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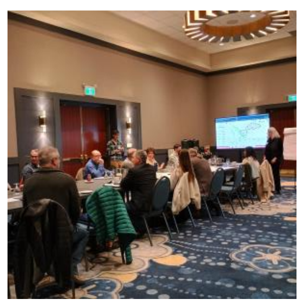

North Saskatchewan River Basin Water Management Roadmap

Final Report

August 8, 2025

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List of Acronyms

Abbreviation	Definition
AER	Alberta Energy Regulator
BMP	Best Management Practice
CEP	Conservation, Efficiency, and Productivity
DIZ	Designated Industrial Zone
EMRB	Edmonton Metropolitan Region Board
ENGO	Environmental Non-Governmental Organization
EPA	Ministry of Environment and Protected Areas
FSL	Full Supply Level
GCM	General Circulation Model
GDP	Gross Domestic Product
GoA	Government of Alberta
HBV-EC model	Hydrologiska Byråns Vattenbalansavdelning - Environment Canada
IFN	Instream Flow Needs
IIRC	International Integrated Reporting Council
IIRF	International Integrated Reporting Framework
IO	Instream Objective
I-O	Input-Output Analysis
IWMP	Integrated Watershed Management Plan
LID	Low-Impact Development
MBCDS	Multivariate Bias Correction with Distribution-free Shuffle
NSR	North Saskatchewan River
NSRB	North Saskatchewan River Basin
NSWA	North Saskatchewan Watershed Alliance
PES	Payment for Ecosystem Services
PM	Performance Measure
Project	NSRB Water Management Roadmap Project

Abbreviation	Definition
Raven	Raven Hydrological Modelling Framework
Roadmap	Water Management Roadmap
SNA	System of National Accounts
SROI	Social Return on Investment
SSP	Shared Socioeconomic Pathways
SVI	Social Value International
SWAD	Surface Water Allocation Directive
Tool	Decision-Support Tool
TSS	Total Suspended Solids
UNDRIP	United National Declaration on the Rights of Indigenous Peoples
WCO	Water Conservation Objective
WG	Working Group
WURS	Water Use Reporting System

Executive Summary

Alberta's *Water For Life* strategy is the Government of Alberta (GoA)'s commitment to managing and protecting water resources for a safe, secure drinking water supply, healthy aquatic ecosystems and a reliable supply for a sustainable economy. Alberta is experiencing strong municipal and economic growth, which depends on continued access to a reliable supply of water. It is imperative that water managers and users continue to have up-to-date tools available to meet the needs of the North Saskatchewan River Basin (NSRB), especially in the context of a changing climate.

Watershed management and climate adaptation are complex and require a collaborative approach to ensure the resultant options are applicable at local and regional scales. A Working Group (WG) was therefore formed to discuss and provide direction on sustainable water management in the NSRB. This project, known as the NSRB Water Management Roadmap Project (Project), allowed for open discussions to identify basin-wide concerns, issues, needs, actions, and adaptation strategies which could support sustainable water management. To support these conversations, a baseline understanding of the water availability and demands within the NSRB was required, leading to the creation of a decision-support tool (Tool), an integration of a hydrological model and a water management model.

The goal of the Project was to create, in collaboration with the WG, a sustainable Water Management Roadmap (Roadmap) for the NSRB (Figure 0-1). The Roadmap outlines a set of adaptations which are grounded in science, guided by community knowledge, and designed to align with Alberta's regulatory frameworks and strategies. With the support of the Tool, the WG members assessed climate, growth, and development adaptations to understand their potential impacts on water availability. The Roadmap was developed to reflect the intricacies of the basin, the participants' interests, and to facilitate informed decision-making in defining the most appropriate adaptation strategies and actions to adopt. The Roadmap can be used to inform future planning and water management efforts, guide government, water managers, and users on sustainable watershed management practices, highlight immediate needs, and outline next steps.

This report summarizes the results of the Project, which was centered around four strategic drivers that reflect Alberta's evolving water management landscape, as identified and discussed by the WG:

- **Enhance the use of sustainable water management practices**: Supporting innovation and efficiency in water use across sectors through conservation, reuse, data improvements, and basin-level planning is essential to sustainable water management.
- **Conserve and restore ecosystems to maintain and improve watershed health**: Natural assets such as wetlands, riparian zones, and connected floodplains are integral to watershed function. Restoring and conserving these assets supports ecological health and resilience and contributes to Alberta's environmental objectives.
- **Maintain or improve water quality**: Protecting drinking water sources, including tributaries, lakes, and small community supplies, requires improved monitoring, data-sharing, and support for infrastructure solutions that are both environmentally sound and economically viable.

- **Advance inclusive and shared governance in water management:** Effective water management requires collaboration across governments, sectors, and communities.

The WG used the following assumptions to characterize the Roadmap and adaptation items:

- Timing to implementation:
  - Short-term: One to three years.
  - Medium-term: Four to six years.
  - Long-term: Over six years.
- Identified benefits including economic growth, environmental outcomes, and sustainable water management.
- While a detailed cost analysis was not completed for the Roadmap, assumptions were made about costs, in 2025 dollars, based on professional judgement and adaptations were broken down into the following high-level categories:
  - Low: Under $1M to implement.
  - Medium-low: Between $1M - $5M to implement.
  - Medium-high: Between $5M - $10M to implement.
  - High: Over $10M to implement.

All the adaptations identified in the Roadmap are promising and critical to ongoing sustainable water management in the NSRB. These strategies are not intended to be rated or ranked in importance through this work, but rather should all be advanced. In addition to the Roadmap adaptations, the WG identified complementary, ongoing actions that should continue in the basin, and future implementation considerations.

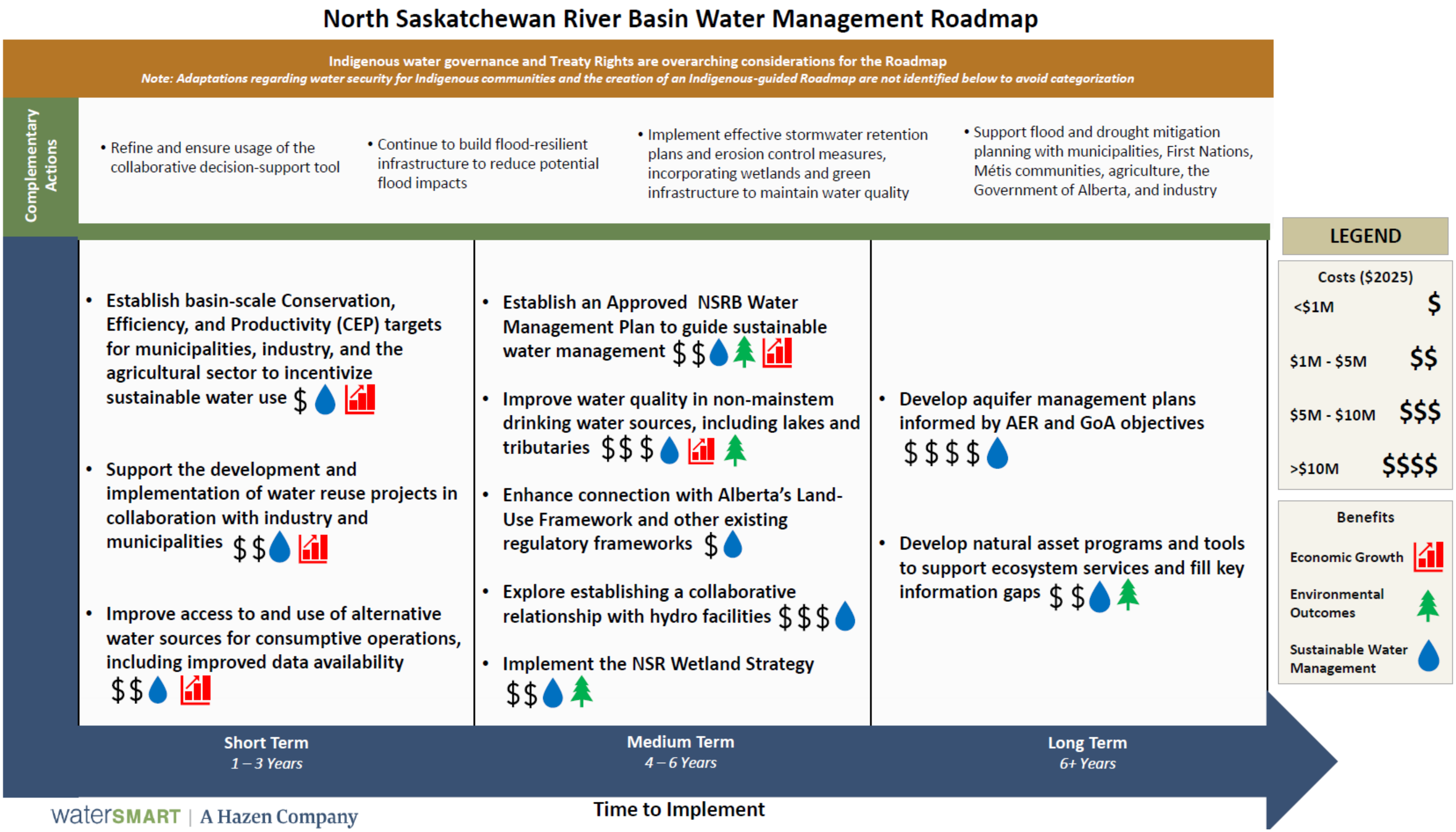

Figure 0-1: North Saskatchewan River Basin Water Management Roadmap.

This section summarizes the adaptations for sustainable water management across the NSRB.

Establish an Approved NSRB Water Management Plan to guide sustainable water management: A formal planning instrument developed under the authority of the *Water Act*, a Water Management Plan provides strategic direction for the allocation, use, and conservation of water. Developing a Water Management Plan would provide greater transparency for water users, regulators, and the public, strengthen drought preparedness and water resilience, and balance ecological and human needs in the basin.

Establish basin-scale Conservation, Efficiency, and Productivity (CEP) targets for municipalities, industry, and the agricultural sector to incentivize sustainable water use: Improving water use efficiency across sectors is a key strategy for meeting future water demand while protecting aquatic ecosystems. CEP targets set measurable goals for reducing waste, optimizing use, and improving outcomes per unit of water used. CEP targets would encourage innovation and investment in water-saving technologies and practices, support water utilities in managing demand and infrastructure costs, enhance water security and resilience, and signal leadership in water management.

Support the development and implementation of water reuse projects in collaboration with industry and municipalities: Water reuse is the practice of treating and repurposing wastewater or process water for other beneficial uses. It offers a significant opportunity to reduce pressure on the North Saskatchewan River (NSR) and its tributaries. Supporting water reuse would reduce demand on surface water withdrawals, improve drought resilience for industry and municipalities, support innovation in water technology and infrastructure, and advance conservation goals.

Improve access to and use of alternative water sources for consumptive operations, including improved data availability: This adaptation aims to increase the use of alternative water sources, such as municipal wastewater, saline groundwater, recycled process water, and stormwater, for industrial and other consumptive operations. Use of alternative water sources and improved access to related data would reduce stress on surface water systems, enhance industrial and municipal resilience, promote innovation and water recycling technologies, and support long-term water security and ecological protection in the basin.

Develop aquifer management plans informed by Alberta Energy Regulator (AER) and GoA objectives: Aquifer management plans provide a structured approach to understanding, protecting, and sustainably using groundwater resources. Management plans would improve understanding of groundwater-surface interactions, inform drought management, support integrated watershed management goals, provide clarity and guidance to users and regulators, and align with Alberta's broader groundwater objectives.

Develop natural asset programs and tools to support ecosystem services and fill key information gaps: Natural assets, such as wetlands, floodplains, riparian buffers, and beaver-modified landscapes, deliver critical ecosystem services that support watershed health, biodiversity, water quality, and climate resilience. Building capacity to manage natural assets would support the implementation of the North Saskatchewan Watershed Alliance's (NSWA) Integrated Watershed Management Plan (IWMP) and Wetland Strategy, enable municipalities and landowners to integrate nature-based solutions into planning, advance watershed restoration priorities, and improve co-existence with keystone species to improve ecosystem resilience.

Implement the NSR Wetland Strategy: NSWA's Wetland Strategy outlines a framework for protecting, restoring, and enhancing wetlands as part of a healthy and functioning watershed. Benefits of implementation include the protection of remaining high-value wetlands, strategic restoration of wetlands, targeted investments in wetland construction or enhancement, and long-term cost savings through nature-based infrastructure solutions.

Improve water quality in non-mainstem drinking water sources, including lakes and tributaries: Many rural communities rely on tributaries, lakes, and other non-mainstem sources for their drinking water. These sources are often more vulnerable to contamination due to limited flow, smaller catchment areas, and fewer treatment options. Improving water quality in these areas would support the health and safety of small and rural communities, protect vulnerable aquatic ecosystems, enhance long-term source water security, and reduce future treatments costs and public health risks.

Improve water security for Indigenous communities, ensuring adequate and safe water is available for drinking, household, community needs, and emergency services: This adaptation seeks to strengthen water security for Indigenous communities in the NSRB, which is foundational to community health, resilience, and cultural continuity. Improving water security would address longstanding disparities in access to clean and reliable water, support autonomy in water governance, incorporate Indigenous knowledge into broader watershed planning, strengthen community resilience, and fulfill principles of partnership and reconciliation.

