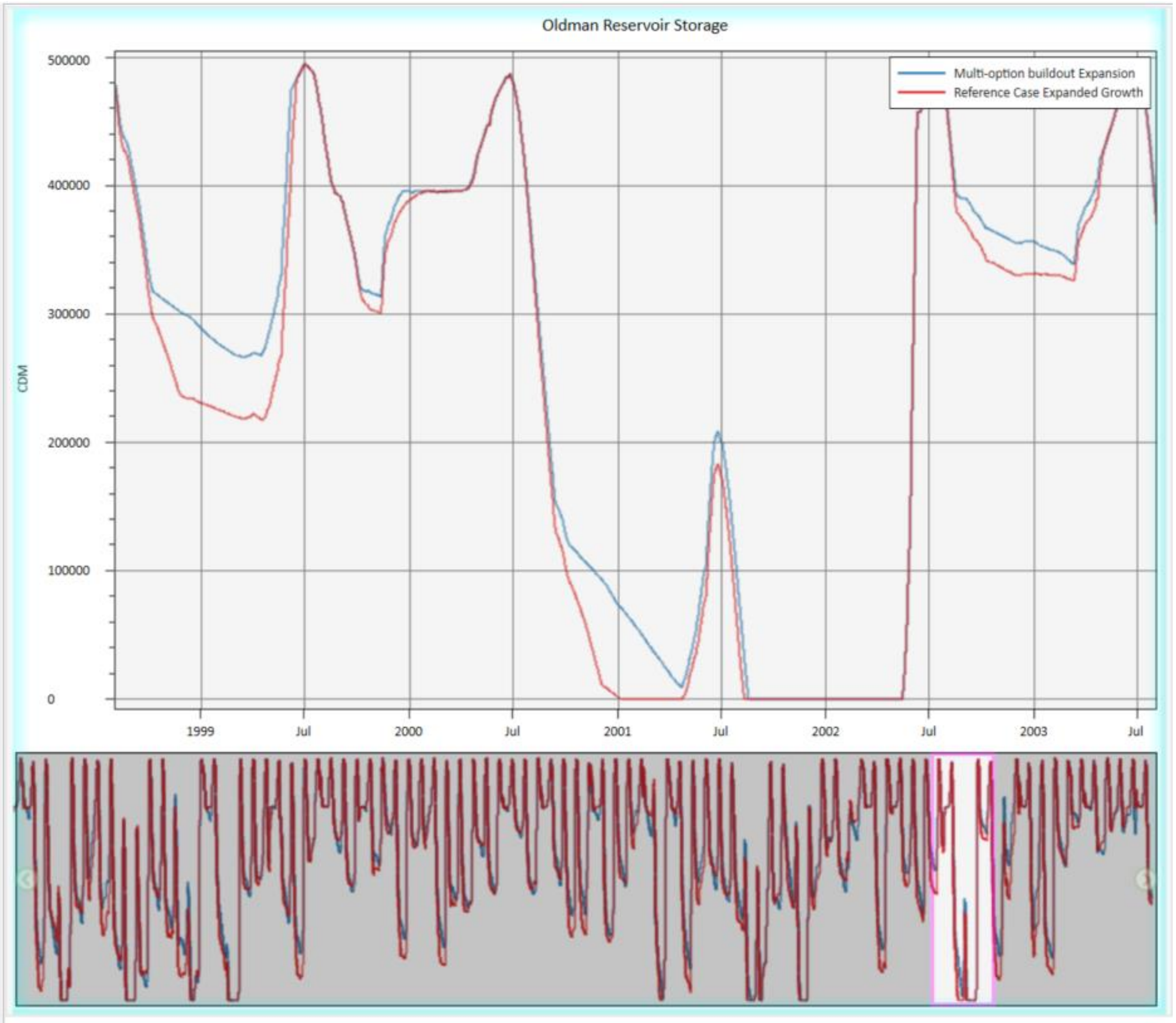


**Figure 78. Comparison of the multi-option buildout expansion (blue) compared to the Reference Case Expanded Growth Scenario (red) and the Reference Case (blue) showing the Oldman Reservoir storage level.**

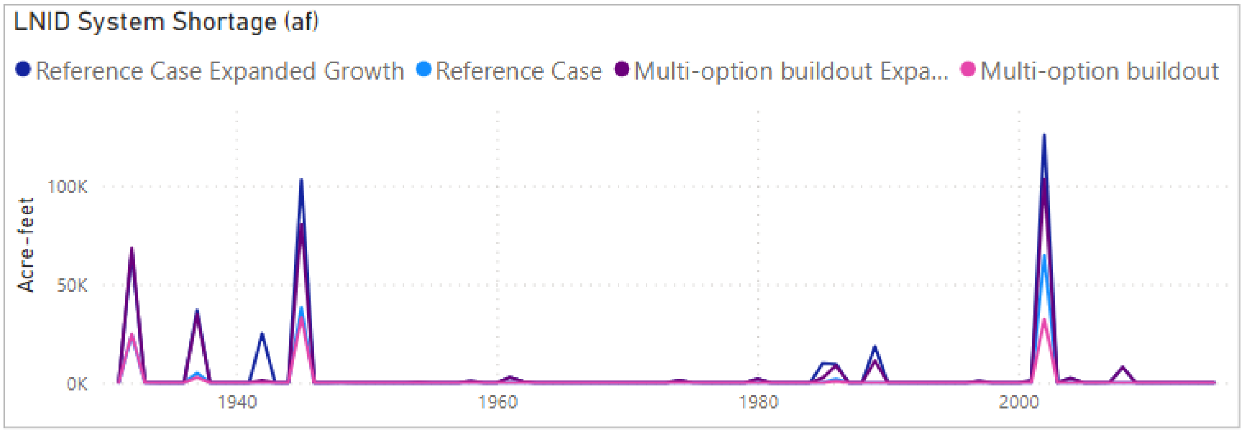


**Figure 79. Comparison of the Reference Case Expanded Growth Scenario (dark blue) compared to the Reference Case (light blue) and the multi-option buildout expansion compared to the multi-option buildout scenarios showing LNID shortages.**

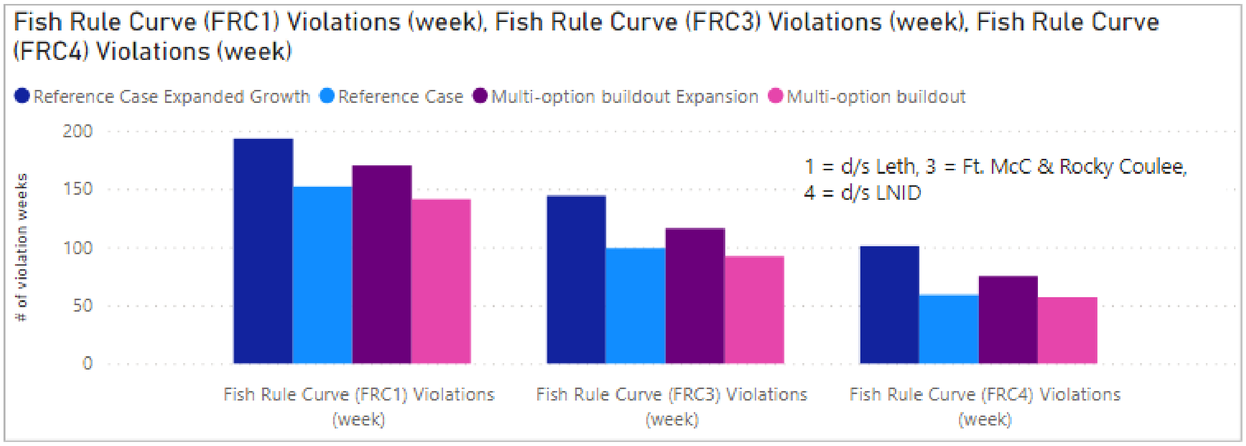


**Figure 80. Comparison of the Reference Case Expanded Growth Scenario (dark blue) compared to the Reference Case (light blue) and the multi-option buildout expansion compared to the multi-option buildout scenarios showing the Fish Rule Curve violations.**

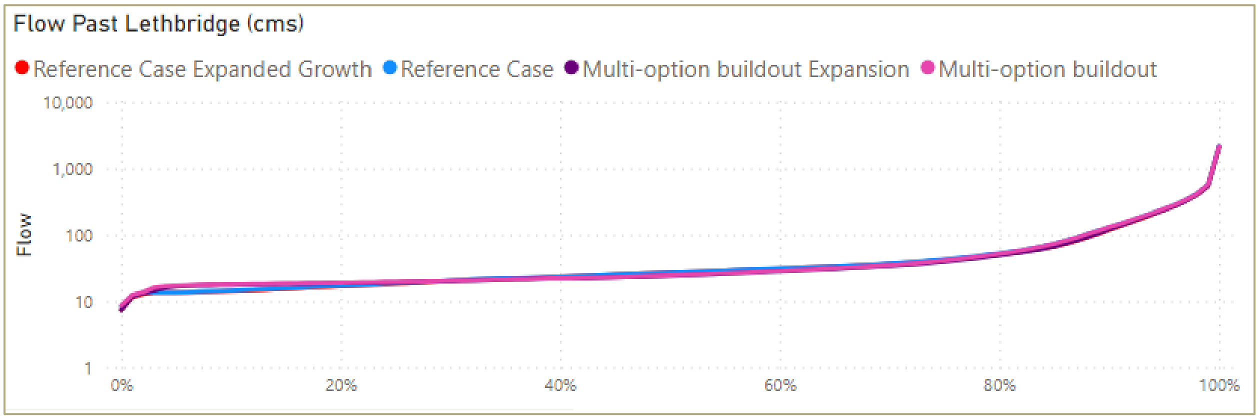


**Figure 81. Comparison of the Reference Case Expanded Growth Scenario (dark blue) compared to the Reference Case (light blue) and the multi-option buildout expansion compared to the multi-option buildout scenarios showing the flow past Lethbridge.**

With the introduction of the growth scenario, the Upper Belly Reservoir would be used more frequently to support the additional demand in UID and would also provide support for SMRID via flows into the St. Mary Reservoir. Under the growth scenario, the Upper Belly Reservoir is drawn down faster to support the additional acres, but still frequently refills and provides security for the downstream irrigation districts (Figure 82).

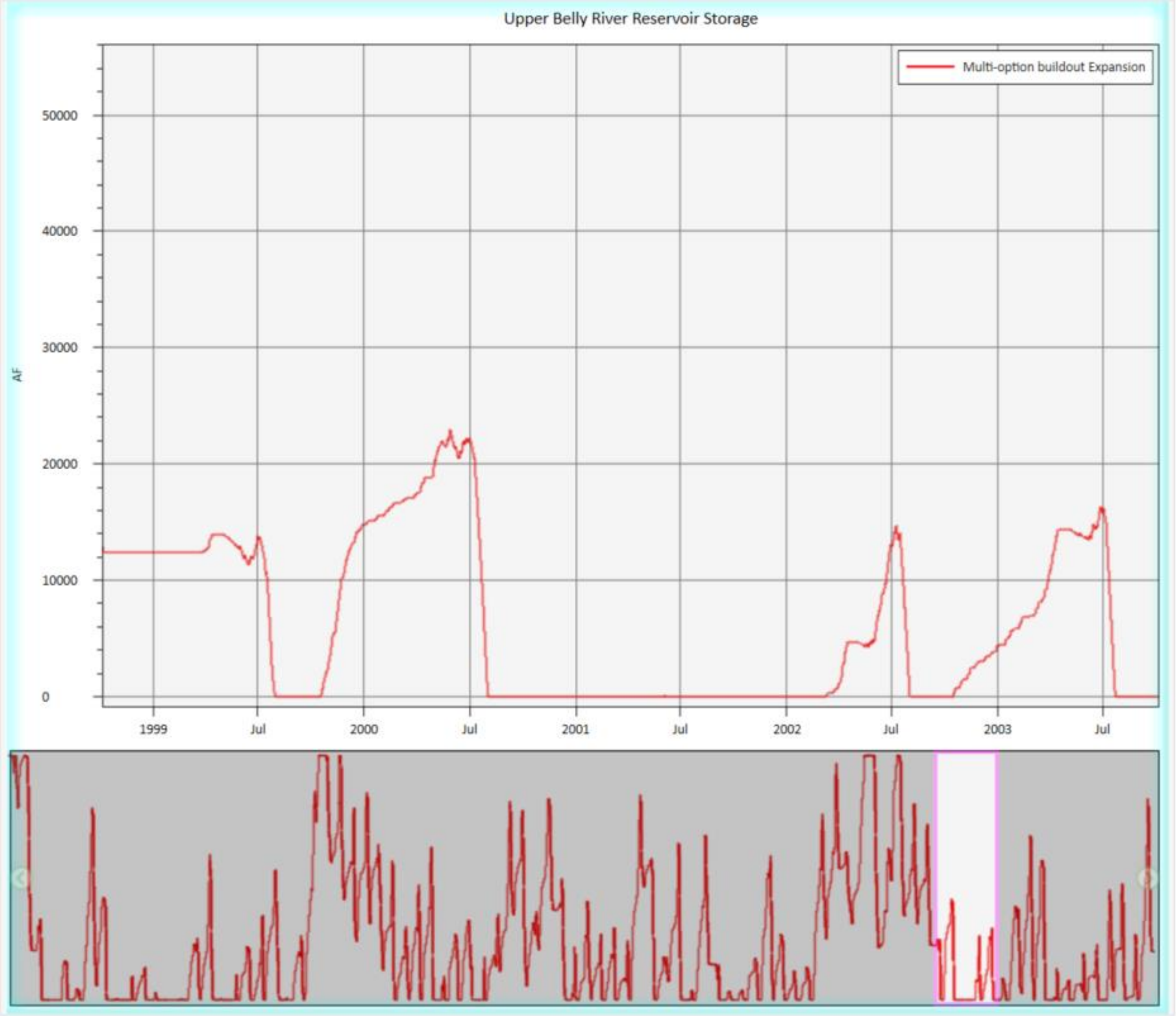


**Figure 82. Upper Belly River Reservoir storage under the multi-option buildout expansion scenario.**

## 3.3 Climate Stressed Conditions

The multi-option buildout scenario was run in SSROM against the three climate scenarios outlined in Section 2.4.4 to understand how the high performing options could perform in a changing climate. As discussed earlier, the modelled climate scenarios consistently highlight an earlier freshet and lower late summer flows compared to summer conditions. The purpose of the climate analysis was to understand how water security in the basin changes over time without basin growth and the risk to the economic and environmental status quo. This is highlighted by the Reference Case modelled against climate change. Furthermore, the analysis highlights how the Adaptation Roadmap for the SSRB projects can reduce the risk posed by the changing climate to maintain current water security in the basin.