Create an Indigenous-guided future Roadmap for water in the NSRB: This adaptation supports a Roadmap to articulate shared priorities, responsibilities, and visions for water protection, governance, and use that is centered on Indigenous rights, knowledge systems, and leadership. Creating this Roadmap would honour Indigenous rights and responsibilities related to water, support autonomy in water governance, build long-term and trust-based relationships, enhance the cultural, ecological, and technical foundations of water planning in the basin, and align with reconciliation commitments.

Enhance connection with Alberta's Land-Use Framework and other existing regulatory frameworks: This adaptation advocates for a regional plan to support better integration of the NSWA's IWMP with Alberta's Land-use Framework, regional and sub-regional plans, municipal development strategies, and related regulatory tools. Enhancing integration would operationalize key actions in the IWMP, ensure regional planning incorporates water considerations, support cross-jurisdictional cooperation, advance cumulative effects management, and improve source water protection.

Explore establishing a collaborative relationship with hydro facilities, in support of a shared understanding: Hydroelectric facilities in the NSRB play a significant role in shaping river flow patterns and seasonal water availability. Establishing a cooperative relationship would improve transparency and shared understanding of operational constraints and opportunities, support more predictable and optimized water flows, mitigate the impacts of flood and drought, and strengthen adaptative capacity in the face of climate variability.

In addition to the Roadmap adaptations outlined above, several important actions are already underway across the NSRB that contribute to sustainable water management:

Refine and ensure usage of the collaborative Tool: The hydrologic and water management model built as part of the Roadmap project should continue to be a tool used by water users and partners across the NSRB.

Continue to build flood-resilient infrastructure to reduce potential flood impacts: The need for flood-resilient infrastructure is a recognized and ongoing need that is being addressed by municipalities, utilities, and industry as part of standard infrastructure planning and asset management.

Implement effective stormwater retention plans and erosion control measures, incorporating wetlands and green infrastructure to maintain water quality: These practices are increasingly embedded in municipal and industrial planning frameworks as a standard approach to managing runoff and protecting aquatic health.

Support flood and drought mitigation planning with municipalities, First Nations, Métis communities, agriculture, the GoA, and industry: Ongoing work through regional partnerships supports coordinated drought and flood preparedness planning.

This project demonstrates how implementation of the adaptive water management strategies outlined in the Roadmap can facilitate economic growth while maintaining or improving environmental outcomes 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 variability. Improved resilience leads to less frequent and less severe impacts on rights holders, licence holders, water users, and the environment. The findings indicate efforts should be made to implement all projects of the Roadmap to support basin resiliency and promote sustainable collaborative watershed management.

1. Introduction

1.1 Water and the North Saskatchewan River Basin

The NSRB, as shown in Figure 1-1, starts in the Columbia Icefield of Banff National Park and flows northeast to the Alberta-Saskatchewan border. The NSRB encompasses four natural regions: Boreal Forest (33%), Parkland Natural Region (30%), Foothills (20%), and Rocky Mountain (17%) (Alberta Biodiversity Monitoring Institute, n.d.). After flowing through Alberta, the NSR joins the South Saskatchewan River near Prince Albert, Saskatchewan, and eventually empties into Hudson Bay. The river's flow is primarily sustained by precipitation and snowmelt, while flows are supplemented by groundwater and to a lesser extent, glacial melt. Precipitation and winter snowpack, and consequently runoff, are generally much higher in the mountains and western reaches of the watershed (Figures 1-2 and 1-3) whereas evaporation rates are considerably higher in the east. Most of the water demand is from Edmonton and the capital region, concentrated on the mainstem of the river. The Edmonton water supply system serves many communities across central Alberta via pipelines, as far away as Kinsella and Vermilion.

The basin's environmental, social, and cultural values, and economic prosperity are highly dependent on the NSR. The river supports First Nations communities, municipalities, manufacturing, tourism, energy production, and resource extraction. It serves as an essential water source for drinking, irrigation, and industrial processes, while also offering recreational opportunities and cultural significance to the communities within the basin.

The NSRB is located within Treaty 6 and a portion of Treaty 8 along the Rocky Mountains. Treaty 6 extends from the Eastern Slopes of Alberta to just over the Manitoba border, encompassing most of the Albertan portion of the North Saskatchewan Watershed. Within the NSRB, there are 19 First Nations Reserves and two Métis Settlements. Figure 1-1 illustrates First Nations communities and historical treaty boundaries within the NSRB.

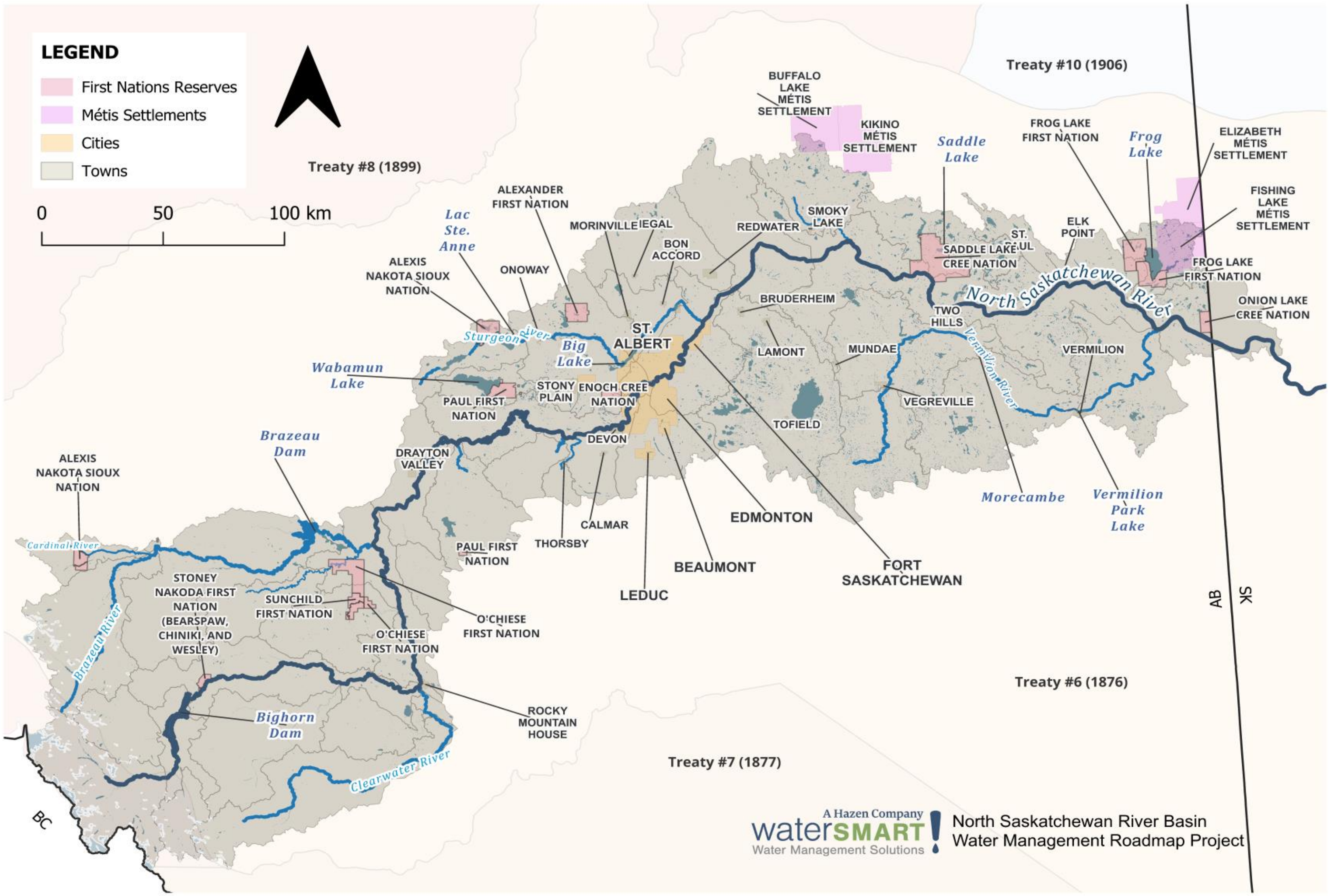

Figure 1-1: Map of the North Saskatchewan River Basin.

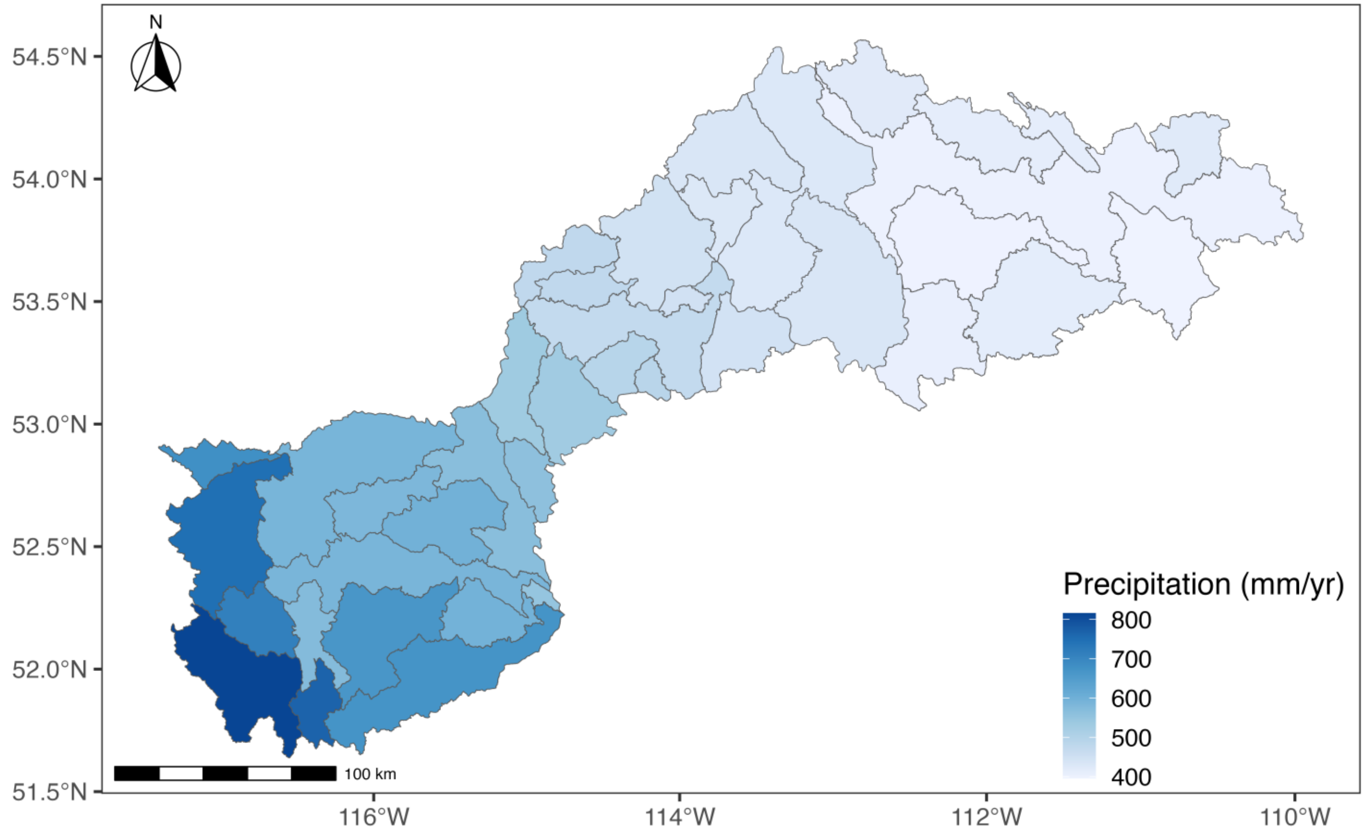

Figure 1-2: Average yearly precipitation in the North Saskatchewan River Basin (1991 – 2020), created on the Raven platform.

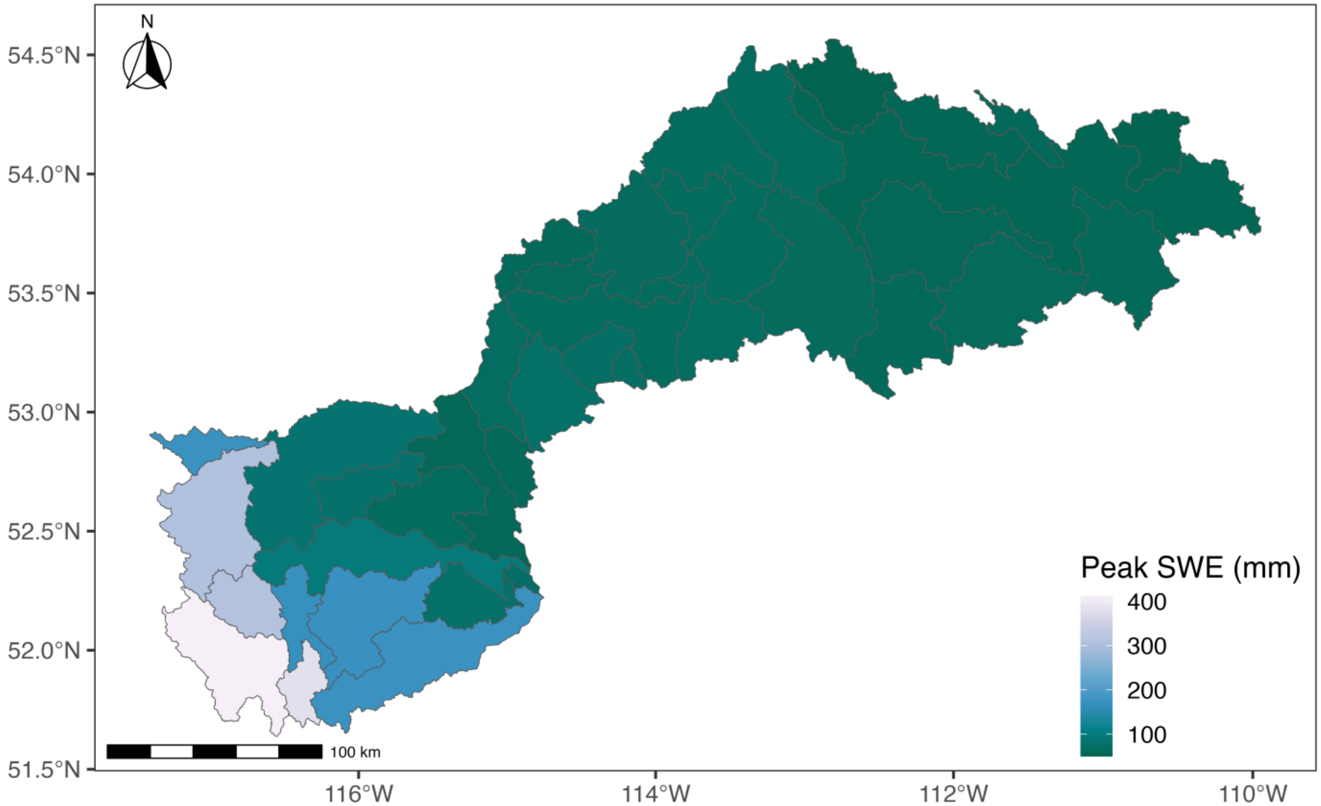

Figure 1-3:Peak yearly Snow Water Equivalent in the North Saskatchewan River Basin (1991 – 2020), created on the Raven platform.

The Ministry of Environment and Protected Areas (EPA) oversees regulatory decisions related to water management practices in Alberta, excluding oil, gas, coal, and minerals (which are similarly overseen by the AER). EPA and the AER utilize various mechanisms for managing water in the NSRB, including:

- The *Water for Life* strategy and action plan – Reaffirms Alberta's commitment to managing the province's water resources for the benefit of all Albertans (Government of Alberta, 2003).
- The *Water Act* (1999) – Protects the quality of water in Alberta and manages its distribution, regulating any activities that may impact rivers, lakes, and groundwater (Government of Alberta, 2003).
- The *Environmental Protection and Enhancement Act* (1993) – Supports and promotes the protection and enhancement of Alberta's environment (Government of Alberta, 2000).
- The Surface Water Allocation Directive (SWAD) – In the absence of an NSRB Water Management Plan (WMP), water is governed by this directive, which provides guidance on water management to minimize impact on the aquatic environment (Government of Alberta, 2019).
- The Master Agreement on Apportionment (1969) – An agreement between the Governments of Alberta, Saskatchewan, Manitoba, and Canada, that 50% of the natural annual flow by volume of westward-flowing watercourses be passed from Alberta to Saskatchewan (Government of Canada; Govenrment of Alberta; Government of Saskatchewan; Government of Manitoba, 1969).

1.1.1 Major Water Licences

Approximately 18% of the mean annual volume has been allocated for a variety of uses in the NSRB. Table 1-1 shows a list of the largest water licences, representing approximately 97% of the total allocated water in the basin. Water licences and associated information can be found using the GoA's Alberta Licence Viewer and Water Use Reporting System (WURS), however, the licences outlined in Table 1-1 were vetted through the collaborative modelling process, and may not align with publicly available licence data, due to inconsistencies of public information. Further details on water licences modelled as part of this Project can be found in Section 2.2.2.1.

Table 1-1: List of the top 20 water licences within the North Saskatchewan River Basin.

Rank	Licensee	Maximum Annual Diversion (m^3/year)	Average Annual Diversion (m^3/year)	Average Annual Consumption (m^3/year)	Classification
1	Capital Power Generation Services Inc.	450,220,200	83,740,957	4,187,048	Industrial
2	EPCOR Water Services Inc.	135,683,000	79,716,044	21,738,559	Edmonton and Regional Customers
3	EPCOR Water Services Inc.	67,840,000	39,822,080	11,352,580	Edmonton and Regional Customers
4	Regional Water Customers Group Inc.	60,000,000	35,220,000	7,044,000	Edmonton and Regional Customers
5	TransAlta Corporation	43,189,700	8,033,284	4,016,614	Industrial
6	University Of Alberta	43,171,850	8,029,964	401,500	Industrial
7	TransAlta Corporation	40,740,740	7,577,778	4,225,185	Industrial
8	Capital Power Generation Services Inc.	22,128,394	4,115,881	2,057,941	Industrial
9	Dow Chemical Canada ULC	21,493,390	6,448,683	6,448,683	Industrial
10	Nutrien (Canada) Holdings ULC	15,646,544	2,910,257	2,619,342	Industrial
11	TransAlta Corporation	14,185,000	2,638,410	825,952	Industrial
12	Windsor Salt Ltd.	12,038,770	2,239,211	223,922	Industrial
13	Capital Power Generation Services Inc.	12,000,000	2,232,000	0	Industrial
14	Eco-Industrial Business Park Inc.	10,484,600	1,950,136	721,550	Industrial
15	Imperial Oil Ltd.	9,251,110	7,185,147	4,270,852	Industrial
16	Shell Chemicals Canada	8,243,120	1,533,220	833,172	Industrial
17	Shell Canada Ltd.	8,146,800	1,515,305	1,153,587	Industrial
18	Cenovus Energy Inc.	6,752,500	5,000,000	5,000,000	Industrial
19	Shell Canada Ltd.	6,564,000	1,220,904	1,220,904	Industrial
20	Suncor Energy Inc	5,788,740	3,162,838	2,377,016	Industrial

1.2 The Opportunity

Edmonton is the largest city within the NSRB, with $107 billion in Gross Domestic Product (GDP). The greater Edmonton area has a current population of 1.5 million, making it the fifth-largest economy, and the second-fastest growing region in Canada (Edmonton Metropolitan Region Board, 2023). Projections suggest that over the next 25 to 30 years, Edmonton's population is anticipated to increase by approximately 1 million people (Edmonton Metropolitan Region Board, 2021). There is significant industrial and agricultural investment in the NSRB requiring a secure water supply, such as net-zero hydrogen energy ($1.6 billion) (Air Products, 2022) and biofuel ($720 million) (Strathcona County, 2023). Population and industrial growth have the ability to impact the management of water resources due to a changing water supply and increasing water demand (Alberta Water Council, 2021).

Additionally, as climate variability continues, changing precipitation and temperature patterns will alter water availability, as shown in Figure 1-4, introducing challenges in balancing competing needs for water, from a quantity and quality perspective. Geographic and seasonal differences in climate variability can lead to unequal impacts throughout both the province and basin (Alberta Water Council, 2021).

Climate Hazard	Description
Rising Temperatures	Rising average temperatures, leading to longer summers, earlier springs and later falls, and shorter winters—overall, the Region will be far less cold and slightly warmer.
Extreme Heat	Hotter summers, with more extreme heat, and more intense and longer heat waves.
Milder Winters	Shorter winters will be milder, with fewer cold days, frost days, and freeze-thaw cycles. Earlier snowmelt and less summer run-off, reducing summer flows in major river systems (e.g. North Saskatchewan River).
Winter/Spring Precipitation	More rain falling in winter and spring, less falling in summer, though changes in all seasons are very modest.
Heavy Rainfall	More heavy rainfall events, as water vapour in the atmosphere increases.
Wildland Fire and Smoke	Increased fire weather, with increased risk of wildland fires and wildfire smoke days.
Hail Storm	More extreme weather events such as large hail and freezing rain events.

Figure 1-4: Summary of climate variability hazards (Edmonton Metropolitan Region Board, 2023).

Implementing effective water management strategies is a form of adaptation for these pressures, ensuring water remains available for environmental, economic, and municipal needs. Without a robust strategy for agile, adaptive, and localized water management, the strain on water resources will intensify as climate impacts and industrial development change the balance between water supply, demand, and quality across the basin (Alberta Water Council, 2021). This challenging and uncertain environment prompted NSRB water managers to seek consultation and work collaboratively with other water users to develop a basin-wide sustainable water management approach.

1.3 North Saskatchewan River Basin Roadmap Project

Over the course of 13 months, a few water licence-holders, rightsholders, and other stakeholders from across the basin, known as WG members, met online and in-person six and five times, respectively, to collaborate on the direction of sustainable water management in the NSRB (Appendix B). This collaborative Projectwas documented and facilitated by WaterSMART Solutions, a Hazen company (WaterSMART) under contract with the NSWA.

The collaborative meetings allowed for open conversations that identified the basin-related concerns, issues, needs, actions, and adaptation strategies that could support sustainable water management. To support these conversations, a baseline understanding of the water availability and demands within the NSRB was needed, leading to the creation of a Tool. The Tool is an integration of a hydrological model and a water management model. More information regarding the Tool is discussed in Section 2.2.

1.3.1 Project Outcomes

The goal of the Project was to create, in collaboration with the WG, a sustainable Roadmap for the NSRB. The Roadmap outlines a set of adaptations which are grounded in science, guided by community knowledge, and designed to align with Alberta's regulatory frameworks and strategies. With the support of the Tool, the WG members assessed climate, growth, and development adaptations to understand their potential impacts on water availability. The Roadmap was developed to reflect the intricacies of the basin, the participants' interests, and to facilitate informed decision-making in defining the most appropriate potential adaptation strategies and actions to adopt. The Roadmap can be used to inform future planning and water management efforts, guide government, water managers, and users on sustainable watershed management practices, highlight immediate needs, and outline next steps.

A Roadmap is a set of strategies and implementable actions, developed by an inclusive basin-wide Working Group using collaborative modelling and dialogue, that provides a recommended path toward sustainable water management in a basin.

The Project has enabled steps towards achieving strategic water management in the basin by advancing several key factors. These include:

- Establishing a shared understanding of water availability, basin operations, needs, and concerns.
- Demonstrating how water-dependent economic growth and development can be supported within the basin.
- Identifying complementary and mutually beneficial sustainable water management opportunities.
- Enabling conversations and connections on water security across different water user groups.

1.4 Lived Experience

The worldview and perspectives of Indigenous peoples are important considerations in any discussion concerning the management of water and aquatic ecosystems, due to the cultural and traditional relationships between First Nations and water, as well as the need to recognize and build upon Treaty relationships and reconciliation between Indigenous communities and non-Indigenous Albertans.

The Roadmap benefited from the participation of Indigenous individuals, who represented a portion of the broader group of First Nations and communities in the basin. A deeper dialogue with First Nations is required for further discussion on water and water issues in the basin.

The following quote provided to the Alberta Water Futures project completed by the Alberta Water Council in 2021 illustrates some of the challenges raised by the Indigenous participants during the Project.

"The biggest challenge facing how water and water affecting activities are regulated concern historical issues about jurisdiction and responsibility towards water and the environment. These challenges stem from treaty relationships, and Indigenous peoples' rights and responsibilities in managing their relationships with water.

Indigenous communities have been left as by-standers in the management of natural resources during any discussions concerning water regulation. Beginning conversations about water regulation without addressing the fundamentally different perspectives on issues like water ownership, stewardship, and rights shared by Indigenous communities does not set the stage to start on equal footing.

The overlapping responsibilities of three governing bodies—the Government of Canada, the Government of Alberta, and Samson Cree Nation—plus other stakeholders further complicate our ability to practice self-determination. […] Jurisdictional issues will be further complicated by a changing climate that already disproportionately affects Indigenous and vulnerable communities in an increasingly water stressed region.

There is tremendous opportunity to include Indigenous communities in a deep and respectful way so that future challenges can be approached in collaborative partnership. Indigenous communities should be front and center in issues like water regulation from the outset. There are many opportunities to create long-lasting partnerships, but we must be included in determining the scope and parameters of involvement. We would love to see a world where Albertans are educated about water issues and Indigenous issues so that they can approach these concerns in a respectful and reciprocal manner."

Excerpts from the project survey response, used with permission

Nipîy Committee, Samson Cree Nation, Treaty 6

The NSWA is currently undertaking a Lived Experience project that will gather input from First Nations, agricultural, and forestry groups to understand how the NSRB has changed over time. This work will aim to provide additional context and background on the NSRB and on the challenges faced in the past that could inform future decision making. This work is expected to be completed in 2025.