For clarity, the results presented below show the multi-buildout scenario run with the IPSL-CM6A-LR (SSP 1-2.6) climate scenario, which represents the lowest mean annual flow with large shifts in the timing of flows. These results were considered the “worst” of the modelled climate flows, as they had the greatest negative impact on basin flow timing and volumes. Since most alternatives still fared well in the face of these flows, we limit most of our discussion to comparisons of results against this “worst” climate. Additional climate scenarios were modelled, but results remained largely consistent; i.e. the “Kitchen Sink” provides substantial value and is capable of mitigating the effects of the changing flow regime.

### Red Deer River performance

The Red Deer River Basin is currently comparatively well positioned to weather climate change forecasts. Despite the shift in freshet timing and lower summer flows, heavy use of Gleniffer reservoir by the basin could allow it to supply consumptive use in the basin. This does lead to Gleniffer completely or nearly completely emptying nine times in the record (see Figure 83). Furthermore, as most users are senior to the WCO, river flows take a substantial hit (see Figure 84).

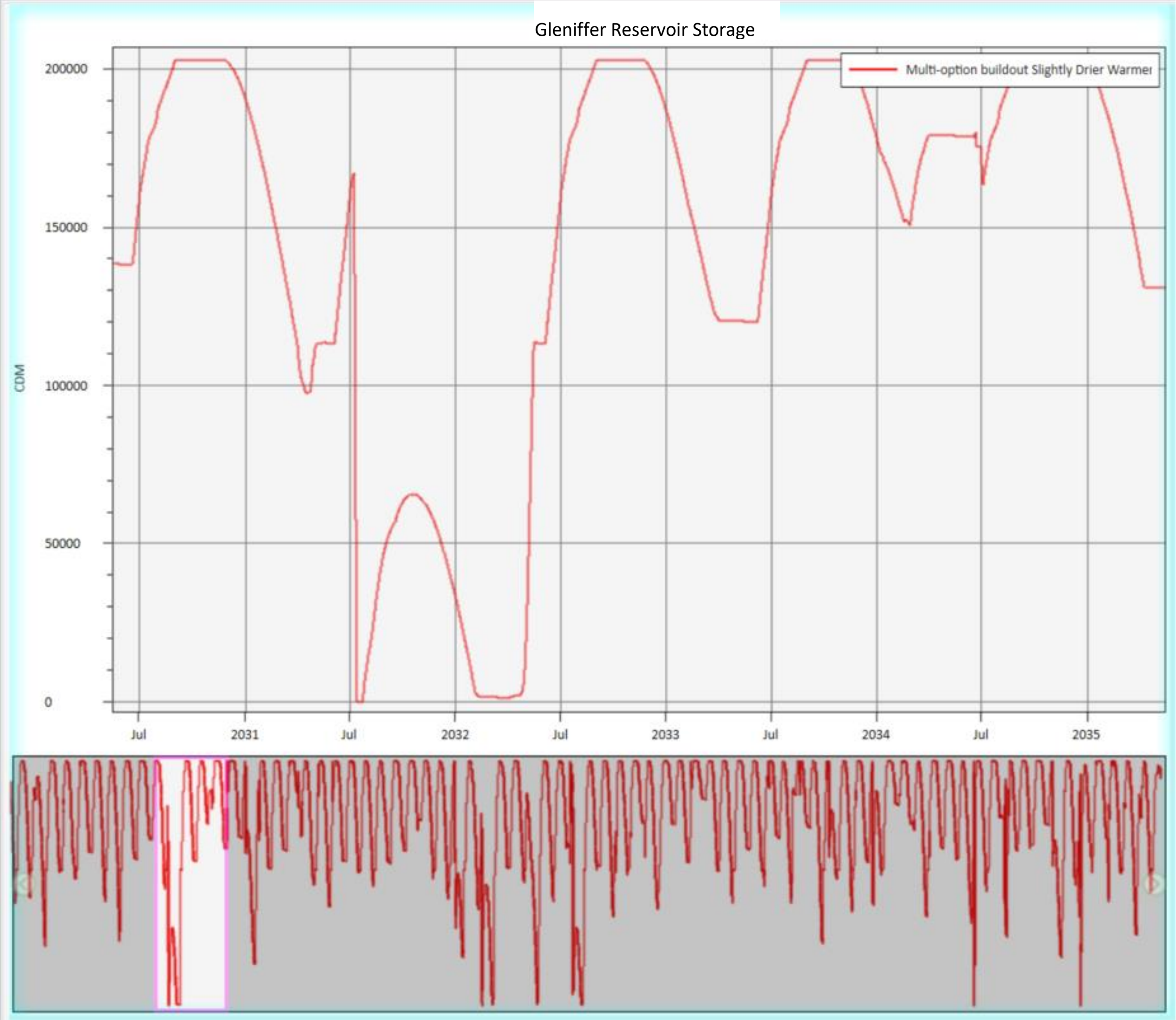


**Figure 83. Multi-option buildout (red) under the Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) climate change scenario showing the Gleniffer Reservoir storage.**

When Ardley Reservoir is introduced in the multi-option build out, the basin gains resilience and is more acceptable to climate stressed conditions, although operations would need refinement. For example, modelling attempted to use Ardley Reservoir to support future irrigators exactly enough that they would empty local storage. While WCO violations outside of irrigation season are eliminated, irrigation season WCOs are not improved in every year (Figure 84). However, Ardley Reservoir does not utilize its full storage even in this “worst flow scenario.”

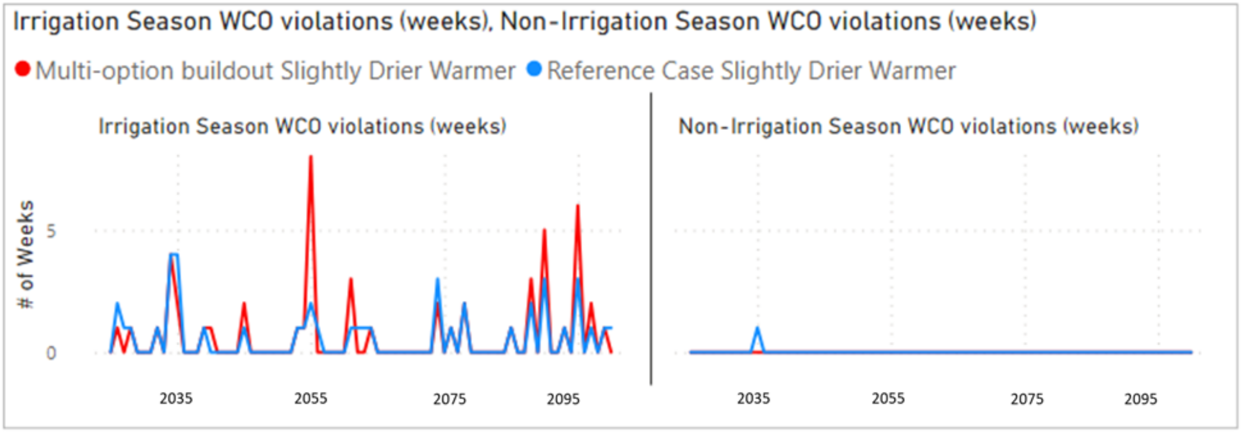


**Figure 84. Multi-option buildout (red) Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) compared to the Reference Case Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) climate change scenarios showing the number of WCO violations during the irrigation season.**

Approximately 200,000 dam$^3$ remain after its maximum drawdown (Figure 85). Use of this water through improved operations could likely significantly improve WCO outcomes. TDL shortages are substantially improved (Figure 86), again raising the question of whether such licenses could be converted to full licenses in the presence of Ardley.

Figure 85 shows the storage plot for the Ardley Reservoir in the year 2031, which reflects a severe drought in the climate record. Even during severe drought such as this, there is still water remaining in Ardley, which shows that in addition to mitigating risks within the Red Deer basin, the reservoir can also be used to facilitate expansion, provide additional supplemental environmental benefit, and provide additional apportionment contribution. The quantification of these benefits should be included in a future study of Ardley Reservoir.

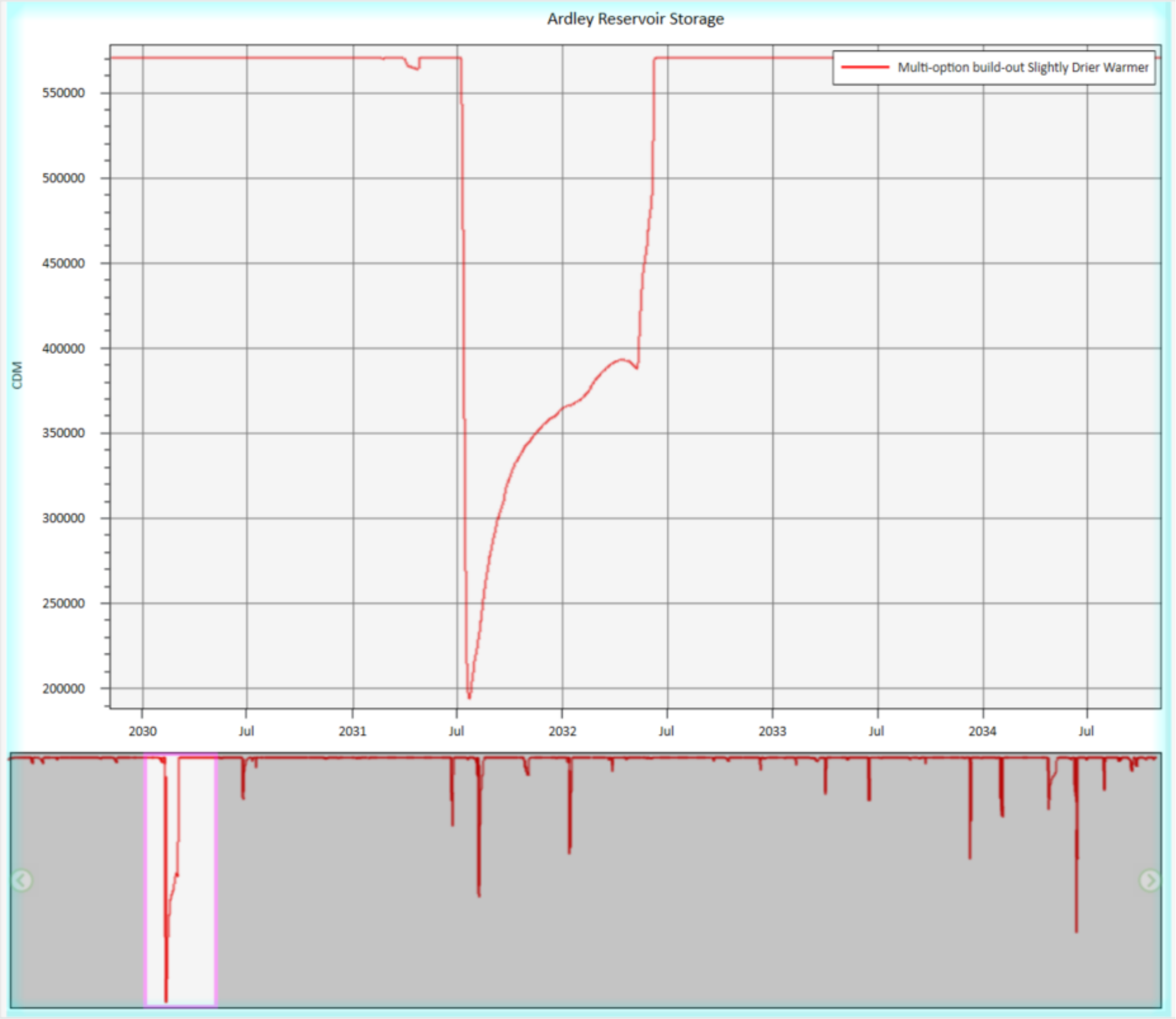


**Figure 85. Multi-option buildout (red) under the Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) climate change scenario showing the Ardley Reservoir storage levels. Note that Ardley Reservoir is not in the Reference Case, so there is no comparison between the multi-option build-out and the Reference Case.**

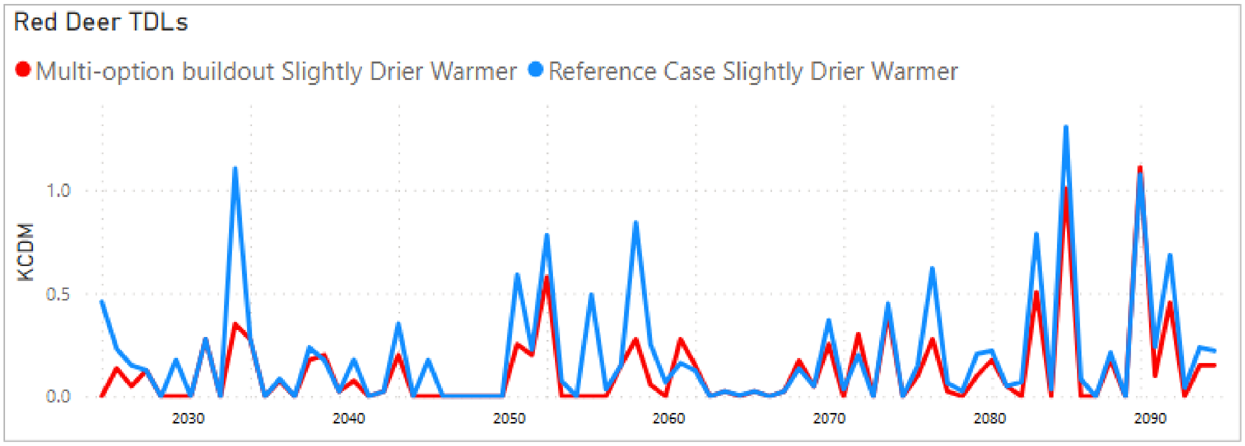
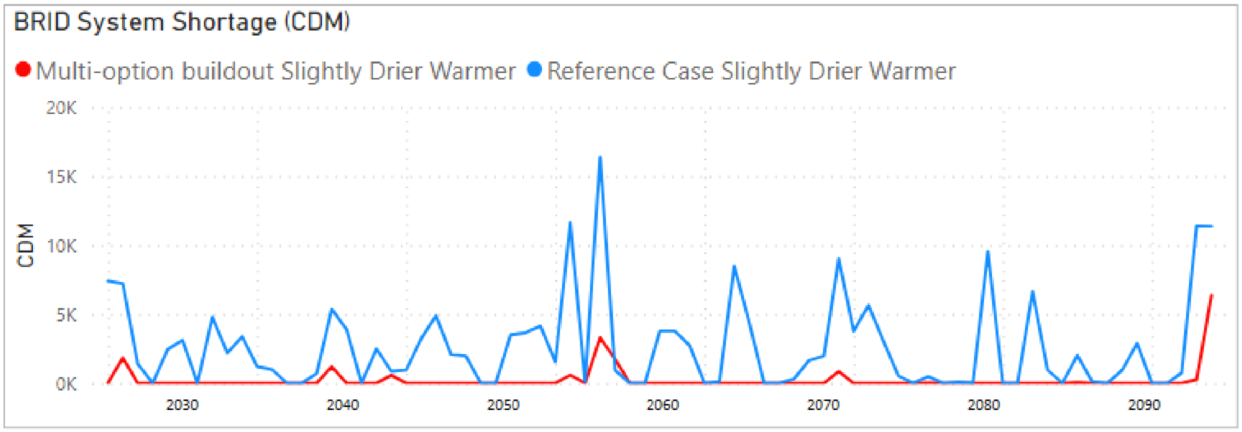


**Figure 86. Multi-option buildout (red) Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) compared to the Reference Case Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) (blue) climate change scenarios showing the number of TDL violations during the irrigation season.**

**<u>Bow River basin performance</u>**

As with the other basins, freshet timing and summer flow reductions impact the Bow in substantially negative ways. Irrigation shortages impact the BRID and EID, despite their substantial internal storages, and the loss of available summer flows substantially impacts WID (Figure 87). Critical low flows become much more frequent as well, notably at Carseland (Figure 88).