2. North Saskatchewan River Basin Water Management Roadmap Project

2.1 The Collaborative Modelling Process

Collaborative modelling is designed to explore and test water management techniques and concepts using 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 adaptations for the basin. The discussions and outcomes provide this guidance in the form of a Roadmap.

No single entity or initiative can address the challenge of building resilience and sustainability in the face of climate variability and increased economic development. Instead, these challenges require a collaborative management approach involving all water users. Therefore, a key component of any collaborative modelling project is the active participation of an engaged and diverse WG. Members of the WG are selected to represent major water users and managers from various sectors within the basin, bringing their perspectives and experience to the table. A summary of WG roles and responsibilities can be found within the Terms of Reference in Appendix A, while a full list of the WG members can be found in Appendix B.

The collaborative process is summarized in Figure 2-1. In Step 1, using input data from the best available sources (e.g., EPA allocation and licence data, infrastructure operations, landcover information, etc.), WG members work collaboratively to identify basin impacts and opportunities during live modelling sessions. In Step 2, the WG can suggest and implement new water management adaptations into the Tool. This is an iterative step which allows participants to implement changes in the model, review the outcomes, and suggest modifications and identify new adaptations. Once adaptation scenarios have been evaluated by the WG, they are added onto the Roadmap in Step 3 and, if possible, assessed economically. While not all adaptations can be directly modelled within the Tool, qualitative adaptations, such as policy changes or data gaps, can be identified and included in the Roadmap.

This collaborative process resulted in adaptation assessments, strong relationships between members which can last beyond the duration of the project, a trusted tool, and the development of a Roadmap.

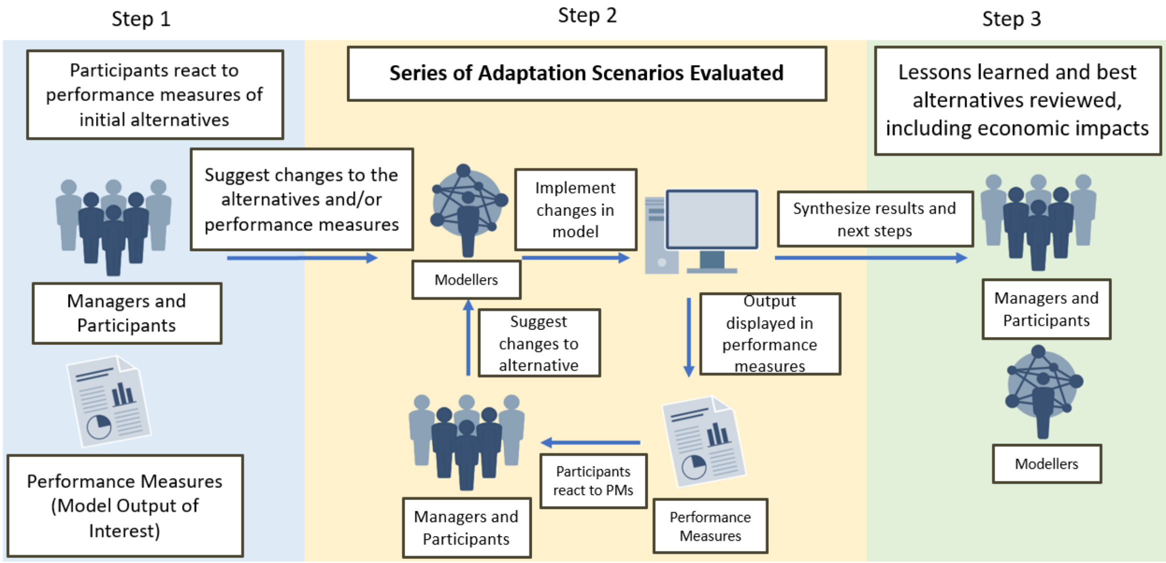

Figure 2-1: The collaborative modelling process.

2.1.1 Summary of Working Group Discussions

Figure 2-2 outlines the process through which the Project adaptations were analyzed once identified by the WG. It is important to highlight that input from the WG was incorporated into the analysis through an iterative process, and members were provided the opportunity to review and adjust the analysis throughout.

The Project consisted of a kick-off meeting, five WG meetings, and five sub-group meetings. Leveraging the Tool (see Section 2.2), live modelling was conducted at several of the meetings. A short summary of each meeting is included below.

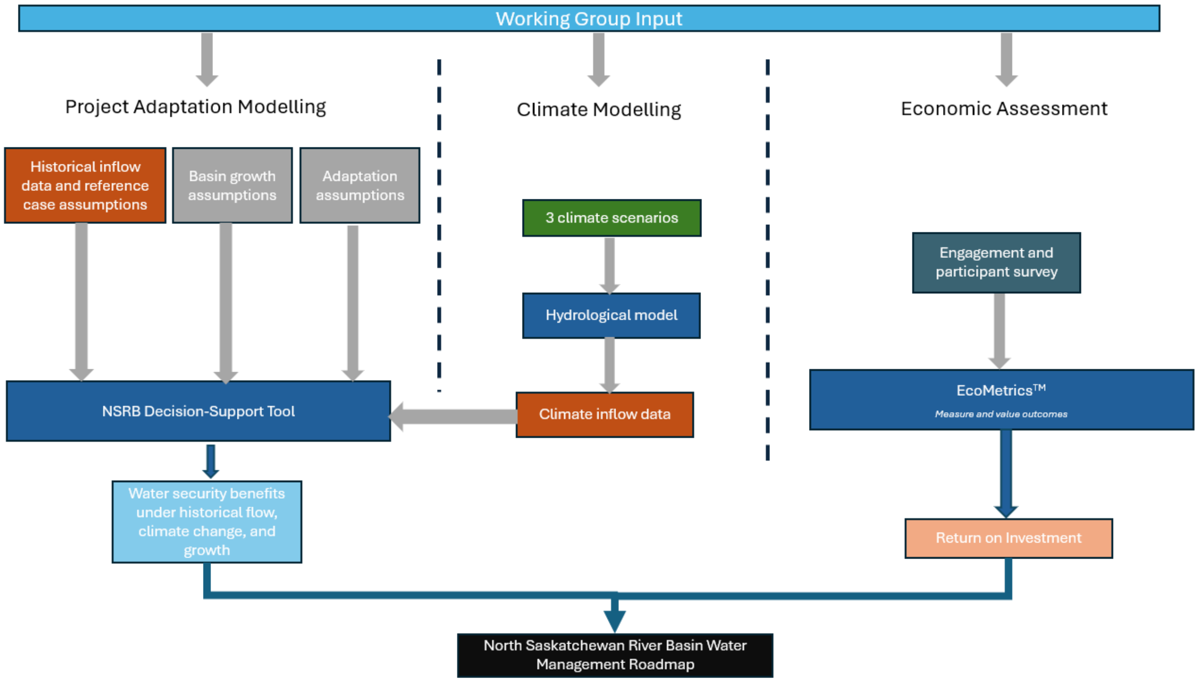

Figure 2-2: Process used to assess adaptations brought forward by the North Saskatchewan River Basin Working Group.

Kick-off:

- Held May 15, 2024.
- Held virtually, the kick-off introduced the WG members to each other, and to the Project background and purpose. It reviewed the Terms of Reference and explored high-level water issues and opportunities in the basin.

Working Group 1:

- Held June 12, 2024.
- Working Group Meeting 1 was held in Edmonton for WG members to further explore water issues and opportunities in the basin and identify preliminary Performance Measures (PM).

Model Sub-Group:

- Held September 11, 2024.
- The model sub-group meeting was held virtually to develop a shared understanding of the Tool, including the coupling of the hydrological and water management models.

Working Group 2:

- Held October 1, 2024.

- Working Group Meeting 2 was held in Edmonton to explore the Tool, to understand its construction and capabilities, and to develop a shared understanding of the basin with the WG. This meeting was used to review and update PMs and begin identifying potential water management adaptations.

Climate Sub-Group:

- Held October 23, 2024.
- The climate sub-group was held virtually to present the methodology for running and analyzing climate scenarios and confirmed the climate scenario selection criteria. A preliminary recommendation of three scenarios to include in the model was then presented.

Working Group 3:

- Held November 13 & 14, 2024.
- Working Group Meeting 3 was held on Enoch Cree Nation territory to explore and refine identified adaptations using live modelling, under both the reference case and climate scenarios. This meeting was used to discuss the economic assessment approach and discuss growth scenarios in the basin. In this meeting the WG members completed the EcoMetrics™ survey to highlight potential project outcomes.

Economics Sub-Group:

- Held January 22, 2025.
- The economics sub-group was held virtually to review the economic assessment methodology, and present preliminary economic and EcoMetrics™ results. Using information from preliminary adaptations, the Project Team identified potential benefits and costs to industry, municipalities, and Indigenous communities for discussion.

Working Group 4:

- Held February 25 & 26, 2025.
- Working Group 4 was held in Edmonton to refine the identified adaptations using live modelling under growth scenarios, and to review the preliminary results of the economic assessment. The draft of the Roadmap template was reviewed and refined.

Roadmap Sub-Group:

- Held April 16, 2025.
- The Roadmap sub-group was held virtually to review the updated Roadmap, incorporating comments from Working Group 4.

Model Sub-Group:

- Held April 29, 2025.

- An additional model sub-group was held virtually to review modelling assumptions and results in advance of Working Group 5.

Working Group 5:

- Held May 6, 2025.
- The final Working Group meeting was held in Edmonton to finalize the Roadmap and the group's assessment of the most promising adaptation strategies, in addition to presentation of the initial economic assessment results.

2.2 The Decision-Support Tool

As shown in Figure 2-3, the Tool is an integration of outputs from a hydrological model and a water management model that can be adapted to include other models and data, such as economic assessments, industrial growth, and population growth. Although primarily guided by quantity-based inputs, the Tool allows for discussion around water quality concerns through the development of both quantity and quality-related PMs as described in Section 2.3.2. Simply put, modelled outputs are contextualized in PMs which can be compared against other scenarios. Further details on the Tool, including background and results, can be found in Appendix C.

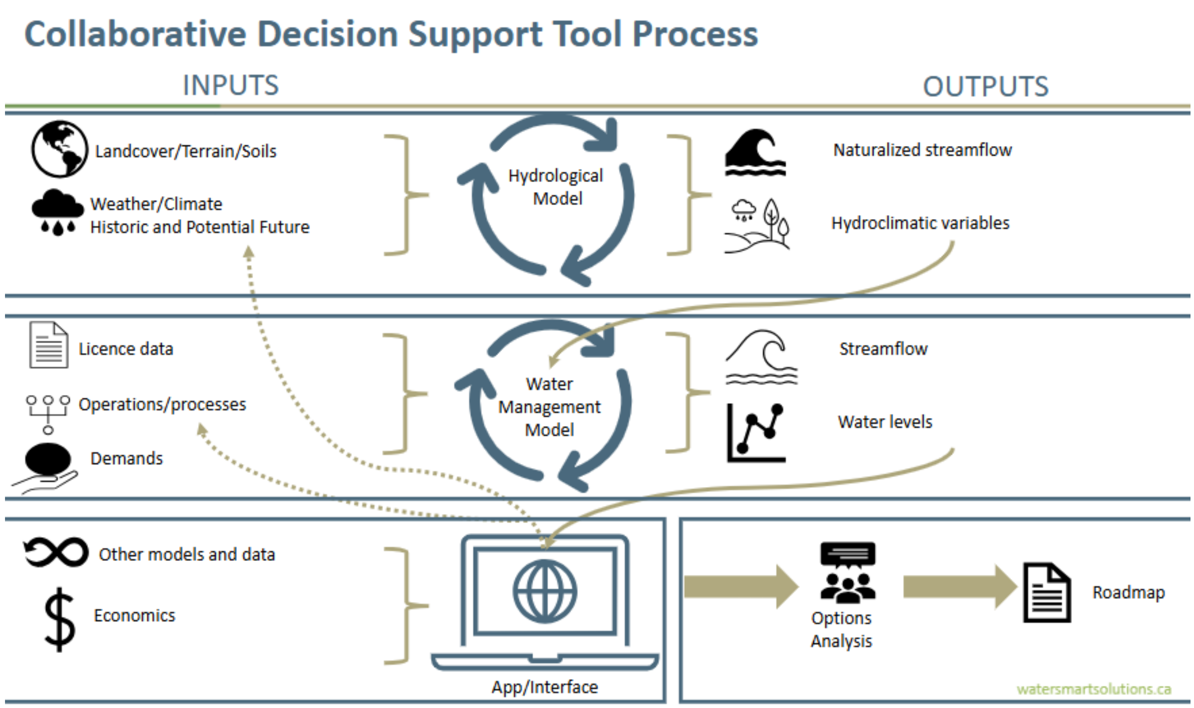

Figure 2-3: The collaborative decision-support tool conceptual overview.

Note: Solid lines reflect how the water management and hydrological model outputs are layered to create the Tool. Dotted lines reflect the iterative collaborative modelling process, where WG members can implement changes to the hydrological and water management models, and review results within the Tool.

Using the Tool outputs, water users in the basin collaboratively discussed potential scenarios, and identified the most significant water management practices that enhance water security and sustainability. This process led to the creation of a Roadmap, a shared document that reflects the basin's issues and concerns, as well as relevant adaptation strategies and actionable plans.

2.2.1 Hydrological Model Overview

The hydrological model is a modified version of the Hydrologiska Byråns Vattenbalansavdelning - Environment Canada (HBV-EC) model, with its behavior and functions emulated within the Raven Hydrological Modelling Framework (Raven) version 3.8 (Craig, 2023). Developed by the University of Waterloo, Raven supports a wide variety of modelling options and is used by several Canadian reservoir management and flood forecasting organizations.

2.2.1.1 Spatial Discretization

In the model, small lakes were treated as storage reservoirs, releasing water steadily, while major lakes were treated as natural reservoirs with outflows based on lake characteristics and flow attenuation. Both types of lakes were assumed to freeze below 0 degrees Celsius (°C), gather snow when frozen, and thaw after the snow melts. Sub-basin division was based on the outflow of major lakes and aligned with hydrometric monitoring locations in the region. These were further divided based on the unique overlay of elevation bands, hill shade, land cover, and soil texture.

2.2.1.2 Model Forcing Data

A peer-reviewed EPA hybrid climate dataset, which provided the best representation of historical (1950-2019) climate conditions, was used as the original input to the hydrological model (Eum & Gupta, 2019). This dataset includes daily maximum and minimum air temperatures (°C), and precipitation in millimeters per day (mm/day). The model spatially distributes daily minimum and maximum air temperature, precipitation, and relative humidity from all weather stations across the study region. Precipitation was then categorized as rain or snow based on the air temperature. This approach provided a detailed representation of the spatial variability within the watershed.

The hydrological model simulates naturalized streamflow in cubic meters per second (m^3/s) and other hydro-climatic variables, at a daily timestep. This affects simulated hydrological processes, including canopy interception, snow accumulation and melt, evapotranspiration, soil infiltration, percolation, baseflow, and surface runoff.

2.2.1.3 Hydrological Model Calibration and Validation

To calibrate and verify the hydrological model, publicly available meteorological and hydrometric observations from the study area were used. This included Environment Canada air temperature and precipitation data, a Canadian historical snow water equivalent dataset, and regional streamflow data from long-term (1991-2022) Water Survey of Canada records as represented in Figure 2-4. Other data sources include EPA, British Columbia Environment, and Meteorological Service of Canada.

The hydrological model performed very well at estimating air temperatures, with very accurate results (over 92% accuracy) and very little error. It also performed well in estimating monthly rainfall (accuracy between 74% and 99%), although it slightly underestimated rainfall at some lookout sites. It is important to note that some of these sites only had data collected from observation during the summer months. To review the hydrological model performance statistics, see Appendix C.

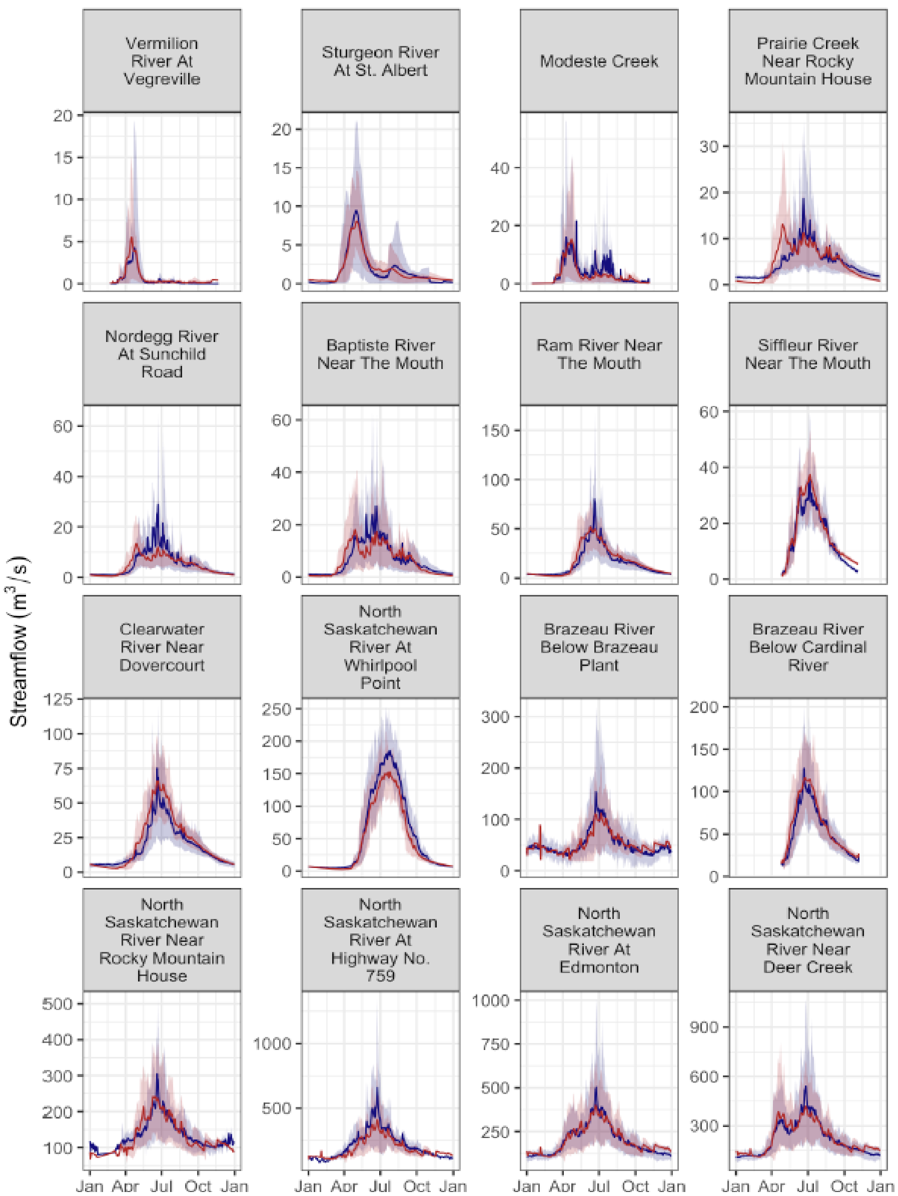

Figure 2-4: Observed and simulated streamflow at all sites used in model calibration from 1991 – 2022 (Figure 9 of Appendix C).

Note: Solid lines correspond to average flows while shaded areas correspond to 10-90% quantiles. Blue is observed streamflow, while red is simulated.

2.2.1.4 Incorporating Future Climate Projections

To configure the model for future simulations, climate data was sourced from EPA's projected climate dataset (Eum, Farjad, Tang, & Gupta, 2023). Fourteen scenarios were selected to represent the full range of future climate variability captured by CMIP6 projections[1] (Eum, Farjad, Tang, & Gupta, 2023) using an integrated geometry algorithm (Farjad, Gupta, Sartipizadeh, & Cannon, 2019).These scenarios were bias-corrected using a Multivariate Bias Correction with Distribution-free Shuffle (MBCDS) method (Eum, Gupta, & Dibike, 2020) to preserve climate-model-driven signals and interstructure between climate variables. The scenarios are based on outputs from seven General Circulation Models (GCMs) and span a range of Shared Socioeconomic Pathways (SSPs) as detailed in Table 2-1. These range from SSP1-2.6, which assumes substantial emissions reductions, to SSP5-8.5, which assumes continued emissions growth and strong radiative forcing. Additional details on climate scenarios can be found in Appendix C.

Table 2-1: Climate scenarios provided by EPA under CMIP6, downscaled to the Alberta Hybrid Climate Dataset (Table 3 of Appendix C).

General Circulation Model	Shared Socioeconomic Pathway			
	1 – 2.6	2 – 4.5	3 – 7.0	5 – 8.5
BCC-CSM2-MR	x	-	x	-
CNRM-CM6-1	x	-	-	x
EC-Earth3-Veg	x	-	x	-
GFDL-CM4	-	x	-	-
GFDL-ESM4	-	-	-	x
IPSL-CM6A-LR	x	-	x	-
Median	-	x	-	x
MRI-ESM2-0	-	-	x	x

2.2.1.5 Accounting for Glacier Retreat

Several headwater sub-basins contain substantial glacier coverage, which contributes significantly to late-summer streamflow. Assuming glaciers remain at their current extent would overestimate future water availability. To account for this, the hydrological model simulated glacier retreat based on cumulative mass loss under each climate scenario, as summarized in Figure 2-5. Under all fourteen climate scenarios, significant glacier loss is anticipated by 2100. Glacier-covered areas were reclassified as alpine once a threshold mass loss - representing average ice thickness - was reached. This threshold was estimated using glaciological projections from (Clarke, Jarosch, Anslow, Radic, & Menounos, 2015), accounting for spatial variability in ice depth.

1 CMIP6 (Coupled Model Intercomparison Project Phase 6) is a global climate modeling initiative that provides standardized climate projections from multiple modeling centers. It supports assessments of future climate variability under a range of greenhouse gas emission scenarios, known as Shared Socioeconomic Pathways (SSPs) (Eyring, 2016).

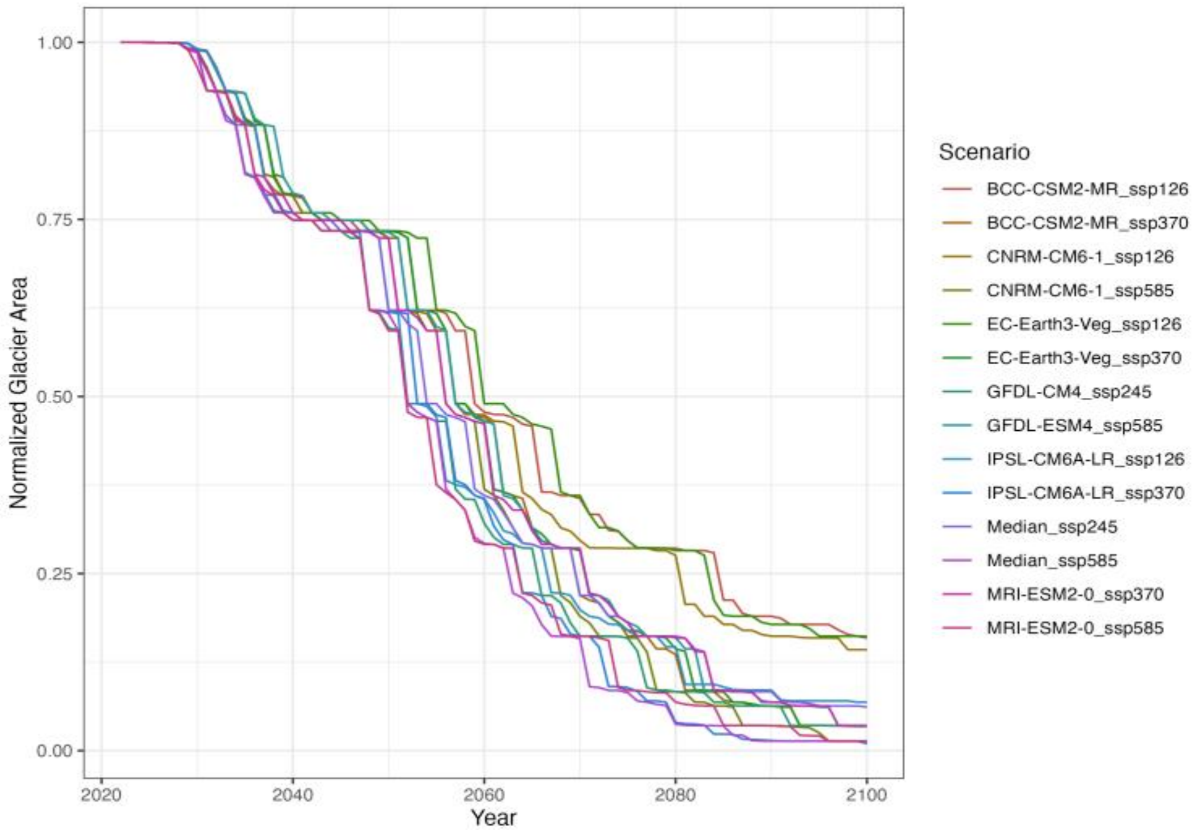

Figure 2-5: Normalized glacier area by year for each future climate scenario run, relative to the current-day extent (Figure 3 in Appendix C).

2.2.2 Water Management Model Overview

To support advanced, real-time water management optimization in the Tool, specific features were added or modified within the Raven framework in February 2025. These enhancements enabled automated, constraint-aware decision making across complex hydrological systems (Chlumsky, 2025). A core objective was implementing scalable, per time step optimization to meet water demands, environmental flow requirements, and addressing up to 3,000 user-defined constraints and goals per time step. NSRB licence data, water demands, and reservoir operations were subsequently introduced into the model to create a comprehensive water management model.

2.2.2.1 Water Licences

All active water licences were modeled as a diversion and return flow. Water licences were considered as of January 2020 due to GoA data availability. Return flows were estimated to be the fraction of the return flow divided by the annual diversion. As water licences typically divert and return water at similar locations, the points of diversion and return flow were assumed to occur at the same location unless specified otherwise in the licence. If the licence did not specify a return flow, it was assumed to be zero to be conservative considering water consumption.