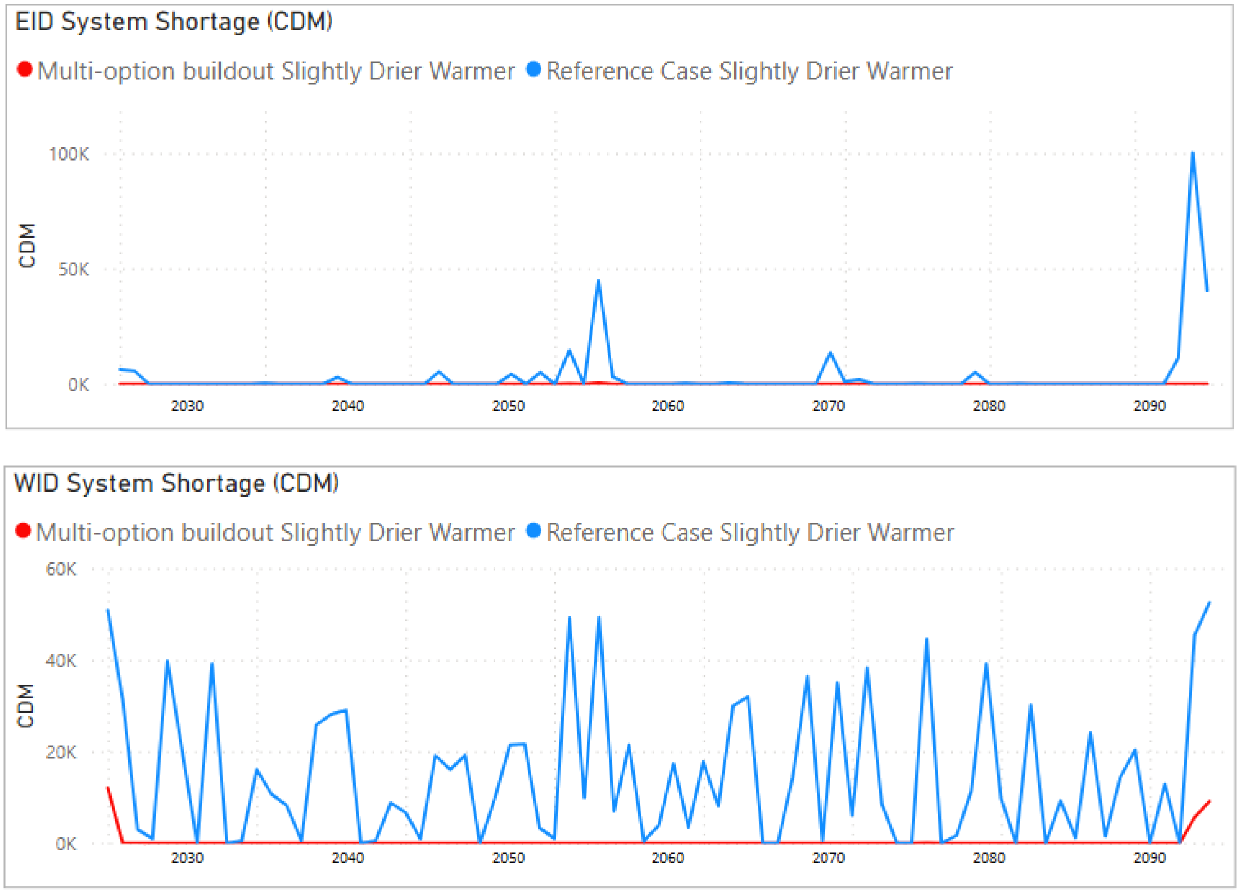


**Figure 87. Multi-option buildout (red) Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) compared to the Reference Case Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) (blue) climate change scenarios showing BRID, EID, and WID irrigation shortages.**

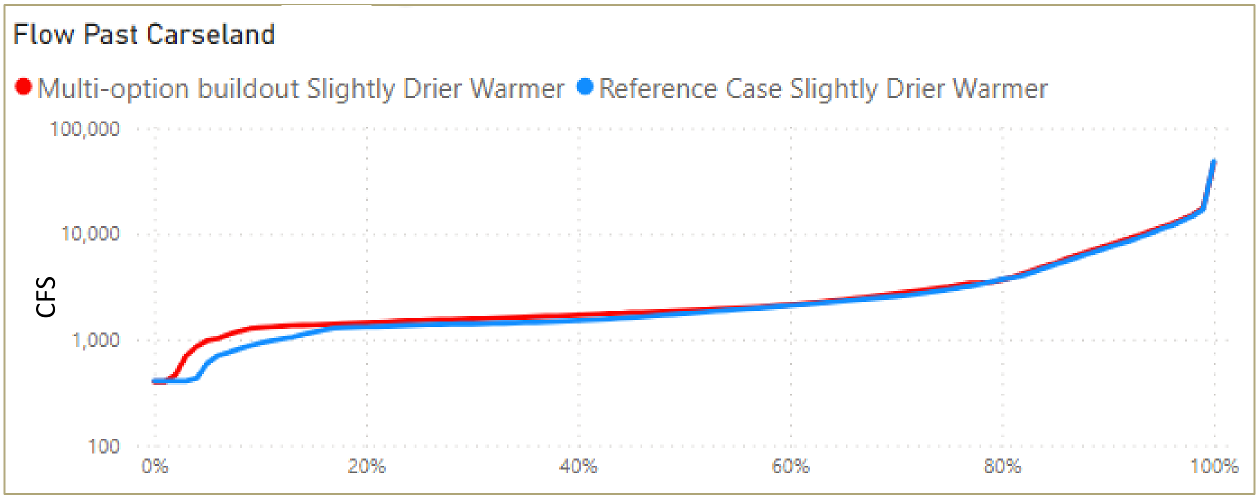


**Figure 88. Multi-option buildout (red) Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) compared to the Reference Case Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) (blue) climate change scenarios showing the**

**flow past Carseland.**

The components suggested in the Adaptation Roadmap for the SSRB can substantially mitigate these issues. After adding in the elements of the multi-option buildout alternative, shortages to irrigators are reduced to near zero across the board. Flows at Carseland improve as well, with an over 50% reduction in days under 22.6 $m^3/s$ (800 cfs), and about a 30% reduction in days under 39.6 $m^3/s$ (1400 cfs) (Figure 89). This is further reflected in the reduction of high temperature days, a larger problem in this climate scenario due to higher air temperatures. Days of water temperatures over 22°C[1] fall by about 30% due to additional flow releases from upstream (Figure 89 and Figure 90).

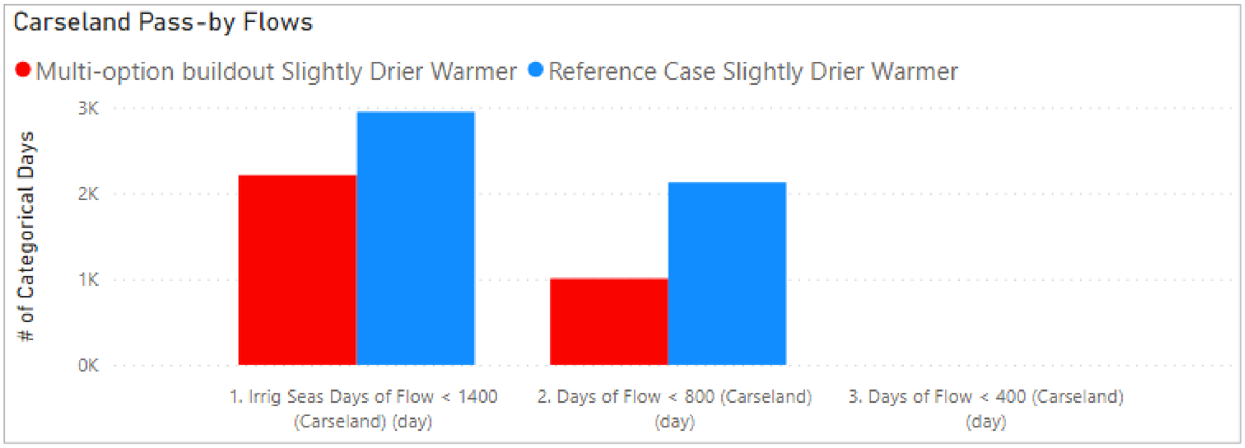


**Figure 89. Multi-option buildout (red) Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) compared to the Reference Case Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) (blue) climate change scenarios showing the Carseland pass-by flows.**

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[1] Long periods above the 22°C threshold result in death of key native fish species which rely on cooler temperatures to spawn.

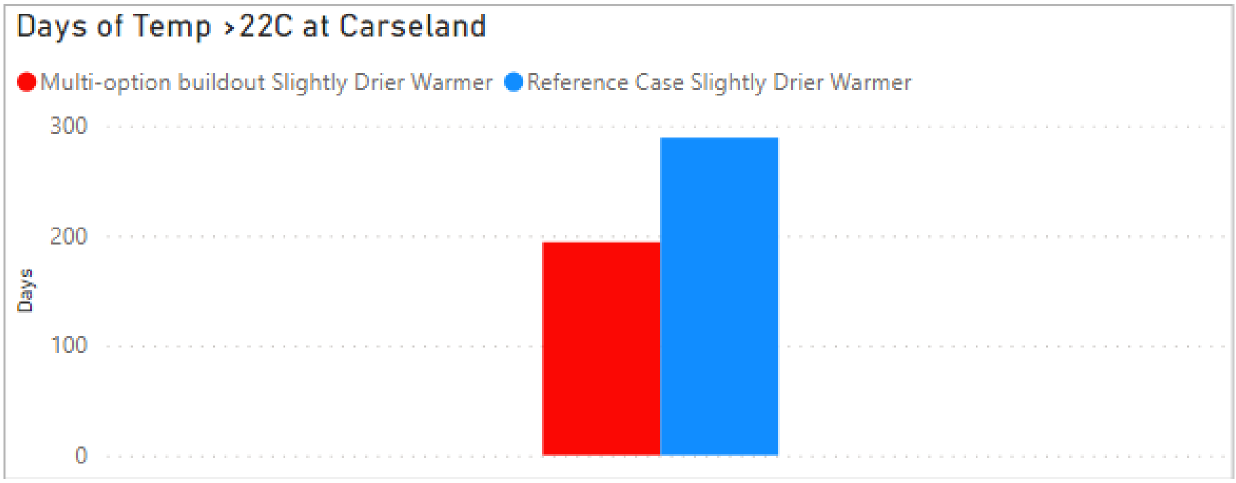

**Figure 90. Multi-option buildout (red) Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) compared to the Reference Case Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) (blue) climate change scenarios showing the number of days stream temperature is above 22°C at Carseland.**

These results are achieved through upstream Bow storage and Eyremore Reservoir working together. The upstream reservoirs (Spray, Relocated Ghost, WID storage) can effectively capture the freshet and release it during low periods, while Eyremore can then recapture release flows to make use of them for irrigators, the downstream Bow, and the Oldman. These reservoirs remain highly utilized; however, as can be seen in their storages (Figure 91, Figure 92, and Figure 93). Restored Spray in particular is worth noting, as under this climate its catchment does not allow it to effectively refill. Utilizing a restored Spray in a severe climate condition will likely require substantial coordination with TransAlta and reoperation of the entire reservoir. Because of this, even though it is one of the less expensive options, it may be preferable to start with a different storage alternative when considering climate adaptation in addition to historical hydrology.