For the water management model inputs, water allocation details were sourced from the Alberta Licence Viewer, while water use data was obtained from Alberta's Water Use Reporting System (WURS) and EPCOR. To replicate a base case of water use, which reflects current conditions, the dataset was filtered to include all reported usage since 2010. These water licences were then categorized as:

- Municipal: Licences that service municipalities; Examples including hamlets, rural municipalities, subdivisions, condominiums, townhouses, municipalities with populations under 2,500, between 2,500 and 10,000, and greater than 10,000.
- Management: Licences that service lake level stabilization, wetlands, flood control, drainage, and storage reservoirs for wildlife or fish habitat enhancement.
- Industrial: Licences that service industries; Examples including electrical generation cooling, hydraulic fracturing, oil and gas processing, drilling, injection, and hydropower.
- Commercial: Licences servicing commercial entities; Examples including public roads, civil infrastructure, parks and recreation, food processing, cement and concrete plants, and dust control.
- Edmonton and Regional Customers: Licences servicing large cities, hamlets, and rural municipalities. While similar to the Municipal category, Edmonton and Regional Customers provided actual water use and projected growth data to the Project, while Municipal licences were assumed to be at full licence allocation to show the same seasonality trend, as further discussed below.
- Agriculture: Licences servicing agricultural processes; Examples including stockwater, private irrigation, feedlots, fish farms, gardens, and district irrigation.

For each sub-basin, licences with allocations less than 316,000 cubic meters per year (m^3/year) were grouped by classification type. Licences over 316,000 m^3/year were modelled individually. Average monthly diversions for each classification were calculated by dividing reported water diversions by the annual maximum allocation, revealing distinct seasonal patterns for each classification as illustrated in Figure 2-6.

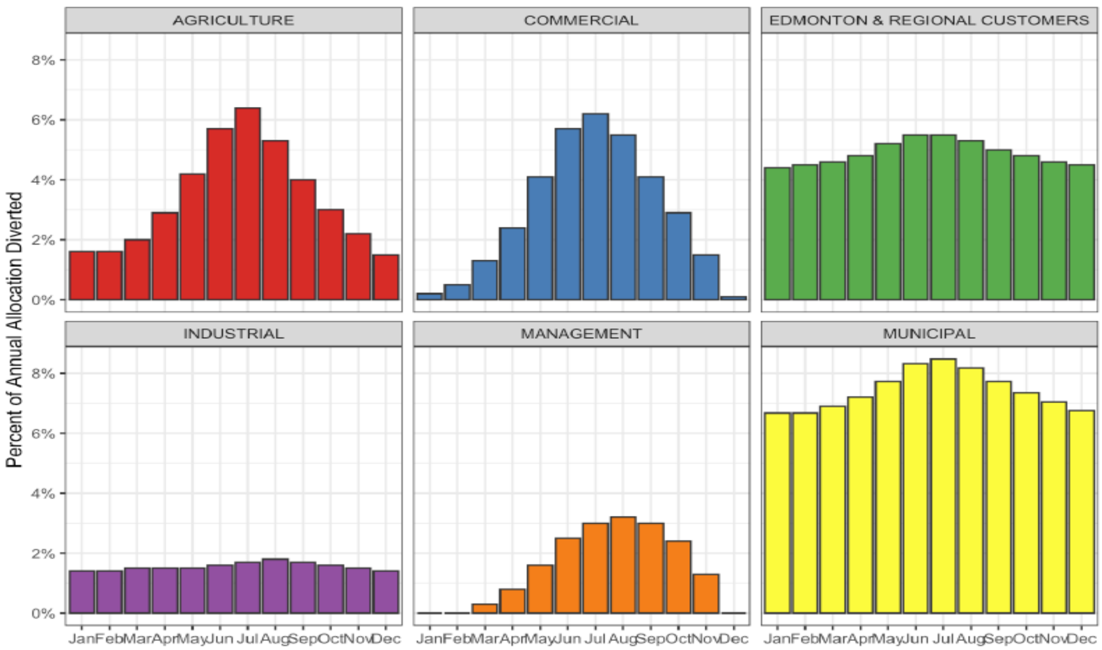

Figure 2-6: Average monthly estimated water diversion for each licence Classification type, presented as the percentage of licenced maximum annual allocation (Figure 5 in Appendix C).

The bulk of the allocated volumes are classified as Industrial or Municipal, as summarized in Table 2-2. However, considering consumptive use, Industrial and Municipal licences tend to have substantial return flows. In contrast, Agriculture and Commercial licences have largely consumptive amounts.

Table 2-2: Summary statistics for water licences considered in this study under the base Case (Table 6 in Appendix C).

Class	Count	Maximum Annual Diversion in cubic meters (m^3)	Return Flow (m^3/year)	Consumptive Use (m^3/year)
Industrial	200	813,848,723	577,374,646	236,474,077
Edmonton & Regional Customers	3	263,523,000	179,113,000	84,410,000
Agriculture	5,675	18,724,905	225,880	18,499,025
Commercial	228	22,011,470	6,814,658	15,196,812
Management	146	18,900,624	2,373,238	16,527,386
Municipal	51	15,219,221	8,560,377	6,658,844

Note: Return flows are based on either licence data or participant feedback where available. In the absence of this information, return flows were estimated based on other similar licences.

2.2.2.2 Reservoir Operations

Reservoirs with static control structures (e.g., weirs or fixed-height canals) or without any outlet control structures were not included in the operational simulations, as no operations exist due to their static nature. This applied to individually represented water bodies such as the Sturgeon River (including Lac Ste. Anne and Big Lake), Frog Lake, Saddle Lake, Vermilion Park Lake on the Vermilion River, and Wabamun Lake.

The operations of Bighorn Dam and Brazeau Dam, which reside in the NSRB, were considered in the model with the following goals in order of decreasing priority, established through conversations with operators and through a review of existing documentation:

- Ensure that the combined minimum flow out of the two dams is above 70.8 m^3/s.
- Maintain water levels below the dam spill elevation.
- Maintain water levels above the low service level.
- Meet minimum flow requirements below the dam.
- Meet maximum flow requirements below the dam.
- Maintain reservoir levels between the historical 25th and 75th percentiles over the last 30 years (after meeting other constraints).

Additionally, the operations at Vermilion Lakes (a chain of six lakes) were modelled with the following goals in order of decreasing priority, established through conversations with operators and through a review of existing documentation:

- Maintain an outflow between April 15 and October 15.
- Maintain water levels above minimum drawdown elevation.
- Reduce water levels to the minimum drawdown elevation when inflows are above 1.0 m^3/s between April 15 and October 15.

2.2.2.3 Daily Model Outputs

The water management model simulates streamflow and water levels, at a daily timestep. This influences other outputs, including stage, volume, demand, potential storage, and consumptive use. These variables are described in Table 2-3.

Table 2-3: Variable outputs from the Model at a daily timestep at each sub-basin (Table 8 in Appendix C).

Variable	Description	Units
Streamflow	The flow of water in the river or stream, presented as a rate (volume per second).	m^3 / s
Stage	The water level of a lake or reservoir (often the absolute elevation above sea level, but sometimes as a relative level).	Meters (m)
Volume	The volume of water in a lake or reservoir.	Cubic decameters (dam^3)
Demand	The daily rate of maximum water withdrawal.	m^3 / s
Potential Shortage	The daily rate of unmet demand.	m^3 / s
Consumptive Use	The daily rate of met demand that is not returned to the system.	m^3 / s

2.3 Modelling: Key Indicators and Metrics

2.3.1 Hydrologic Indicators

Measurable variables that describe key aspects of the watershed – known as Hydrologic Indicators – can help the NSRB members understand how water moves through the watershed, how much is available, and how it changes over time. The model provides daily outputs for each sub-basin, including both hydrologic and water management variables. A summary of these variables is provided in Table 2-4.

Table 2-4: Key hydrologic and water management indicators used in the North Saskatchewan River Basin Model (Table 9 in Appendix C).

Indicator	Description
Mean Annual Flow (m^3/s)	The average annual streamflow, representative of the amount of water passing through a geographical point in a calendar year.
Minimum 7-Day Flow (m^3/s)	Low flows are often considered to be a concern for water quality and may cause stress on aquatic environments. The minimum 7-day average flow is therefore a commonly used statistic for understanding and managing effluent effects. This flow is representative of the lowest flow levels over the year and has historically coincided with degraded water quality (and effluent dilution), and stress on aquatic environments.
Minimum Summer 7-Day Flow (m^3/s)	Low flows are often considered to be a concern for water quality and may cause stress on aquatic environments. The minimum 7-day average flow over the summer (June-September) period is representative of the lowest low levels over the open-water period and has historically coincided with a heightened risk of droughts, degraded water quality, and is a critical period for aquatic ecosystems.

Q20 Non-Exceedances (Open-Water) (Days)	The number of days during the year when streamflow is below the 20th quantile of historical (1991-2020) simulated streamflow during the April-October period.
Q20 Non-Exceedances (Winter) (Days)	The Number of days during the year when streamflow is below the 20th quantile of historical (1991-2020) simulated streamflow during the November-March period.
Peak Annual Flow (m^3/s)	The average annual peak flow. This peak flow is typically a bank-full streamflow and associated with maintaining sediment transport processes and channel morphology.
Peak Flow timing (Days)	The average Julian day of peak daily streamflow in a calendar year, representative of the timing and spring snowmelt-driven runoff which are important to aquatic ecosystems.
Mean Annual Consumptive Use (m^3/s)	The average annual water delivery minus returns.
Mean Annual Demand (m^3/s)	The average annual water demand.
Total Annual Potential Shortage (dam^3)	The total annual (potential) unrealized water demand.

2.3.2 Performance Measures

Unlike hydrologic indicators, which are calculated for each sub-basin of interest and reflect localized watershed dynamics, PMs are targeted metrics tied to specific locations and designed to capture broader, basin-wide aspects of system health. These measures address a range of concerns, including water supply, water quality, aquatic habitat, environmental conditions, and socioeconomic implications. The units and timeframes of these metrics vary; some are expressed as days, while others as percentages or volumes. To assess long-term trends and performance under different scenarios, each metric is summarized on an annual basis and averaged over 30-year periods, as shown in Table 2-5.

Table 2-5: Performance Measures available at an annual timestep and as 30-year averages at key points across the watershed (Table 10 in Appendix C).

Performance Measure	Definition
Apportionment (%)	The percentage (%) of water that crosses interprovincial boundaries from Alberta to Saskatchewan. This metric is used to assess if the Master Agreement of Apportionment is satisfied.
Assimilative Capacity (Days)	The number of days when flow in the NSR near Pakan is below the long-term average 10th quantile of simulated historical (regulated) streamflow for the Open-Water (April-October; ~128 m^3/s) and Winter (November-March; ~106 m^3/s) periods. This flow approximates low flow conditions in this reach where some water quality parameters may become elevated and waste assimilation may become more difficult.
Edmonton Peak Flows (Days)	The number of days when flow in the NSR at Edmonton exceeds 1300 m^3/s. This flow is approximately equal to the lower bound of the 2-year peak flow (Measured). This is treated as a proxy for conditions where flood risk is higher, inundation of properties possible, and water treatment operations are threatened.
Headwater Fish Habitat (Days)	The number of days when flow in the Clearwater River falls below the Instream Objective (IO) – a target flow level established to support fish habitat and maintain overall river health. This is representative of conditions where headwater fish species experience stress, and fishing is prohibited.
High Summer Water Temperature (%)	The percentage of days from July to August that daily average water temperature exceeds 18°C on the NSR at Edmonton. Water Temperature is estimated using

	an empirical relationship derived for the reach using air temperature and streamflow by (Makowecki, 2025).
Loading Potential (Days)	The number of days when flow in the NSR at Edmonton is above the long-term average 90th quantile of simulated historical (regulated) streamflow during the Open-Water (April-October; ~450 m^3/s) period. This flow is an approximation of high flow conditions in this reach where some water quality parameters (e.g., total suspended solids, metals, *E. coli*) may become elevated.
Potential System Shortage (dam^3)	The cumulative volume of potential unmet water demand in a calendar year across the NSRB.
St. Albert Peak Flows (Days)	The number of days when flow in the Sturgeon River at St Albert exceeds the 5-year peak flow (~27 m^3/s). This is treated as a proxy for conditions where flood risk is higher, and inundation is possible.
Tributary Low Flows (%)	The percentage of gauge-days when flow in a location is below the long-term Minimum 7-Day Flow for the historical (regulated) period. This statistic is calculated at all tributary (i.e., non-mainstem) locations, excluding the lower Brazeau River.
Vermilion Low Flows (%)	The percentage of days from July to September that the streamflow is below the average natural Minimum Summer 7-Day Flow (0.25 m^3/s) on the Vermilion River at Lea Park. This metric describes the variability and occurrence of low flows which often coincide with droughts.

Note: all values are based on model simulated outputs (i.e., not observations). The minimum flow management goals identified and implemented in the Tool were set based on statistical thresholds in the absence of available minimum flow studies in the basin. This was used as a proxy to estimate low flows and therefore potential impacts to ecosystem health.

2.3.3 Water Quality

Water quality in the NSRB is influenced by various natural and anthropogenic sources, such as erosion, land use, and effluent releases. For example, agricultural areas can lead to greater erosion of soils, mobilizing salts, nutrients, and fertilizers downstream, while urban areas can increase runoff of trace metals and road salts (Emmerton, et al., 2023).

The City of Edmonton is the largest metropolitan region in the basin, including 225 stormwater outfalls (EPCOR, n.d.) and the Gold Bar Wastewater Treatment Plant. Upstream of Edmonton, the Rocky Mountain House, Drayton Valley, and Devon Wastewater Treatment Plants continuously discharge effluent into the mainstem, while 27 other municipal sewage lagoons discharge periodically into the mainstem or into tributaries (EPCOR, 2020). Downstream of Edmonton is the ARROW Wastewater Treatment Plant and the Designated Industrial Zone (DIZ), an area of condensed industrial development and effluent discharge. Water quality is monitored throughout the basin. Environment Canada samples water at Whirlpool Point in the headwaters and at the Alberta-Saskatchewan border, while EPA samples water near Nordegg (NSR at Saudners Campground), Rocky Mountain House, Devon, and Pakan as part of the Long-Term Network Project (EPCOR, 2020). Water quality is regularly monitored at the mouth of 20 tributaries in the basin as part of the SaskWatch (formerly WaterSHED) Program, which is a unique collaboration between EPA, EPCOR, NSWA, and the City of Edmonton. In addition, EPCOR routinely monitors water quality at both water treatment plants in Edmonton for a wide range of parameters, including but not limited to turbidity, colour, conductivity, pH, temperature, ammonia, bacteria, metals, total suspended solids (TSS), and pesticides (EPCOR, 2020). EPCOR also monitors water quality at urban creeks within Edmonton, discharges from its stormwater system and the Gold Bar Wastewater Treatment Plant, and their combined influence on water quality in the NSR.

Maintaining and improving water quality throughout the basin is critical for drinking water, industrial use, recreation, and a healthy ecosystem. As part of the collaborative modelling process, WG members identified PMs, as summarized in Section 2.3.2, to flag where changes in flow and water demand may have an influence on water quality in the basin. It is important to note that managing water quality is more appropriately achieved by managing loads, as opposed to managing flows; however this Project considers water quality through the lens of flow, as the Tool is a hydrologic and water management model. Additional water quality modelling would need to be completed to fully understand quality in the basin.

The Assimilative Capacity PM represents the number of days where flow on the mainstem is below the long-term average 10th quantile of simulated historical streamflow, or 128 m^3/s for the open water season, and 106 m^3/s for the winter season. The Assimilative Capacity PM is a flag for potential water quality impacts, as low flows may elevate certain parameters associated with effluent such as ammonia and nutrients. Alternatively, the Loading Potential PM represents the number of days where flow on the mainstem near Edmonton is above the long-term average 90th quantile of simulated historical flow, or 450 m^3/s for the open water season. Loading Potential is also a flag for potential water quality impacts, as high flows may elevate certain water quality parameters. In particular, turbidity is often closely associated with higher flows and precipitation events, as sediment can be re-suspended and loading can increase through runoff (EPCOR, 2020).

Finally, the High Summer Water Temperature PM represents the percentage of days from July to August where the daily average water temperature exceeds 18°C on the mainstem near Edmonton. This PM represents the potential for additional pressure on cool-water fish as temperatures increase.

2.3.4 Groundwater

Information related to the regional groundwater system for the NSRB was gathered from work completed by the University of Alberta (Diaz, Smerdon, Alessi, & Faramarzi, 2025). Several groundwater-related datasets were collected from the results of integrated surface and groundwater simulations over historical (1983-2013) and mid-future (2043-2073) time periods using the HydroGeoSphere model. Datasets included depth to the groundwater table, actual evapotranspiration, the ratio of groundwater evapotranspiration to actual evapotranspiration, and the ratio of surface water evapotranspiration to actual evapotranspiration for historical conditions and their difference resulting from simulations under two future climate conditions (Shared Socio-economic Pathways 126 and 585 of the Coupled Model Intercomparison Project Phase 6 Global Climate Models). The net balance between infiltration and exfiltration was also calculated using the model and presented as a proxy for recharge in the top layer above the groundwater table. These data are presented in the web application using performant cloud-hosted geospatial file formats to enable efficient viewing and navigating using the map.

2.4 Modelling: Scenario Development

At the first NSRB WG meeting, the primary goal of the Project was confirmed: to develop a sustainable and adaptable Roadmap for the basin. As noted in Section 1.3, the WG aimed to create a realistic representation of the basin – one that reflects current conditions and constraints, while also accounting for future challenges such as climate variability, population growth, industrial development, and evolving water management needs.

The Tool was developed to support this goal. Through continued collaboration, the WG identified three key components to guide its application: land cover, climate, and water management. Each of these components was further subdivided into multiple scenarios, enabling exploration of a broad range of potential future water conditions in the NSRB.

2.4.1 Land Cover Scenarios

The model was simulated under the two land scenarios – current conditions and forest disturbance, as outlined in Table 2-6 – using historical climate data from 1951-2020.

Table 2-6: Land cover scenarios chosen for the model simulations (Section 4.7.1 of Appendix C).

Land Cover Scenario	Description
Current Conditions	This scenario represents estimated land cover for the year 2025, incorporating current levels of forest disturbance (from wildfire, agriculture, urban expansion) and glacial coverage.
Forest Disturbance	In this scenario, forest disturbance is reset to 1961 levels — the highest recorded year for wildfire coverage — while forestry-related disturbance remains at current levels.

The results showed only minor differences in PMs between the two scenarios. Slight increases in basin-wide flow were observed under the forest disturbance scenario, resulting in modest reductions in PMs such as Assimilative Capacity Days, Tributary Low Flows, and Vermilion Low Flows. These changes are primarily due to reduced canopy interception, allowing more precipitation to reach the soil, partially offset by increased evaporation in open areas.

Most PMs in this study were designed for large-scale assessment. However, the hydrologic effects of forest disturbance were found to be highly localized and strongly influenced by watershed characteristics, as illustrated in Figure 2-7. Please see Figure 6 within Appendix C for a map of the forest disturbance scenario.

- Rose Creek near Alder Flats (low-relief, highly disturbed): Significant impacts due to >50% disturbance and lack of buffering with no alpine runoff.
- NSR near Pakan (large, mixed watershed): Minimal changes, as localized disturbances are offset by scale, regrowth, diverse runoff sources, and the upstream dams.

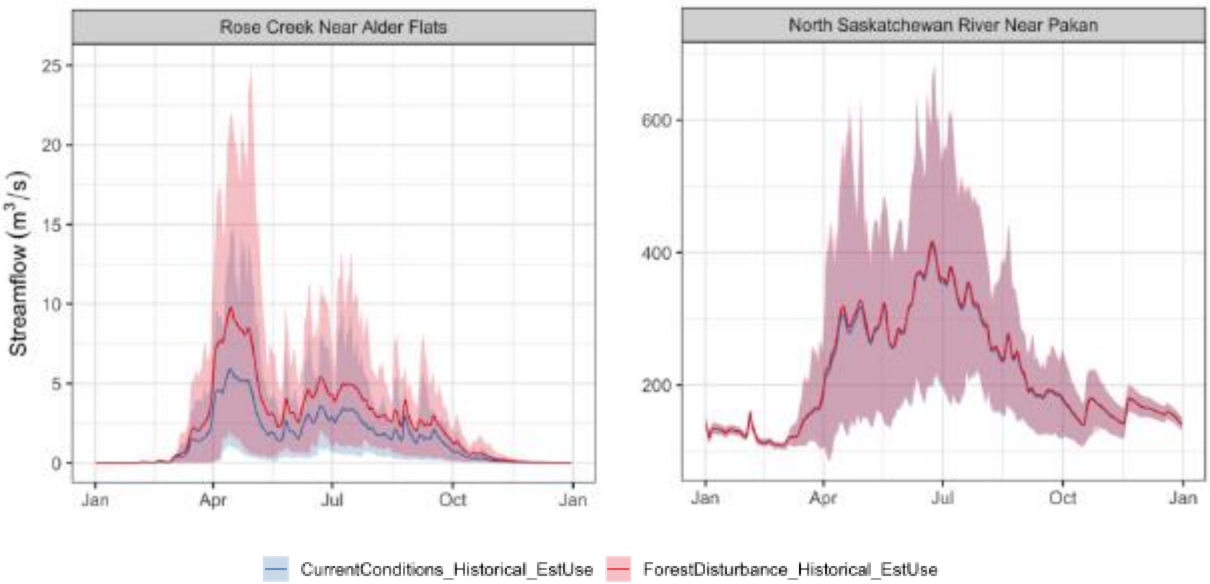

Figure 2-7: Average daily streamflow for two sites in the North Saskatchewan River Basin under the Historical (1991 – 2020) period under two land cover scenarios (Figure 13 in Appendix C).

Note: Shaded areas correspond to 10-90% quantiles.

2.4.2 Climate Scenarios

The hydrological model was simulated under future climate scenarios to evaluate projected changes in streamflow relative to the historical period (1991–2020). Results, shown in Figure 2-8, reveal significant shifts in both the timing and magnitude of flow across the basin:

- Prairie and parkland watersheds (e.g., Modeste Creek, Vermilion River): These areas show an earlier freshet due to earlier snowmelt, along with increased summer average flows driven by more intense rainfall events.
- Foothill regions (e.g., Baptiste River): Similar trends of earlier snowmelt and higher average summer flows, particularly notable in the 2051–2080 period.
- Mountainous headwaters (e.g., NSR at Whirlpool Point): From 2021 – 2050, there may be increased average spring and early summer flows due to greater snowpack and glacial melt. In 2051 – 2080, peak flows may occur before July 1, followed by lower flows for the rest of the summer, reflecting reduced glacier contributions.

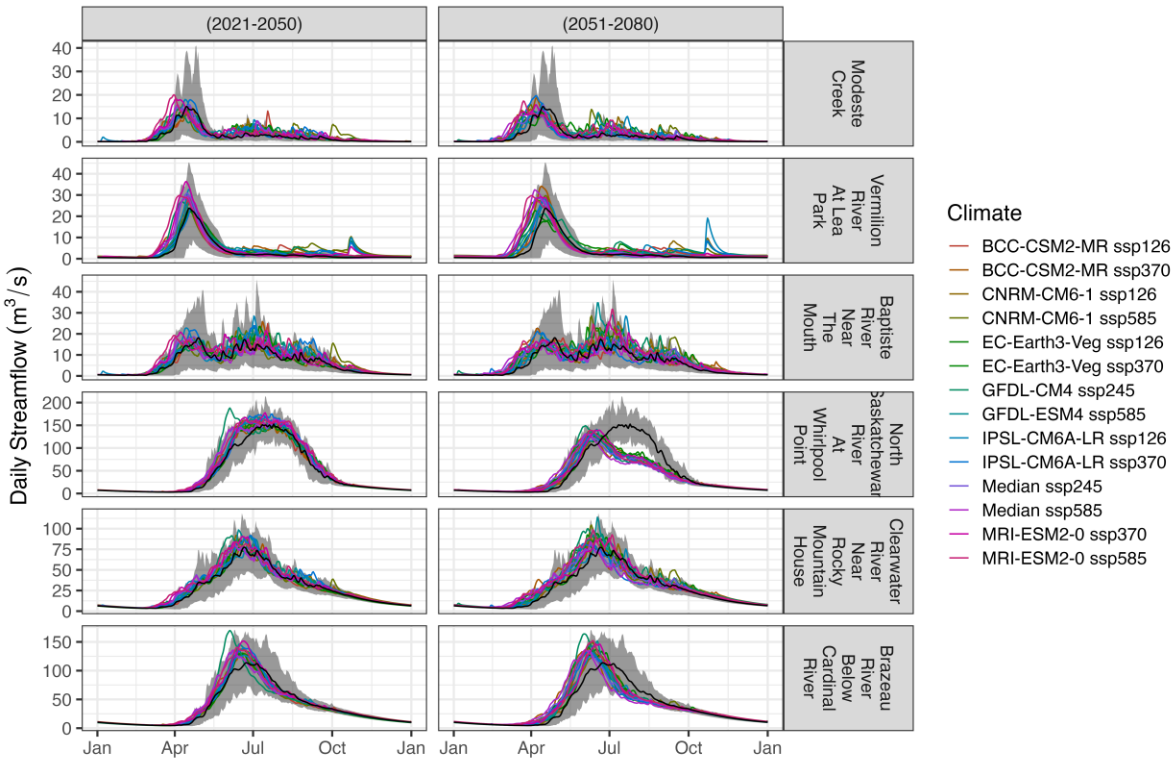

Figure 2-8: Average daily streamflow for selected NSRB sites under the 14 climate scenarios run against the Historical (1991-2020) period (in black) (Figure 11 in Appendix C).