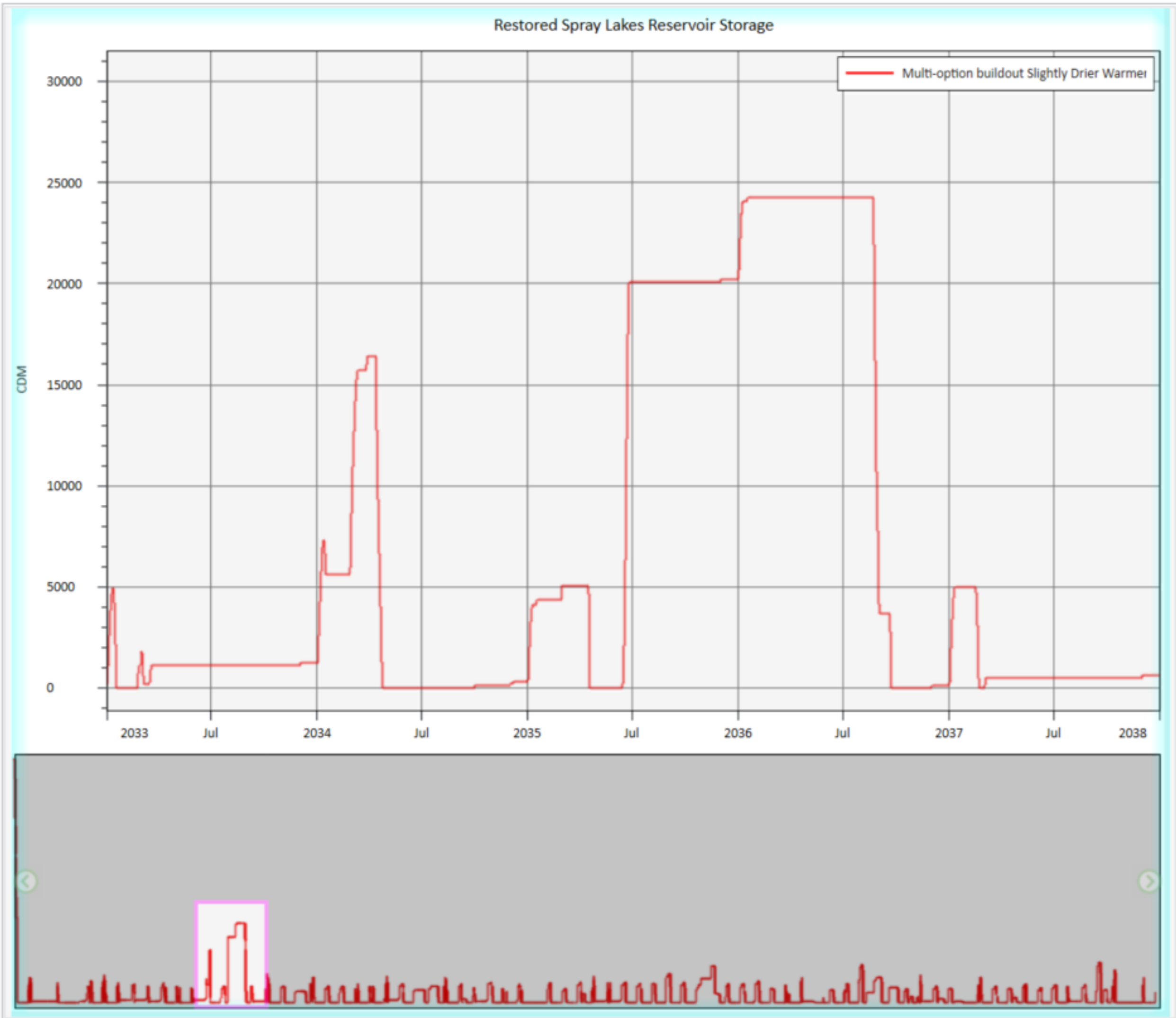

**Figure 91. Multi-option buildout (red) Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) climate change scenario showing the restored Spray Lake Reservoir storage.**

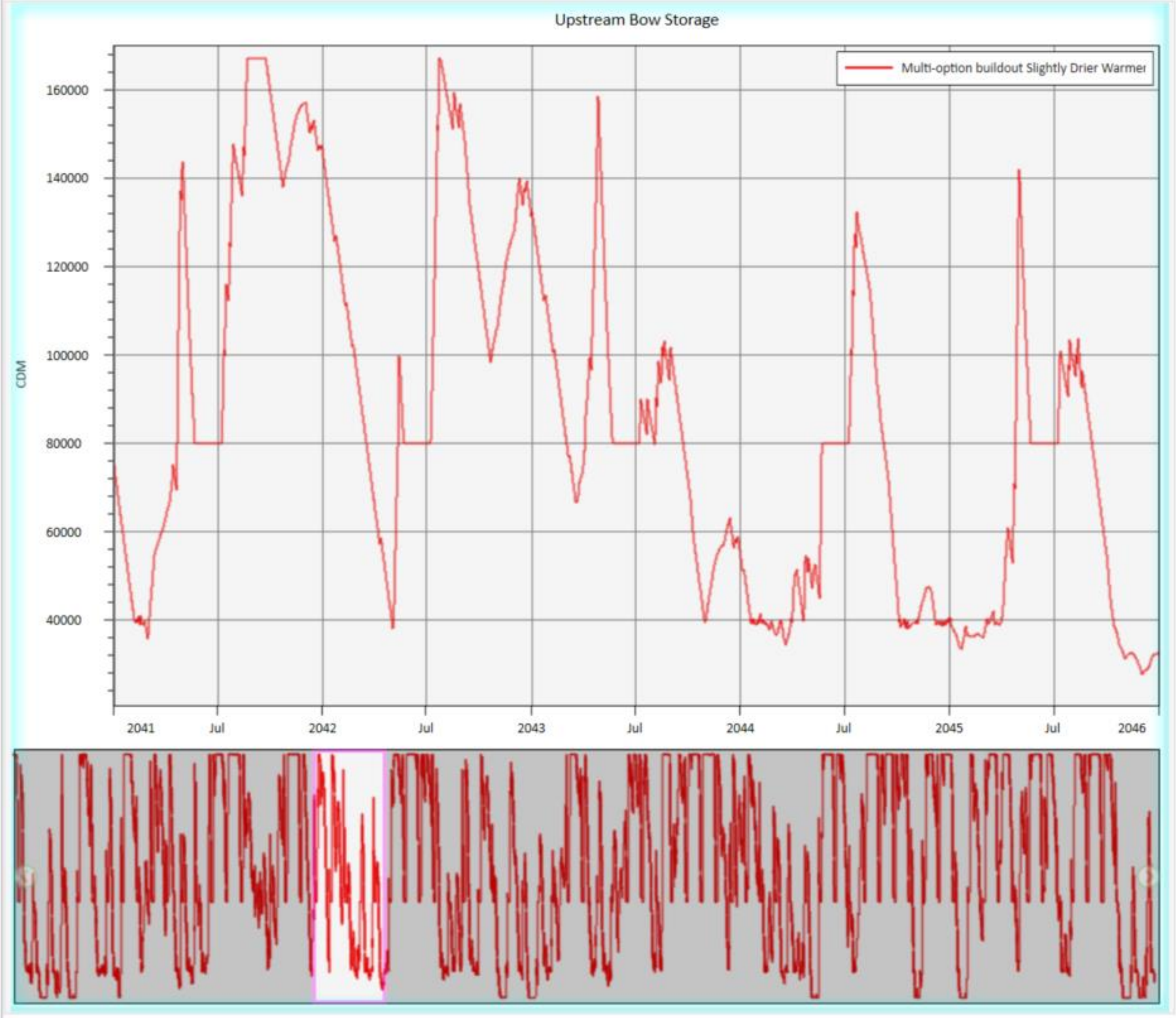

**Figure 92. Multi-option buildout (red) Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) climate change scenario showing the upstream Bow storage levels.**

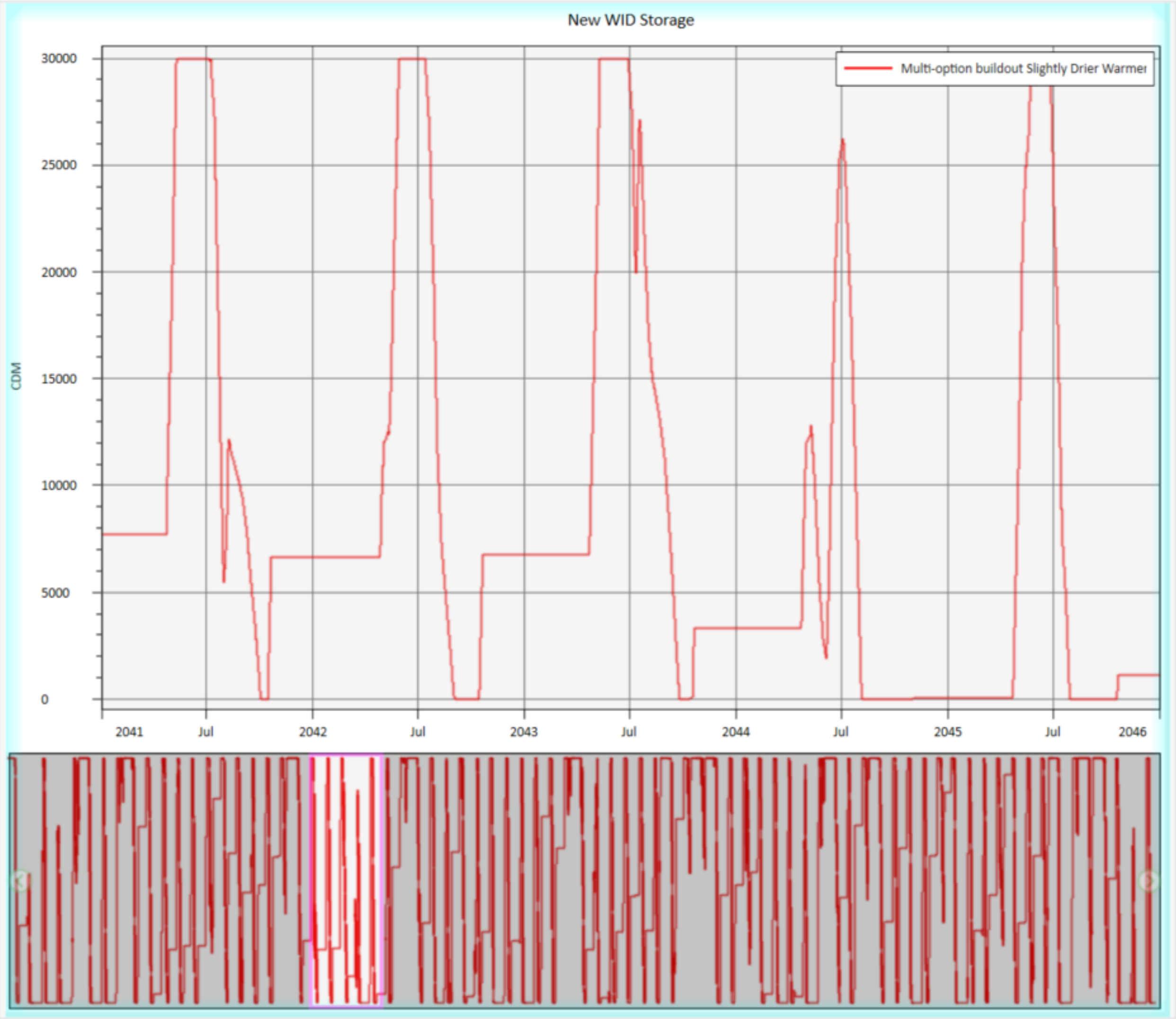

**Figure 93. Multi-option buildout (red) Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) climate change scenario showing the new WID storage levels.**

## Oldman basin performance

Climate change scenarios lead to more frequent winter rainfall (instead of snowfall) in the Oldman basin. In turn, this leads to frequently reduced snowpack and thus smaller freshets in long-term projections. In combination with its earlier shift and the lack of glaciers, the Oldman would expect extended periods of lower summer flows. Under the Reference Case infrastructure, this leads to irrigation shortages for most districts, though those without storage (i.e. UID) are least able to weather the changing climate (Figure 94). From the irrigation side, the introduction of the Belly Reservoir is the most effective component of the multi-option buildout scenario, reducing UID shortages to almost zero, even under this dramatic climate shift. Notably, the Belly Reservoir is able to fill in almost every year.

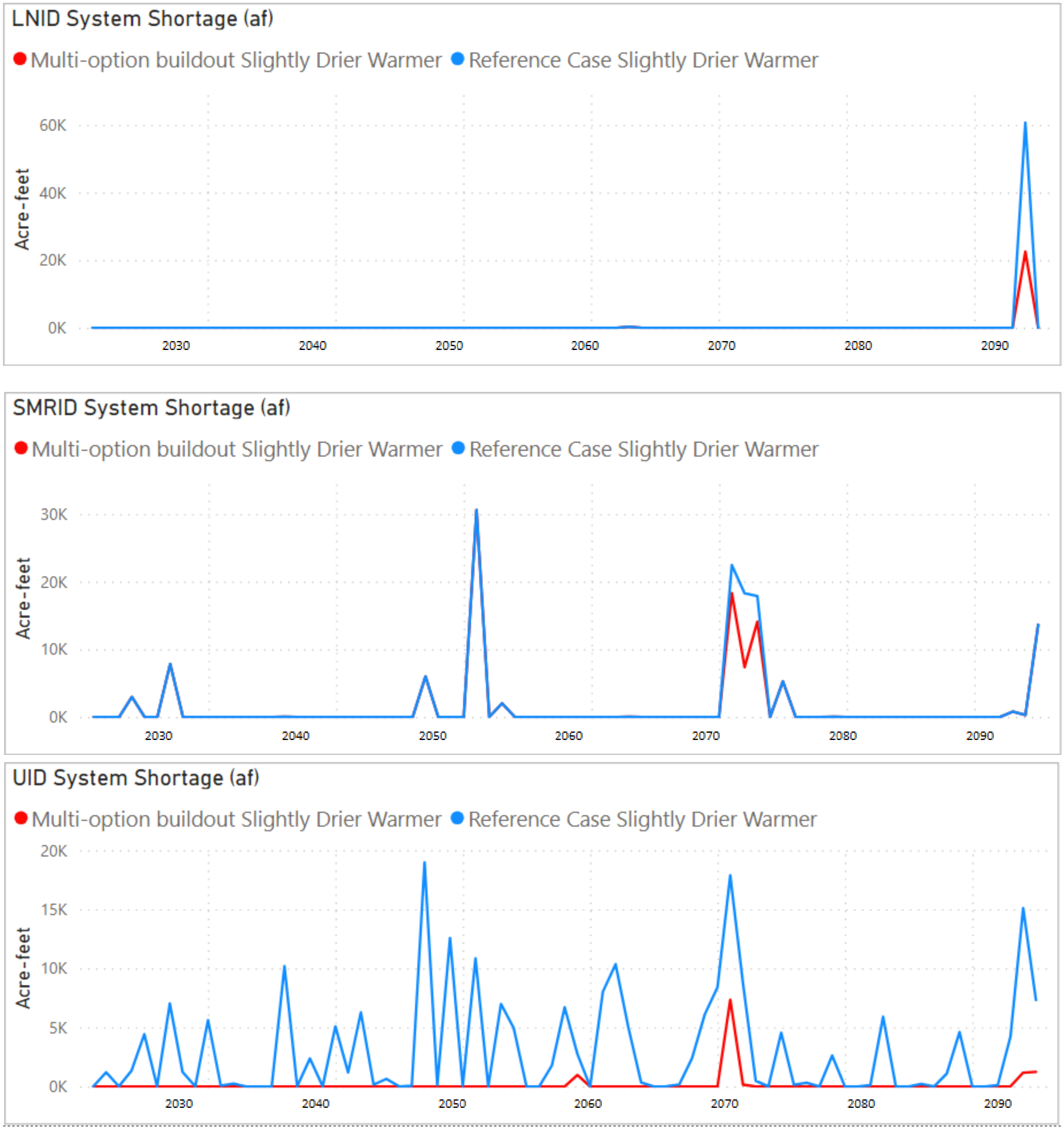

**Figure 94. Multi-option buildout (red) Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) compared to the Reference Case Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) (blue) climate change scenarios showing LNID, SMRID, and UID irrigation shortages.**

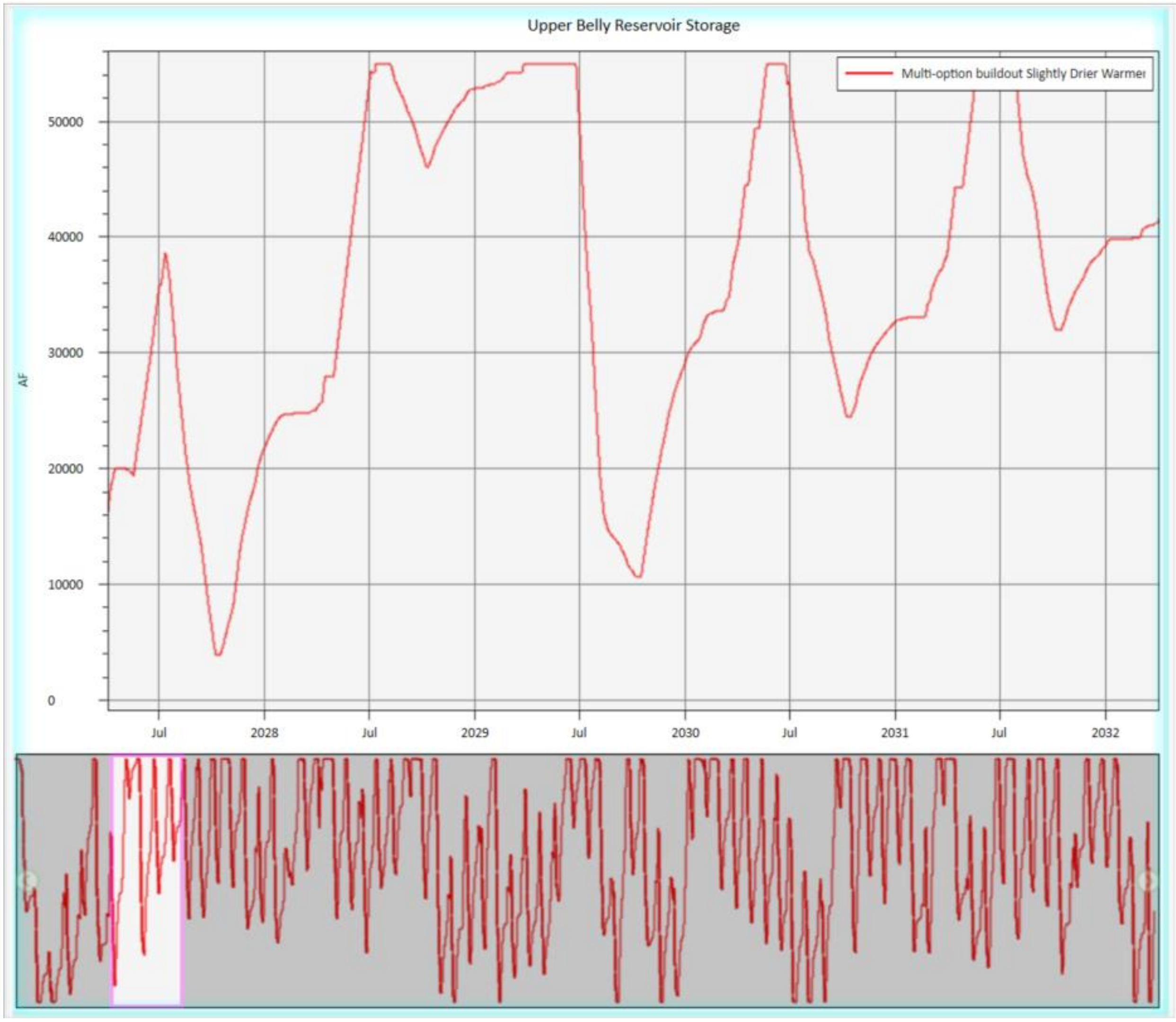

**Figure 95. Multi-option buildout under the Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) climate change scenario showing the Upper Belly Reservoir storage levels.**

The next major component affecting the Oldman sub-basin is the introduction of Eyremore Reservoir and the 16 m$^3$/s year-round minimum at Lethbridge. The relaxed pressure on Oldman reservoir as a result of Eyremore Reservoir meeting downstream obligations, allows it to meet the Lethbridge minimum more easily and effectively. Whereas previously the reservoir “bottomed out” in several years, it was now able to retain a modicum of storage in all but the absolute worst year (Figure 96). The advantage of this storage, although seen lightly in reducing LNID shortages (Figure 97), is primarily visible in the improvements to FRC violations (Figure 98).

**Figure 96. Multi-option buildout under the Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) climate change scenario showing the Oldman Reservoir storage.**

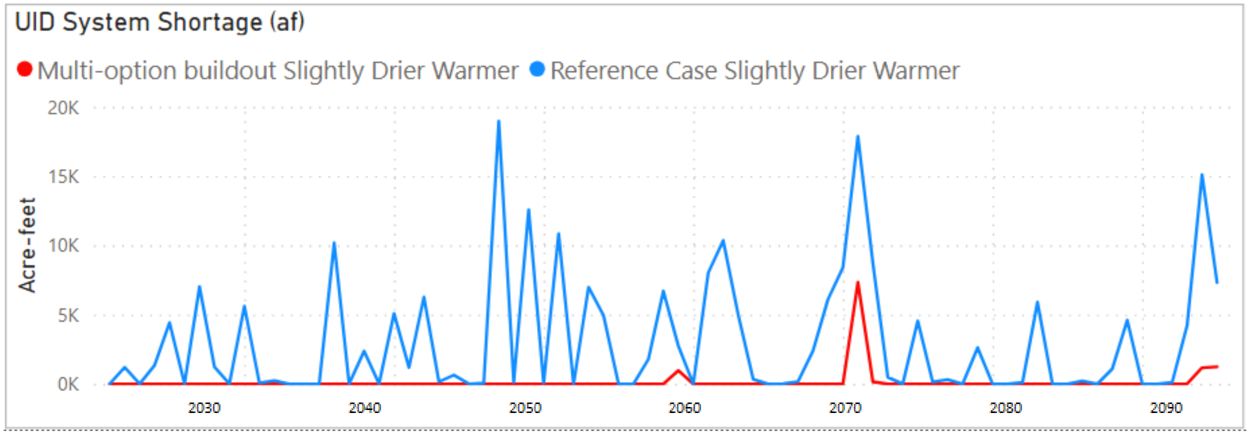

**Figure 97. Multi-option buildout (red) compared to the Climate Change Reference Case (blue) under the Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) climate change scenario showing UID shortages.**

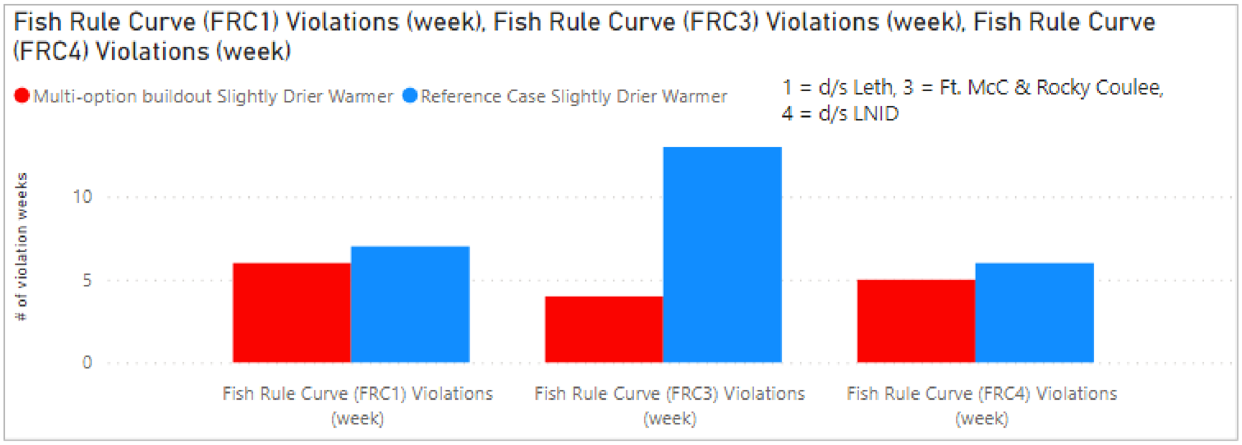

**Figure 98. Multi-option buildout (red) Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) compared to the Reference Case Slightly Drier Warmer (IPSL-CM6A-LR (SSP 1-2.6)) (blue) climate change scenarios showing the Fish Rule Curve violations.**

Additionally, to quantify the outcomes of the multi-option buildout scenarios against climate change, analysis of the flow of water at the mouth of the South Saskatchewan River below (Table 15) provides a summary of this incremental water volume, or “delta water”.

**Table 15. Average annual total system inflow under the multi-option buildout compared to historical inflows.**

| Year | Naturalized Total Annual Flow at Mouth ($m^3/s$) | Naturalized Multi-option Buildout Total Annual Flow at Mouth ($m^3/s$) | Raven Total Annual Flow at Mouth ($m^3/s$) | Raven Multi-option Buildout Total Annual Flow at Mouth ($m^3/s$) |
|---|---|---|---|---|
| 1951 | 159,155 | 158,759 | 168,477 | 165,600 |
| 1952 | 104,914 | 104,008 | 89,915 | 88,043 |
| 1953 | 124,972 | 124,966 | 98,114 | 94,245 |

| Year | Naturalized Total Annual Flow at Mouth (**$m^3/s$**) | Naturalized Multi-option Buildout Total Annual Flow at Mouth (**$m^3/s$**) | Raven Total Annual Flow at Mouth (**$m^3/s$**) | Raven Multi-option Buildout Total Annual Flow at Mouth (**$m^3/s$**) |
|---|---|---|---|---|
| 1954 | 126,117 | 125,462 | 111,131 | 109,847 |
| 1955 | 87,192 | 86,669 | 64,293 | 62,885 |
| 1956 | 77,550 | 77,328 | 76,756 | 76,533 |
| 1957 | 57,634 | 59,155 | 59,307 | 58,475 |
| 1958 | 64,311 | 63,426 | 54,459 | 53,264 |
| 1959 | 73,990 | 73,155 | 71,721 | 71,177 |
| 1960 | 59,796 | 61,223 | 57,892 | 58,195 |
| 1961 | 51,049 | 48,435 | 47,147 | 44,281 |
| 1962 | 47,162 | 47,473 | 43,005 | 43,683 |
| 1963 | 63,408 | 62,076 | 69,261 | 70,475 |
| 1964 | 81,620 | 82,065 | 71,953 | 74,220 |
| 1965 | 121,687 | 120,683 | 113,017 | 112,430 |
| 1966 | 92,112 | 90,539 | 94,579 | 97,283 |
| 1967 | 103,822 | 104,322 | 108,617 | 109,074 |
| 1968 | 60,252 | 60,365 | 84,901 | 87,976 |
| 1969 | 106,402 | 105,705 | 104,460 | 103,682 |
| 1970 | 61,484 | 62,424 | 89,097 | 91,545 |
| 1971 | 69,551 | 70,374 | 86,898 | 88,112 |
| 1972 | 90,279 | 87,803 | 118,047 | 122,721 |
| 1973 | 59,125 | 59,145 | 69,969 | 73,122 |
| 1974 | 87,561 | 86,739 | 101,908 | 103,198 |
| 1975 | 74,949 | 74,820 | 91,991 | 93,943 |
| 1976 | 64,763 | 62,100 | 81,480 | 84,432 |
| 1977 | 32,314 | 34,732 | 52,278 | 54,494 |
| 1978 | 63,875 | 62,309 | 105,434 | 107,783 |
| 1979 | 46,510 | 47,023 | 64,392 | 67,282 |
| 1980 | 51,616 | 50,228 | 79,182 | 83,056 |
| 1981 | 92,098 | 91,108 | 96,291 | 97,286 |
| 1982 | 57,518 | 57,552 | 75,540 | 78,967 |
| 1983 | 41,478 | 42,617 | 55,324 | 56,613 |
| 1984 | 29,170 | 28,557 | 50,546 | 51,896 |
| 1985 | 40,130 | 38,603 | 66,292 | 71,166 |
| 1986 | 75,200 | 73,110 | 101,938 | 102,922 |
| 1987 | 41,915 | 42,659 | 60,368 | 64,509 |

| Year | Naturalized Total Annual Flow at Mouth (m³/s) | Naturalized Multi-option Buildout Total Annual Flow at Mouth (m³/s) | Raven Total Annual Flow at Mouth (m³/s) | Raven Multi-option Buildout Total Annual Flow at Mouth (m³/s) |
|---|---|---|---|---|
| 1988 | 33,464 | 33,101 | 51,633 | 53,931 |
| 1989 | 46,638 | 44,972 | 60,208 | 63,178 |
| 1990 | 92,744 | 92,233 | 86,873 | 85,718 |
| 1991 | 90,761 | 90,523 | 104,473 | 106,865 |
| 1992 | 57,414 | 57,083 | 80,240 | 81,094 |
| 1993 | 110,327 | 108,919 | 105,328 | 101,397 |
| 1994 | 58,890 | 61,271 | 72,397 | 74,071 |
| 1995 | 107,486 | 105,359 | 85,205 | 82,435 |
| 1996 | 86,778 | 86,040 | 86,084 | 88,117 |
| 1997 | 84,415 | 84,054 | 102,942 | 106,951 |
| 1998 | 86,074 | 86,229 | 80,323 | 79,489 |
| 1999 | 75,034 | 74,117 | 86,466 | 88,634 |
| 2000 | 39,525 | 40,848 | 55,103 | 59,403 |
| 2001 | 30,527 | 32,473 | 34,343 | 35,482 |
| 2002 | 72,334 | 67,250 | 78,433 | 78,875 |
| 2003 | 60,394 | 60,694 | 66,622 | 68,951 |
| 2004 | 56,554 | 52,798 | 53,897 | 55,250 |
| 2005 | 126,641 | 126,500 | 160,344 | 163,294 |
| 2006 | 79,164 | 81,290 | 82,688 | 85,581 |
| 2007 | 83,458 | 82,342 | 67,247 | 68,723 |
| 2008 | 88,444 | 86,833 | 65,896 | 64,961 |
| 2009 | 48,819 | 48,575 | 49,378 | 51,458 |
| 2010 | 94,190 | 93,997 | 90,255 | 77,875 |
| 2011 | 154,621 | 154,180 | 119,029 | 93,827 |
| 2012 | 118,087 | 117,099 | 98,476 | 83,094 |
| 2013 | 153,165 | 153,041 | 109,566 | 86,020 |
| 2014 | 137,318 | 136,911 | 102,893 | 78,259 |
| 2015 | 76,877 | 76,365 | 59,661 | 50,242 |

# 4.0 Implementation and Support for an Adaptation Roadmap for the SSRB

As part of implementing these options, consideration of the timelines of the impacts from each option should be addressed. As presented in Figure 99, each arrow represents a phased approach which is to be considered when implementing these options. Phase 1 (purple) may require conceptual or preliminary studies, Phase 2 (blue) may involve engineering studies, and Phase 3 (orange) may include a construction period to build the project. These timelines are important to keep in mind, as many large infrastructure projects take several years to implement, such as upstream storage on the Bow River.

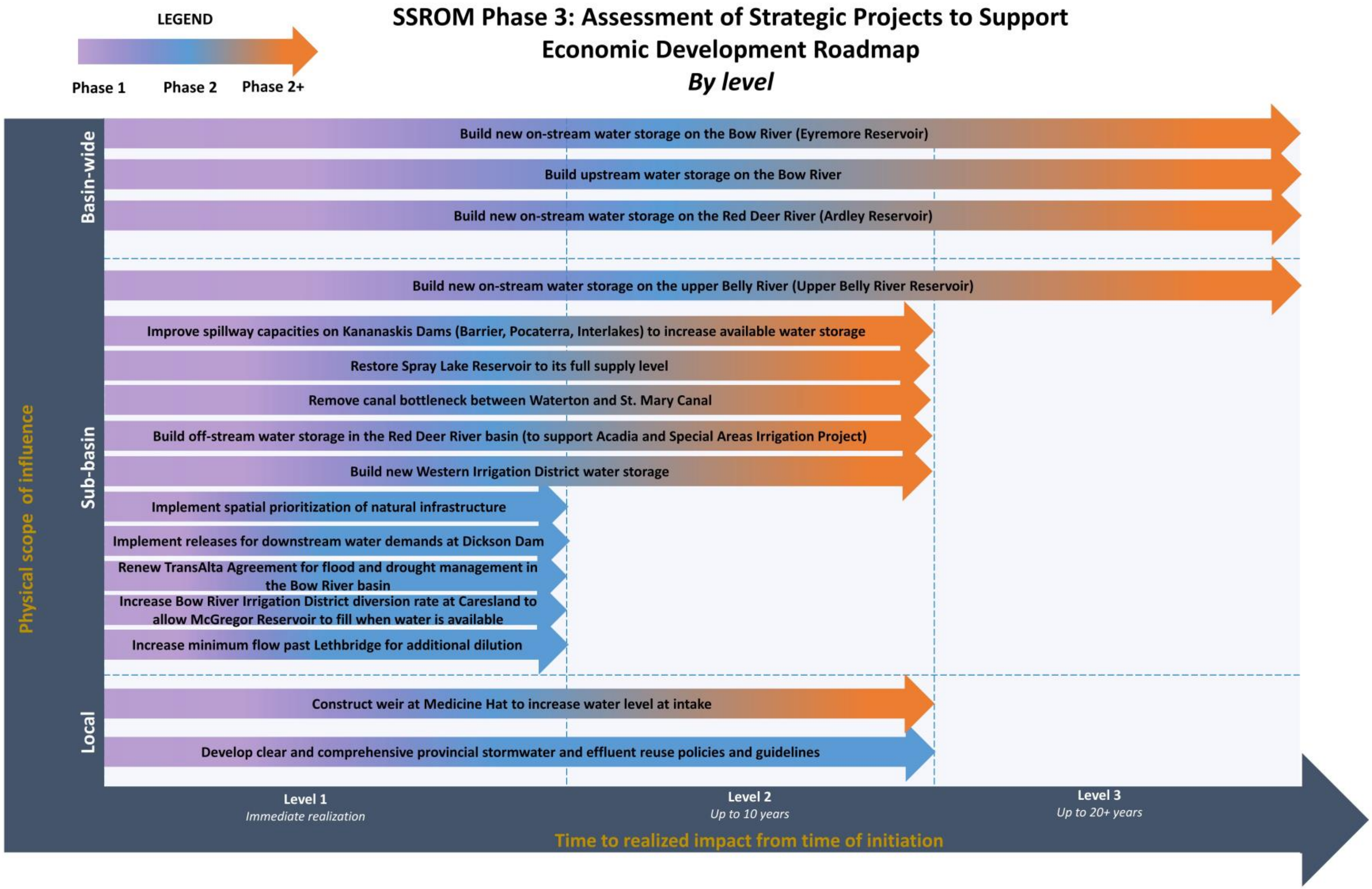

**Figure 99. Implementation of the Adaptation options through Levels 1, 2, and 3.**

Successful implementation of the Adaptation Roadmap for the SSRB project is critical to water security in the SSRB. Summarizing benefits and identifying partners and key actions is frequently a barrier to implementation, especially with more complex projects. To provide a reference point for project proponents, the benefits, potential barriers, and suggested next steps have been identified for each Adaptation Roadmap for the SSRB project.

## 4.1 Knowledge mobilization

The purpose of the SSRB Adaptation Roadmap for the SSRB is to provide strategies which ensure water management in the basin is done in a strategic and sustainable way, enabling continued growth and development. The responsible use of our water resources is critical to ensuring we have enough water in the future to support anthropocentric and environmental needs. The Adaptation Roadmap for the SSRB provides a summary of promising strategies, ranging from ongoing conversation efforts to large infrastructure development. The Adaptation Roadmap for the SSRB includes input from experienced water managers working within the SSRB to determine how the projects being considered, which depend on Southern Alberta's water resources, fit into a larger scheme, which maximizes economic potential while abiding by current laws and treaties and minimizing stress on the watershed. The Adaptation Roadmap for the SSRB is designed to be presented and communicated to various groups, without bias as to the importance of one option over another, outlining the timely actions and projects to ensure economic development within the SSRB.

Key actions from the development of the Adaptation Roadmap for the SSRB was identified as part of the last WG meeting. These actions include, but are not limited to:

- Continuing to develop Adaptation Roadmap for the SSRB options to be implemented (e.g., Upstream Bow Reservoir, influence effluent reuse, and water security policies and guidelines).
- Potentially feeding results into other studies (e.g., International Joint Commission studies) to mitigate impacts.
- Using outcomes from the Project in discussion with Ministers and the GoA.
- Using the Project in support of developing water sharing agreements within the SSRB.
- Presenting the Adaptation Roadmap for the SSRB at several conferences/meetings.
- Reporting the findings through news releases/newsletters.

The Adaptation Roadmap for the SSRB is a starting point. This section summarizes the benefits of each option and outlines potential benefits and next steps for each option to be progressed further. The hope is this can be used as a guide for proponents to promote each option.

## 4.2 Continuous Implementation

Projects included in the Continuous Implementation section of the Adaptation Roadmap for the SSRB are meant to reflect efforts which water managers across the basin should consider both individually and when assessing other options for implementation. These projects, whether natural infrastructure, water conservation, or collaboration, can enhance water management in the basin when they are actioned in a meaningful and intentional manner.

### *Implement more natural infrastructure projects (e.g., wetland reclamation and conservation) across the SSRB*

**Potential benefits:**

- Increases biodiversity.
- Provides a habitat for various wildlife species (as well as many species at risk).
- Reduces the impact of flooding due to the wetlands' capacity to slow flow of water and runoff to rivers and lakes.
- Replenishes and stores groundwater.
- Retains carbon and prevents the release of carbon into the atmosphere.
- Controls sediments and reduces erosion.
- Retains nutrients (i.e., nitrogen and phosphorus).
- Filters water by removing excess nutrients which may otherwise leach into rivers and lakes (i.e., algal blooms).
- Stores water to protect against drought.
- Provides several opportunities for recreational activities.
- Improves air quality.

**Barriers to implementation:**

- Spatial targeting – understanding locations where natural infrastructure provides the most water supply benefits.
- Cost of restoration (conservation is often the most affordable route).
- Cost of implementation at a meaningful scale.
- Potentially limited resources to implement projects.

**Action needed:**

- Continue implementing natural infrastructure projects across a variety of environments.
- Governing bodies need to provide opportunities, funding, and a regulatory environment to implement projects.

**Who should be involved:**

- Ducks Unlimited Canada.
- Trout Unlimited Canada.
- Cows and Fish.
- International Institute for Sustainable Development.
- First Nations.
- Government of Alberta.
- Municipalities.
- Watershed Planning and Advisory Councils.

**Timeframe:**

- As natural infrastructure projects vary in scope and complexity, this option is categorized as continually being implemented.

### *Investigate options to reduce impact to water quality, especially during low flow river conditions*

**Potential benefits:**

- Improves water quality for downstream users and the environment.
- Meets the demands of population growth, while maintaining safe drinking water for humans for consumption.
- Implements newer technologies which can be more effective.
- Upgrades aging infrastructure.

**Barriers to implementation:**

- The cost associated with upgrading wastewater treatment plants is high.
- Newer technologies can often be unattainable, especially for smaller municipalities.

**Action needed:**

- Potentially gain more funding from governing bodies, which can help to support upgrading wastewater treatment plants.
- Expand Water for Life Strategy investment to support water infrastructure building.
- Return funding for the Alberta Resilience Program to original level ($530M). The demand continues to grow for these valuable programs.
- Smaller municipalities could work together to develop a single wastewater treatment system serving several small municipalities.

**Who should be involved:**

- Larger municipalities, which generally have the resources to keep up with the rate of new technologies, treatment, and applications of water.
- Government of Alberta.
- First Nations.

**Timeframe:**

- The timeline to implement this strategy will vary depending on population growth and demand and is fully realized at a local scale throughout the SSRB. As such, this is considered a continual implementation strategy.

### *Promote further water conservation across the SSRB*

**Potential benefits:**

- Reduces energy costs for treating incoming water and wastewater.
- Implements newer technologies which can be used to conserve water and reduce consumption/diversion.

**Barriers to implementation:**

- There are technological limits on how far conservation can be done without incurring impractical overall costs.
- To prevent negative consequences on the aquatic ecosystem from net decreased flow rates downstream, it is necessary to balance the effective use or reuse of water which decreases return flow with a corresponding reduction in raw water intake from what it otherwise would be.

**Action needed:**

- Improve information available to small and medium sized municipalities regarding the latest technologies available.
- Improve availability of information on water saving technologies to developers, landowners, homebuyers, and renters, which can reduce their water usage.
- Continue to integrate new technologies which conserve water.

**Who should be involved:**

- Larger municipalities, which generally have the resources to keep up with the rate of new technologies, treatment, and applications of water.
- Regional water commissions.

**Timeframe:**

- The timeline to implement this strategy will vary depending on population growth, which encompasses hundreds of small improvements throughout municipalities within the SSRB. As such, this is considered a continual implementation strategy.

### *Improve land use best practices across the SSRB*

**Potential benefits:**

- Helps to minimize the negative impacts and maximize the positive impacts of land use change on water resources.

**Barriers to implementation:**

- Different types of land uses call for different best practices, and it is difficult to integrate cumulative impacts and prioritize alternatives.
- Regulatory change is lengthy and a complex undertaking.

**Action needed:**

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

**Who should be involved:**

- Individual industries active in the sub-basin, as well as their umbrella associations which can share information.

- Municipalities and their associations.
- Provincial government agencies with regulatory or management responsibilities.
- Stakeholder groups as appropriate to the topic (e.g., Trout Unlimited Canada, Alberta Wilderness Association, OHV associations, Alberta Wildlife Federation, Canadian Parks and Wilderness Society).

**Timeframe:**

- Ongoing.

***Promote collaborative water management working groups***

**Potential benefits:**

- Learn and exchange information across several organizations.
- Come to a common idea/conclusion which can be implemented across the SSRB.
- Improve communication across organizations, which leads to more innovation, efficient processes, and increased success.
- Help to align water management strategies and goals.

**Barriers to implementation:**

- Time and cost.

**Action needed:**

- Continue to encourage communication networks within water management working groups through projects at all levels.
- Incorporate working groups in projects to ensure collaboration and consultation of water users.
- Push for more investment in data collection and dissemination (i.e., funding more groundwater data collection collaborative work).

**Who should be involved:**

- All major water managers within the SSRB.
- All municipalities and their organizations.

**Timeframe:**

- Due to the collaborative nature of water management, there is a need for the continued application of collaborative working groups to further manage water within the SSRB.

## 4.3 Level 1 Implementation

***Spatial prioritization of natural infrastructure projects***

**Potential benefits:**

- Increases biodiversity.
- Provides a habitat for various wildlife species (as well as many species at risk).
- Reduces impact of flooding due to the capacity for wetlands to slow flow of water and runoff to

rivers and lakes.
- Replenishes and stores groundwater.
- Retains carbon and prevents the release of carbon into the atmosphere.
- Controls sediments and reduces erosion.
- Retains nutrients (i.e., nitrogen and phosphorus).
- Filters water by removing excess nutrients which may otherwise leach into rivers and lakes (i.e., algal blooms).
- Stores water to protect against drought.
- Provides several opportunities for recreational activities.
- Improves air quality.

**Barriers to implementation:**
- None identified.

**Action needed:**
- Governing bodies need to provide opportunities and funding to implement the project.

**Who should be involved:**
- Ducks Unlimited Canada.
- Trout Unlimited Canada.
- Cows and Fish.
- International Institute for Sustainable Development.
- First Nations.
- Government of Alberta.
- Municipalities.

**Timeframe:**
- A project of this scale will likely be implemented within two years.

### *Implement releases for downstream water demands at Dickson Dam*

**Potential benefits:**
- Increased flexibility of water management in the Red Deer River basin in response to flood and drought.
- Risk reduction for the East Central Irrigation Project (Acadia and Special Areas Joint Irrigation Project) and TDLs.
- Protection of environmental flows during extreme multi-year droughts.

**Barriers to implementation:**
- Further investigation would be needed to fully understand the operational, recreational, and environmental impacts of the drawdown of Gleniffer Reservoir in response to increased demand downstream.

**Action needed:**

- A precipitating event or senior government direction to drive the need for modifications to downstream operations.
- Development of a communications plan and infrastructure process.

**Who should be involved:**

- Government of Alberta.
- Municipalities.
- Red Deer River Municipal Users Group.
- Watershed Planning and Advisory Councils.

**Timeframe:**

- Future demand within the Red Deer River sub-basin has resulted in the idea of adjusting operations at Dickson Dam. Full implementation could be done in less than three years, as operations are already being refined. In the meantime, functional flows could be implemented when conditions warrant and as advised by researchers.

### *Renew TransAlta Agreement for flood and drought management in the Bow River basin*

**Potential benefits:**

- Increased flexibility of water management in the Bow River basin in response to flood and drought.

**Barriers to implementation:**

- None identified.

**Action needed:**

- The GoA will continue to work with TransAlta to renew agreements for flood and drought management in the Bow River basin.

**Who should be involved:**

- Government of Alberta.
- TransAlta.

**Timeframe:**

- The current TransAlta Agreement (2021) lasts until 2026. Continuing the TransAlta Agreement into the future needs to be considered.

### *Increase diversion rate at Carseland to allow McGregor Reservoir to fill earlier in the spring when water is available*

**Potential benefits:**

- Increased flexibility of water management in the Bow River sub-basin in response to flood and drought.
- BRID can help other water users by diverting less, leaving more water to other irrigation districts or stakeholders when water supply is low.

**Barriers to implementation:**

- Long regulatory process.

**Action needed:**

- GoA and BRID to work together to further assess diversion rate at Carseland.

**Who should be involved:**

- Government of Alberta.
- Bow River Irrigation District.

**Timeframe:**

- Likely up to two years will be needed for this option to be implemented.

### *Increase minimum flow past Lethbridge for additional dilution*

**Potential benefits:**

- Opportunity to increase wastewater dilution to maintain environmental flows and lessen the impact of effluent introduced into the environment.
- Opportunity for the City of Lethbridge to meet future demand with population increase.
- Protection of environmental flows during extreme multi-year droughts.
- Additional contribution to apportionment.

**Barriers to implementation:**

- Limited by the operations of the Oldman Reservoir for supplementing flows to the City of Lethbridge.

**Action needed:**

- Communication between the City of Lethbridge and the GoA to coordinate water releases from the Oldman Reservoir.

**Who should be involved:**

- Government of Alberta.
- City of Lethbridge.
- LNID.
- First Nations.

**Timeframe:**

- Within the immediate future, this option can be fully realized with the changes of operations of the Oldman Reservoir.

## 4.4 Level 2 Implementation

### *Develop clear and comprehensive provincial stormwater and effluent reuse policies and guidelines*

**Potential benefits:**

- Increased flexibility of water management throughout the SSRB.

- Stakeholders can utilize policies and guidelines to implement stormwater and effluent reuse in their own operations.

**Barriers to implementation:**

- Long regulatory process may hinder activities.
- Implementation of water reuse projects may introduce a high capital cost compared to alternative mitigation options.

**Action needed:**

- Undertake engineering studies and a formal application and permitting processes.
- Design, engineer, build, and operate if the decision is to proceed.

**Who should be involved:**

- Government of Alberta.
- Municipalities.
- First Nations.

**Timeframe:**

- A possible 1-10 years would be needed to approve stormwater and effluent policies.

### *Improve spillway capacities on Kananaskis Dams (Barrier, Pocaterra, Interlakes) to increase available water storage*

**Potential benefits:**

- Increased flexibility of water management in the upper reaches of the Bow basin with more storage available for flood and drought management.
- Potential elimination of filling reservoirs in August and September, leaving more water in the river for downstream use.

**Barriers to implementation:**

- Long regulatory process may hinder activities.
- These upgrades would provide limited incremental power generation to date, so improvements to the spillway have not yet been completed.

**Action needed:**

- Undertake engineering and environmental studies and a formal application and permitting processes.
- Design, engineer, build, and operate if the decision is to proceed.

**Who should be involved:**

- Government of Alberta.
- Municipalities.
- First Nations.
- TransAlta.

**Timeframe:**

- A possible 1-10 years would be needed to implement this strategy.

### *Restore Spray Lake Reservoir to its full supply level*

**Potential benefits:**

- Increased flexibility of the water management system by supplementing downstream flow.
- Advantage of upstream storage for meeting downstream demand.
- Potential to work well with downstream reservoirs to keep them full during low flows.
- Releases from Spray Reservoir can supplement low flows in the upper reaches of the Bow River with positive environmental impacts.
- Ability to supplement low flow periods in the Bow River.
- Impacts from hydropeaking at Spray Lake Reservoir may not be as impactful to fish populations if the amount of flow released relative to Bow River baseflow is likely low (need to assess further in a future study).

**Barriers to implementation:**

- High capital cost compared to alternative mitigation options.
- Long regulatory process and time for construction.
- Disruption to aquatic ecosystem function in the reservoir footprint (could negatively alter timing of contributory freshet flows).

**Action needed:**

- Undertake engineering studies and a formal application and permitting processes.
- Design, engineer, build, and operate if the decision is to proceed.

**Who should be involved:**

- Government of Alberta.
- TransAlta.

**Timeframe:**

- Given ongoing studies related to this option, a possible 1-10 years would be needed to implement this strategy.

### *Remove canal bottleneck between Waterton Reservoir and St. Mary Reservoir*

**Potential benefits:**

- Provides an incremental benefit to MID, SMRID, and RID through additional water availability in the St. Mary Reservoir, and to BTAP due to increased canal capacity.

**Barriers to implementation:**

- Long regulatory process may hinder activities.

**Action needed:**

- Undertake engineering and environmental studies and a formal application and permitting processes.
- Design, engineer, build, and operate if the decision is to proceed.

**Who should be involved:**

- Government of Alberta.
- Municipalities.
- First Nations.

**Timeframe:**

- A possible 1-10 years would be needed to implement this strategy.

### *Build off-stream irrigation in the Red Deer River basin (to support the Acadia and Special Areas Irrigation Project)*

**Potential benefits:**

- Increased flexibility of the water management system by supplementing downstream flow.
- Increased water storage available for irrigation.
- Increased economic prosperity within the region.

**Barriers to implementation:**

- High capital cost compared to alternative mitigation options.
- Long regulatory process and time for construction.
- Disruption to aquatic ecosystem function in the reservoir footprint.

**Action needed:**

- Undertake engineering studies and a formal application and permitting processes.
- Design, engineer, build, and operate if the decision is to proceed.

**Who should be involved:**

- Government of Alberta.
- Special Areas Board.
- MD of Acadia.
- Affected landowners.

**Timeframe:**

- Given ongoing studies related to this option, 10 years is a likely timeframe if the project is determined to be in the public interest.

### *Build new Western Irrigation District water storage*

**Potential benefits:**

- Significant mitigation of WID shortages and improved drought resilience for the district.
- Opportunity for incrementally increased water availability in the Bow River through the City of Calgary as a result of minimizing diversions to WID. This could provide benefits for City effluent dilution in low-flow periods.
- Installation of fish exclusion devices during dam creation at diversion points. This could reduce current fish entrainment into canals and improve fish populations on the Bow River between Carseland and the new Eyremore dam relative to the status quo, as current diversion structure

has no fish exclusion devices.

**Barriers to implementation:**

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

**Action needed:**

- Undertake engineering studies and a formal application and permitting processes.
- Design, engineer, build, and operate if the decision is to proceed.

**Who should be involved:**

- WID.
- Government of Alberta.
- First Nations.
- Affected landowners.

**Timeframe:**

- A timeline within the next 10 years for the conceptual, engineering, and construction aspects of water storage to be fully implemented.

## 4.5 Level 3 Implementation

### *Build new upstream water storage on the Bow River*

**Potential benefits:**

- Increases flexibility of the water management system by supplementing downstream flow.
- Provides additional flood and drought management for the City of Calgary.
- Provides supplementary flow through the City of Calgary for effluent dilution, especially during low winter flow periods.
- Can provide positive benefits to environmental flows for positive environmental benefits.
- Can work with other Bow River on-stream storage to improve water security throughout the Bow River basin.
- Reduces irrigation shortages in irrigation districts, especially WID.
- Could provide direct on-stream storage, which can be used to reduce risk to EID and facilitate economic development and recreation in the local area.
- Could provide supplemental flow for environmental benefit, as Bassano is frequently the point of lowest flow in the Bow River. Eyremore can help maintain higher flows in this reach.
- Could help meet apportionment through maintaining consistent releases.
- The Oldman reservoir makes releases to maintain minimum flows past Medicine Hat, and Eyremore can support this objective by allowing Oldman Reservoir to store water for longer.
- Creates strong potential to improve fishery in the Ghost Reservoir to Bearspaw reach, if peak to baseflow ratios is reduced or ideally eliminated (i.e., reduce hydropeaking). This would allow for

better establishment of primary productivity and reduction of stranded fish eggs following spawning.
- With a sufficient "reserve capacity", could reduce impacts to fisheries from successive droughts.
- Could potentially shape channel-forming flows, which would restore lost ecosystem processes (i.e., embedding of gravel, accumulation of aquatic macrophytes).
- Could shape fish spawning flows (and incubation flows) to optimize spawning success for both spring and fall species.

**Barriers to implementation:**

- High capital cost compared to alternative mitigation options.
- Long regulatory process and time for construction.
- Disruption to aquatic ecosystem function in the reservoir footprint.
- Potential for impacts from construction of new dam, and ancillary impacts to newly flooded land.

**Action needed:**

- Undertake engineering studies and a formal application and permitting processes.
- Design, engineer, build, and operate if the decision is to proceed.

**Who should be involved:**

- Government of Alberta.
- First Nations.
- TransAlta.
- BRID.
- EID.
- WID.
- City of Calgary.

**Timeframe:**

- Given ongoing studies related to this option, up to 20 years is a likely timeframe if the project is determined to be in the public interest.

### *Build new on-stream reservoir on the Bow River (Eyremore Reservoir)*

**Potential benefits:**

- Increased flexibility of the water management system by supplementing downstream flow.
- Upstream reservoirs in the OSSK sub-basins can remain at a higher level, potentially alleviating occasional extreme low flows in the Bow River between Calgary and Bassano.
- Flood mitigation for Medicine Hat.
- The proposed location for Eyremore Reservoir is such that when a large rainfall occurs in the headwaters, it would take days for the first flood water to reach this reservoir. This allows days to initiate a release from storage to mitigate downstream flooding, thus removing weather forecasting from the equation. If a flood event does not materialize, water would be kept in storage for possible drought mitigation later in the year.
- Potential low flow mitigation for Medicine Hat.

- Reduction in shortages for irrigation districts.
- Ability to capture some higher-than-natural winter flows to optimize environmental flows.
- Potential use for functional flows below the reservoir.
- Increased capacity to manage Bow and Oldman systems together for resilience in drought and flood periods.
- Opportunity to increase summer minimum flow releases below the Bassano Dam compared to current instream objective, which could be highly beneficial to fish populations relative to the status quo. Current IO of approx. 12 $m^3/s$ greatly limits the potential of the Bow River between Bassano and the South Saskatchewan River confluence to support healthy fish populations.
- Installation of fish exclusion devices during dam creation at diversion points, which could reduce current fish entrainment into canals and improve fish populations on the Bow River between Carseland and new Eyremore dam relative to the status quo. Current diversion structure has no fish exclusion devices.

**Barriers to implementation:**

- High capital cost compared to alternative mitigation options.
- Long regulatory process and time for construction.
- Disruption to aquatic ecosystem function in the reservoir footprint.

**Action needed:**

- Undertake engineering studies and a formal application and permitting processes.
- Design, engineer, build, and operate if the decision is to proceed.

**Who should be involved:**

- Government of Alberta.
- First Nations (Siksika Nation).
- BRID.
- EID.
- WID.

**Timeframe:**

- Given ongoing studies related to this option, 10 years is a likely timeframe if the project is determined to be in the public interest.

### *Build new on-stream water storage on the Red Deer River*

**Potential benefits:**

- Increased flexibility of the water management system by supplementing downstream flow.
- Added benefits to potential irrigators and irrigation expansion for additional water.
- Opportunity for economic expansion within the region.
- Meaningful drought resilience ability/improvement.
- Eliminated water shortages.
- Improved water quality (i.e., less frequent occurrences of not meeting WCOS).
- Potential to increase the limit of water allocation from the Red Deer, increasing the amount of water for in-Province use within the SSRB (may require additional studies).

**Barriers to implementation:**

- High capital cost compared to alternative mitigation options.
- Long regulatory process and time for construction.
- Disruption to aquatic ecosystem function in the reservoir footprint.

**Action needed:**

- Undertake engineering studies and a formal application and permitting processes.
- Design, engineer, build, and operate if the decision is to proceed.

**Who should be involved:**

- Government of Alberta.
- First Nations.

**Timeframe:**

- Given the work involved in constructing water storage, an appropriate time frame would be up to 20 years to include conceptual, engineering, and construction timelines.

***Build new on-stream storage reservoir on the upper Belly River (Upper Belly River Reservoir)***

**Potential benefits:**

- Increased flexibility of the water management system by supplementing downstream flow.
- Added benefits to surrounding irrigation districts for additional water.
- Opportunity for economic expansion within the region.

**Barriers to implementation:**

- High capital cost compared to alternative mitigation options.
- Long regulatory process and time for construction.
- Disruption to aquatic ecosystem function in the reservoir footprint.

**Action needed:**

- Undertake engineering studies and a formal application and permitting processes.
- Design, engineer, build, and operate if the decision is to proceed.

**Who should be involved:**

- Government of Alberta.
- First Nations.
- UID.
- SID.
- MVID.

**Timeframe:**

- Given the work involved in constructing water storage, an appropriate time frame would be up to 20 years to include conceptual, engineering, and construction timelines.

## 5.0 Closing remarks

The results of this project highlight the need for adaptive water management across the SSRB. Climate change puts significant pressure on water availability in a system which is largely fully allocated. The strategies highlighted in the Adaptation Roadmap for the SSRB demonstrates that economic growth can be facilitated through improved water security throughout the SSRB if we act quickly to implement new approaches to water and watershed management in the basin. Effective water management offers water managers multiple levers to call upon when extreme situations arise. The Adaptation Roadmap for the SSRB has been developed with four levels of implementation. The strategies put forward in each of the four levels demonstrate how existing infrastructure and water management approaches can be built upon to improve the adaptive capacity of the SSRB. The project aims to create a water management Adaptation Roadmap for the SSRB which will allow water users and managers to:

- Identify, understand, and manage water supply risks.
- Engage local experts in water management to enable sustainable economic development.
- Initiate new projects which will provide a secure water supply to support industrial, municipal, and agricultural growth while protecting and improving environmental outcomes.
- Communicate publicly regarding climate change’s impacts on water resources.

The Adaptation Roadmap for the SSRB was developed through the collaboration of knowledgeable and experienced water users and managers from across the SSRB. Through the collaborative process, many opportunities were identified to optimize existing infrastructure, introduce new approaches, and construct both natural and grey infrastructure (i.e., storage reservoirs) to support continued economic and population growth. A proactive approach is critical to the success of the opportunities identified, and the Adaptation Roadmap for the SSRB highlights projects with immediate benefit as well as key infrastructure projects for in-depth investigation.

Projects under the Continuous Implementation of the Adaptation Roadmap for the SSRB demonstrate how smaller economic investments can build cumulatively over time to strengthen water security throughout the SSRB. Some of these projects can be implemented with minimal capital cost and provide widespread economic and environmental benefits.

Level 1 projects are those which can be developed in the short term. These projects do not require capital investment or construction of infrastructure. These strategies present an opportunity to optimize basin practices to maximize economic and environmental benefits, as well as provide immediate water security benefits. Many of these projects could be implemented immediately and are only limited by approval and funding timelines in their implementation.

Level 2 projects may require some capital investment and construction, meaning studies to confirm their benefits and impacts, and finalizing their operation should be initiated immediately to meet the estimated timeline of implementation within 10 years. While capital investment varies across the projects, the economics assessment performed by EcoMetrics® clearly highlights how the direct and indirect benefits from implementation of these projects outweigh the capital investment costs. Many of these projects provide additional levers to pull during extreme events, building basin resiliency in a changing climate.

Level 3 projects represent those opportunities which provide the greatest and broadest benefits. These opportunities reduce risks and improve water security far beyond their immediate locality. The Adaptation Roadmap for the SSRB report highlights the extent to which these projects can potentially benefit the basin. Each project significantly improves water security within its own sub-basin, while several provide benefits across the SSRB. These storage projects can operate to meet multiple objectives and targets, meaning they can be used flexibly to provide benefits to municipalities, agriculture, industry, and the environment. Level 3 projects provide the most significant climate resiliency, while also facilitating basin growth. Level 3 projects have a significant capital cost and development timeline associated with them. There is some urgency to investigate the feasibility of the Level 3 projects, as it is likely the climate will have further deviated from historical norms by the time they are operational, even if these projects are initiated immediately.

While the Adaptation Roadmap for the SSRB was developed with levels to indicate the time taken between initiation and completion, these levels do not mean a project should be considered in isolation. This project builds upon previous projects and ongoing studies to highlight how individual water management projects do not stand in isolation within the basin. Implementation of multiple strategies strengthens the beneficial effects of any individual project, and the most effective path to adaptation is understanding how water management projects complement one another. Modelling of multiple projects highlights how a holistic approach to water and watershed management maximizes benefits across the SSRB. Implementation of multiple projects results in multiple levers available to water managers during extreme events.

Water security is a prerequisite of economic growth, and economic growth cannot be prioritized at the expense of the environment. A key theme raised throughout the Adaptation Roadmap for the SSRB project development was the recognition that the most effective adaptive strategies take a long time to implement. Throughout the development, many crucial next steps were identified by the WG as the most critical to immediately progress the Adaptation Roadmap for the SSRB projects. These included:

- Immediate development of water sharing agreements for use in extreme droughts.
- Continued development of municipal water security plans to identify efficiencies and projects to reduce long-term water demands.
- Continued commitment to the development of a reservoir on the Bow River upstream of Calgary.
- Political engagement with Adaptation Roadmap for the SSRB projects and recognition of the importance of water security for basin growth and development.
- The development of comprehensive water reuse and stormwater use guidelines to allow widespread implementation and reduce demand for potable water.
- Continued implementation of flood and drought mitigation strategies within municipalities.
- Continued development of municipal, industrial, and agricultural efficiencies to reduce water demand and implementation of natural infrastructure.

A great deal of time and knowledge were given to this project and the study on the sub-basins by participants and partners. Their excitement for the collaborative process was remarkable, and their expertise and experience were vital to the success of these projects. The people and groups who helped create this Adaptation Roadmap for the SSRB to advance water management in the SSRB are greatly appreciated by WaterSMART Solutions Ltd. The full list of funders and participants can be found in Appendix B.

To better equip the SSRB's water management system to respond to evolving demands and problems, this Adaptation Roadmap for the SSRB offers a strong basis upon which to determine, refine, and carry out relevant activities, modify the plans, and make investments based on science and facts.

Our hope is that the GoA will take this report into consideration and identify a long-term home for the Adaptation Roadmap for the SSRB; that is, someone who can progress and own the Adaptation Roadmap for the SSRB for the good of all Albertans. We have faith that individual water managers, groups representing watersheds, and users of water will seize this chance to advocate for and facilitate the development of practical approaches to water management for their constituents and their watersheds. We thank you for the opportunity to help guide this collaborative work over these many years, and to the hundreds of participants in this process. We continue to be inspired by your knowledge and dedication to our watersheds and our province.

# 6.0 References

Acera Consult Inc. (2021). *Economic Value of Alberta's Irrigation Districts.* Lethbridge, Alberta, Canada: Prepared for Alberta Irrigation Districts Association.

Alberta Innovates & WaterSMART Solutions Ltd. (2013). *South Saskatchewan River Basin Adaptability to Climate Variability Report: Adaptation Strategies for Current and Future Climates in the Bow Basin; Final Report.* Retrieved from https://albertawater.com/dmdocuments/SSRB%20Adaptation%20Project_Climate%20Adaptation%20Strategies%20in%20the%20Bow%20Basin_2013-06-14%20(1).pdf

Alberta Innovates & WaterSMART Solutions Ltd. (2014). *South Saskatchewan River Basin Adaptation to Climate Variability Project Final Report; Phase III: Oldman and South Saskatchewan (OSSK) River Basins Summary Report.* Retrieved from South Saskatchewan River Basin Adaptation to Climate Variability Project Final Report; Phase III: Oldman and South Saskatchewan (OSSK) River Basins Summary Report

Alberta Innovates & WaterSMART Solutions Ltd. (2015). *Climate Variability and Sustainable Water Management in the SSRB Project: Red Deer River Basin Modelling, Final Report.* Retrieved from https://albertawater.com/dmdocuments/SSRB%20Water%20Project_Red%20Deer%20Basin%20Report_Feb%2012%202015_final.pdf

Alberta Treasury Board and Finance. (2021). *Population Projects: Alberta and Census Divisions, 2021-2046.* Government of Alberta. Retrieved from https://open.alberta.ca/dataset/90a09f08-c52c-43bd-b48a-fda5187273b9/resource/9b48e997-92b0-4b74-82d2-017443049790/download/2021-2046-alberta-population-projections.pdf

Alberta Water Council. (2022). *Drought Simulation Exercise Final Report.* Alberta Water Council. Retrieved from https://www.awchome.ca/uploads/source/Drought_Simulation_Exercise_Memo_Final_Report.pdf

Alberta, G. o. (2021). *Bow River - TransAlta Agreement.* Retrieved from Open Government : https://open.alberta.ca/dataset/d0ee8794-b79b-4bd6-b50a-210c9af60104/resource/f27e24b0-303c-4d01-8467-88b21ef8619e/download/aep-bow-river-transalta-agreement-fact-sheet-2022-02-23.pdf

Arthur, N., & Jochen, H. (2022). A multiple scale, function, and type approach to determine and improve Green Infrastructure of urban watersheds. *Urban Forestry and Urban Gardening*.

Bow River Basin Concil. (2023). *About Us*. Retrieved from The BRBC: https://brbc.ab.ca/about

Canada - United States. (1909). *Treaty Relating to the Boundary Waters and Questions Arising Along the Border between the United States and Canada (The Boundary Waters Treaty)*. Retrieved from Treaty E100420: https://www.canada.ca/en/environment-climate-change/corporate/international-affairs/partnerships-countries-regions/north-america/canada-united-states-boundary-waters-treaty.html

Canadian Council of the Ministers of the Environment. (2021). *Natural Infrastructure Framework: Key Concepts, Defintions, and Terms.*

CMRB. (2018). *Population projectsions produced for the Calgary Metropolitan Region Board and its member municipalities.* Retrieved from https://static1.squarespace.com/static/5eb3220bf77e9b62db665c54/t/5ed6f935fd86f82652b7bb39/1591146806403/FINAL+CMRB+Population+Projections.pdf

Consortium, T. B. (2010). *Bow River Project Final Report.* Retrieved from https://albertawater.com/dmdocuments/BowRiverProject-FullReport-March2011%20(2).pdf

Corporate Finance Institute. (n.d.). *Input-Output Analysis*. Retrieved December 2023, from https://corporatefinanceinstitute.com/resources/economics/input-output-analysis/

Craig, J. R., Brown, G., Chlumsky, R., Jenkinson, W., Jost, G., Lee, K., . . . Tolson, B. A. (2020). Flexible watershed simulation with the Raven hydrological modelling framework. *Environmental Modelling and Software, 129*(104728). doi:doi:10.1016/j.envsoft.2020.104728

DeBeer, C., & Pomeroy, J. (2010). Simulation of the snowmelt runoff contributing area in a small apline basin. *14*. doi:doi:10.5194/hess-14-1205-2010

Eum, H.-I., & Gupta, A. (2019). Hybrid climate datasets from a climate data evaluation system and their impacts on hydrologic simulations for the Athabasca River basin in Canada. *Hydrology and Earth Systen Sciences*. doi:https://doi.org/10.5194/hess-23-5151-2019

Goodwin, R. (1981). THE SASKATCHEWAN NELSON BOARD STUDY IN RETROSPECT. *Canadian Water Resources Journal, 6*(1), 86-95. doi:https://www.tandfonline.com/action/showCitFormats?doi=10.4296/cwrj0601086

Government of Alberta. (2003, November 1). *Water for life : Alberta's strategy for sustainability*. Retrieved from Resources: https://open.alberta.ca/publications/0778530582

Government of Alberta. (2006). *Approved water management plan for the South Saskatchewan River Basin (Alberta)*. Retrieved from Resources: https://open.alberta.ca/publications/0778546209

Government of Alberta. (2011). *Alternative Water Supply Storage and Management Methods.*

Government of Alberta. (2021). *Population Projections: Alberta and Census Divisions, 2021 - 2046.* Government of Alberta Treasury Board and Finance. Retrieved from https://open.alberta.ca/dataset/90a09f08-c52c-43bd-b48a-fda5187273b9/resource/9b48e997-92b0-4b74-82d2-017443049790/download/2021-2046-alberta-population-projections.pdf

Government of Alberta. (2023, 03 27). Alberta Economic Multipliers By Industry and Commodity - 2019. Canada. Retrieved from https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3610059501

Government of Alberta. (2023, April). *Water Act*. Retrieved from Resources: https://open.alberta.ca/publications/w03#summary

Government of Alberta. (2024). *Resources - Springbank Off-stream Reservoir*. Retrieved March 2024, from Government of Alberta: https://www.alberta.ca/resources-springbank-off-stream-reservoir

Government of British Columbia. (2017). *What are Input-Output Models?* Retrieved from https://www2.gov.bc.ca/gov/content/data/statistics/economy/input-output-model/what-are-input-output-models#:~:text=An%20input%2Doutput%20model%20consists,are%20produced%20by%20each%20industry.

Government of Canada. (n.d.). *CMIP6 and Shared Socio-economic Pathways Overview*. Retrieved from Government of Canada: https://climate-scenarios.canada.ca/?page=cmip6-overview-notes#coupled-model-intercomparison-project-phase-6-(cmip6)

Government of Canada, Government of Alberta, Government of Saskatchewan, Government of Manitoba. (1969). *Master Agreement on Apportionment*. Retrieved from https://www.ppwb.ca/about-us/what-we-do/1969-master-agreement-on-apportionment/master-agreement-on-apportionment

Oldman Watershed Council. (2022). *About the watershed*. Retrieved from Explore your Watershed: https://oldmanwatershed.ca/about-the-watershed

Red Deer River Watershed Alliance. (2023). *Get to know our watershed*. Retrieved from Our Watershed: https://rdrwa.ca/our-watershed/

Rennie Intelligence. (2018). *Population Projections: Produced for the Calgary Metropolitan Region Board and Its Member Municipalities.* Rennie Intelligence. Retrieved from https://static1.squarespace.com/static/5eb3220bf77e9b62db665c54/t/5ed6f935fd86f82652b7bb39/1591146806403/FINAL+CMRB+Population+Projections.pdf

Rivera, M. (2023, January 23). *OASIS: Modeling for Water People*. (Hazen and Sawyer) Retrieved August 24, 2023, from https://www.hazenandsawyer.com/articles/oasis-modeling-for-water-people

Sheer, D. P., Baeck, M., & Wright, J. R. (1989). The Computer as Negotiatior. *Journal American Water Works Association, 81*(2), 68-73.

Simieritsch, T. (2013). *Wetland Conservation and Restoration as Flood Mitigation Tools in the Bow River Basin.*

WaterSMART Solutions Ltd. (2016, January). *Climate Vulnerability and Sustainable Water Management in the South Saskatchewan River Basin, Final Report*. Retrieved 2023, from https://albertainnovates.ca/wp-content/uploads/2022/06/WIP-WSWM-2065-N-Watersmart-SSRB-Climatre-Vulnerability-Final-Report-15Jan2016.pdf

WaterSMART Solutions Ltd. (2022). *Summary of Findings: Municipal District of Acadia and Special Areas Joint Irrigation Feasibility Study.* Special Areas Board. Retrieved from https://sh6e03.p3cdn1.secureserver.net/wp-content/uploads/2022/08/Report-Summary-of-Findings-MD-Acadia-and-SAB-Joint-Irrigation-Feasibility-Study.pdf

WaterSMART Solutions Ltd. (2022). *Updates to the South Saskatchewan River Operational Model (SSROM) and the Underlying OASIS Platform - FInal Report.* WaterSMART Solutions Ltd. Retrieved from https://watersmartsolutions.ca/knowledge-base/updates-to-the-south-saskatchewan-river-operational-model-ssrom-and-the-underlying-oasis-platform/

Wood Environment and Infrastructure Solutions. (2020). *Bow River Reservoir Options Phase 1: Conceptual Assessment Main Report.*

# Appendix A SSROM Phase 3 Terms of Reference

See attached Appendix A Terms of Reference document

# Appendix B Project Funders and Contributors

See attached Appendix B document for a complete list of project funders and contributors.

# Appendix C Climate Change Scenario Selection Memorandum

See attached Appendix C document for Climate Scenario Selection Memoandum

# Appendix D South Saskatchewan River Basin Water Flow Diagram

See attached Appendix D document for SSRB flow diagram.

# Appendix E EcoMetrics® Report

See attached Appendix E document for full EcoMetrics® methodology.