2.4.2.1 Risk-intensified Climate Scenarios

The 14 future climate scenarios were also run through the water management model to assess their potential impacts on system performance. Based on the results, three scenarios were selected for use in the model runs conducted during the WG meetings, as detailed in Table 2-7. These included a historical baseline scenario (1951–2020) and two high-stress scenarios. The latter were not chosen to represent the most likely future conditions, but rather to explore risk-intensified climate futures - that is, scenarios characterized by particularly challenging hydrologic extremes.

Table 2-7: Climate scenarios selected for model simulations.

Climate Scenario	Description
Historical	Baseline model simulations based on observed historical (1951-2020) climate data.
CNRM-CM6-1_ssp126	A future climate scenario (2021-2100) under SSP 1-2.6 which represents a relatively low-emissions future. It was selected because it is one of the driest future projections, characterized by a relatively lower degree of warming and less precipitation.
BCC-CSM2-MR_ssp126	A future climate scenario (2021-2100) under SSP 1-2.6 which represents a relatively low-emissions future. It was selected because it produces the highest simulated flood among the tested scenarios, making it valuable for evaluating flood-related risks.

2.4.3 Water Management Scenarios

Drawing on insights from the WG meetings and outputs from the Tool, a set of water management strategies – referred to as scenarios in the modeling process – was developed to address the basin's specific challenges, opportunities, and future uncertainties. As shown in Table 2-8, these scenarios build on the climate and land cover inputs and can be applied independently or in combination, allowing for a comprehensive assessment of water availability and use in the NSRB.

Table 2-8: Water management scenarios (Section 4.7.3 of Appendix C).

Water Management		Description
Category	**Scenario**	
Baseline Scenario	EstUse	Represents estimated current water use and operations. Reflects existing practices, including diversions, returns, and dam management.
Growth and Full Allocation	Growth	Simulates increased water demand from projected population and industrial growth. Diversion multipliers applied: Edmonton & Regional Customers (1.7), Municipal (1.2), Industrial (2.0). All other operations remain as in EstUse.
	FullAllocation	Assumes all licence holders fully divert their allocations, with return flow fractions unchanged. Diversion multipliers: Agriculture (2.48), Commercial (2.9), Edmonton & Regional Customers (1.7), Industrial (5.38), Management (5.52), and Municipal (1.12). All other operations remain as in EstUse.
Off-Stream Storage	Sundance	An off-stream 42,000 dam³ reservoir near Wabamun Lake. Pumps from NSR above Edmonton when modelled flow >150 m³/s; releases when below Q10 (Open-Water/Winter).
	DIZ	An off-stream 50,000 dam³ reservoir downstream of Edmonton. Water from NSR is pumped in up to 1 m³/s when modelled flows from Pakan are above 200 m³/s and releases water to NSR in June–Sept when flows are below Q10 (Open-Water). It is noted that the refill rate (1 m³/s) is low, however this value was not changed as the dam was not emptying during its operating period. Future work to refine these operations could explore a higher refill rate.
Edmonton Flow Targets	EdmMax	Maximum flow limit at Edmonton set to the modelled 10-year peak flow (967 m³/s). Higher priority than water licences, but lower than TransAlta dam operations (except reservoir level targets, which are lowest priority).
	EdmMin	Minimum flow target at Edmonton set to 10th percentile of modelled flow: 135 m³/s (Open-Water),110 m³/s (Winter). Higher priority than water licences, but lower than TransAlta dam operations (except reservoir level targets, which are lowest priority).
Reservoir Operations and Capacity	EarlyRefill	Moves refill targets for Brazeau and Bighorn dams 14 days earlier to match earlier freshet under climate change.
	TAUStorage	Increases storage capacity of Brazeau and Bighorn reservoirs by 15%. Dam operations adjusted to reflect updated Full Supply Levels (FSL) and target water levels.

Note: all values are based on model simulated outputs (i.e., not observations). The minimum flow management goals identified and implemented in the Tool were set based on statistical thresholds in the absence of available minimum flow studies in the basin. This was used as a proxy to estimate low flows and therefore potential impacts to ecosystem health.

2.5 Modelling: Scenario Integration and Insights

To simulate potential futures, the scenarios are integrated into the hydrological and water management model as user-adjustable inputs, or toggles. These toggles allow users to explore a wide range of conditions and water management strategies by selecting different combinations of scenarios. Each model simulation includes one scenario from each of the three components – land cover, climate, and water management – as illustrated in Figure 2.9.

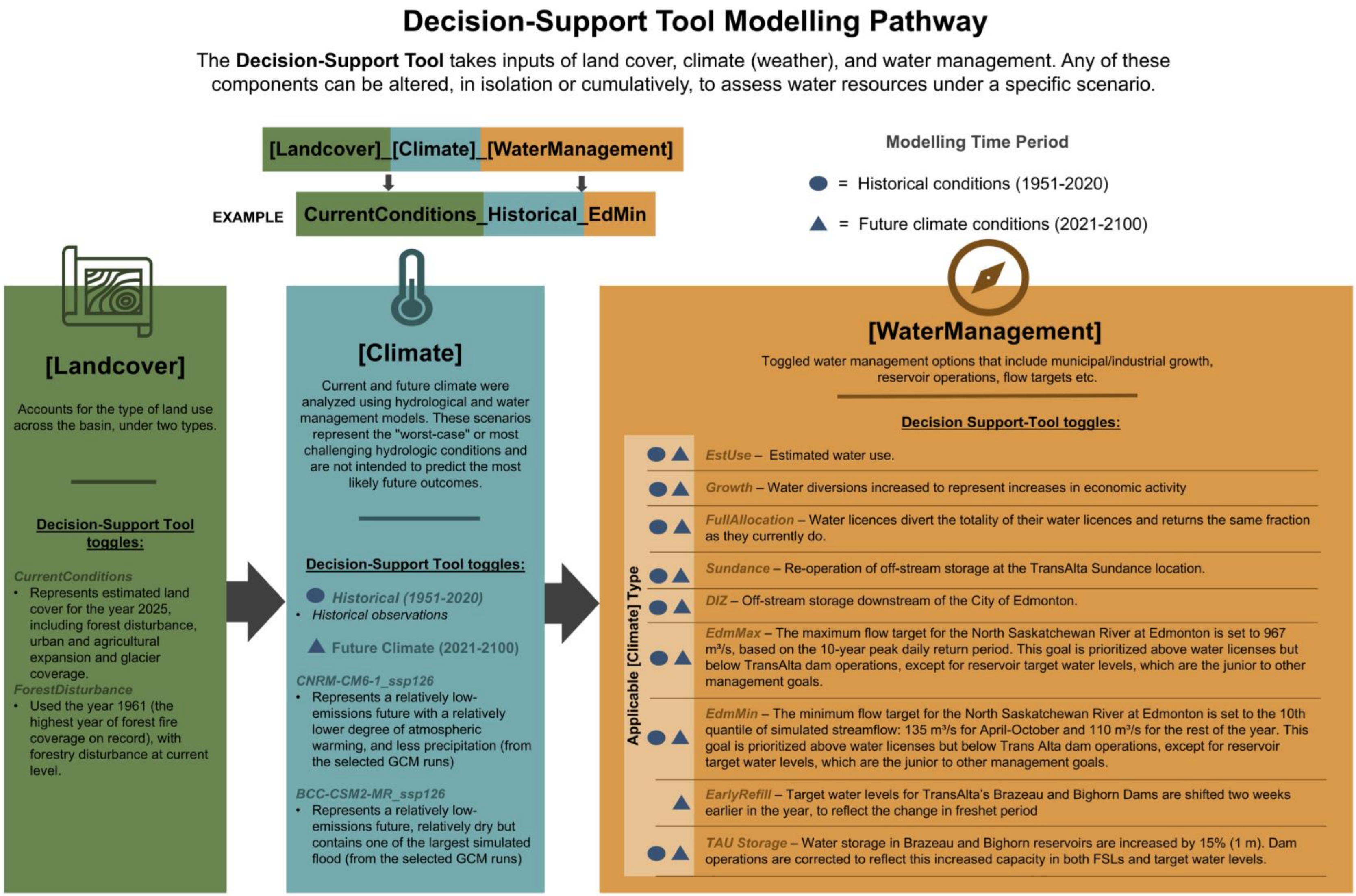

Figure 2-9: Decision-Support Tool modelling pathway.

2.5.1 Projected Trends

Using the defined scenarios as model inputs, simulations were conducted to explore a range of potential futures for the NSRB. This section summarizes key trends identified across scenarios, highlighting how different conditions and management strategies may affect system performance. Detailed results and additional graphs can be found in Appendix C.

2.5.1.1 Increased Water Demand Impacts Tributaries More than the Mainstem

Scenarios: Growth and Full Allocation

Under historical climate conditions, system strain grows with increasing water demand:

- Mean Annual Demand increases from 11.0 m^3/s in the EstUse scenario to 19.5 m^3/s under Growth, and 38.0 m^3/s under Full Allocation.
- In the Growth Scenario, this added demand is mostly concentrated along the Edmonton–Pakan mainstem corridor.
- Under Full Allocation, demand also rises in more arid tributaries, amplifying localized impacts.

This trend is reflected in the Potential System Shortage PM, which shows a minimal increase between EstUse and Growth, but a sharp rise under Full Allocation. Other indicators—such as Vermilion Low Flows, Assimilative Capacity, and Apportionment—also worsen under Full Allocation, though Apportionment remains above its 50% threshold.

2.5.1.2 Off-Stream Storage Supports Late-Season Flows and Improves Water Quality Indicators

Scenarios: Off-Stream Storage

The off-stream storage scenarios (Sundance and DIZ) showed the following hydrologic effects, with greater benefits under Sundance:

- Assimilative Capacity improved by over 20% with Sundance, offsetting degradation from the Growth scenario.
- Potential System Shortage was unaffected, as both storages operate on the mainstem where diversions are unconstrained unless the river is dry.
- Dry-year benefits were most apparent: in early September, EstUse flows dropped triggering storage releases to maintain flow above the 10^{th} percentile.
    - DIZ storage ceased releases in October (end of operating season).
    - Sundance continued releases into mid-October, until storage was depleted.

It was noted that the DIZ refill rate (1 m^3/s) is low; however this was not changed as the dam was not emptying during its operating period. Further work, including hydrological modelling and a cost-benefit analysis, is necessary before concluding that storage is not required in the basin.

2.5.1.3 Upstream Reservoirs Offer Limited Peak Flow Mitigation at Edmonton

Scenario: Max Flow Target at Edmonton (967 m^3/s)

Upstream reservoirs (Brazeau and Bighorn) can partially reduce peak flows at Edmonton, but their effectiveness is limited:

- In a 1972 flood, the reservoirs helped lower peak river flow in Edmonton from over 1,600 m^3/s of modelled flow to about 1,200 m^3/s of modelled flow, showing that they can reduce the worst of the flooding.
- Under future climate scenario BCC-CSM2-MR_ssp126, the timing and intensity of a July flood event further reduced the effectiveness of dam operations:
    - Storage was already limited, with Bighorn near its minimum Full Supply Level FSL in mid-June. A note, however, that this does not consider the EarlyRefill scenario (Section 2.5.1.5).
    - Reservoirs filled quickly, forcing a return to maximum outflows to maintain water levels below FSL.
    - No proactive operations were included in the model, such as a forecast predicting a large storm, leading to operators emptying the reservoir to create storage for the event.

The two dams are limited in their ability to mitigate flood flows as they only control flows from 34% of the watershed upstream of Edmonton. Therefore, major flood flows could originate from areas outside of the dam's control. However, the Brazeau dam in particular controls a large portion of the watershed that experiences significant precipitation and would be expected to have some ability to mitigate floods.

2.5.1.4 Minimum Flow Targets Improve Water Quality but Strain Water Supply in Future Dry Years

Scenario: Minimum Flow Target at Edmonton

Implementing a minimum flow target at Edmonton improves water quality by reducing low-flow days:

- Under historical conditions (1991–2020), the EdmMin target nearly eliminated low-flow days going from 37 to 1, with no increase in water shortages.
- Under future climate scenario CNRM-CM6-1_ssp126, low-flow days increased under EstUse to 70 days; however, under EdmMin this is reduced to 10 days.

Despite these improvements, challenges arise under future dry conditions:

- Reservoirs may struggle to meet both flow targets and water demand, especially with added growth.

- In 2069, Bighorn Reservoir nearly emptied after poor inflows in the prior year.
- Results suggest that without adaptive operations, EdmMin could increase shortages under future climate and demand scenarios.

In practice, operators would likely scale back minimum flow requirements in these conditions to avoid depleting reservoirs entirely. This is not reflected in the model.

2.5.1.5 Current dam operations may be ineffective under future climate and demand scenarios

Scenarios: EdmMinGrowth, EarlyRefill and TAUstorage

Future climate and demand conditions reduce the effectiveness of the current operations of Bighorn and Brazeau dam. Two operational changes were tested:

- Early Refill: Adjusting the reservoir rule curves two weeks earlier (to align with an earlier spring freshet) resulted in modest improvements:
    - Fewer days exceeding Assimilative Capacity thresholds.
    - Reduced Loading Potential days.
    - Slight reduction in Potential System Shortages.
- Increased Storage (TAUstorage): Simulating a 15% increase in Brazeau and Bighorn storage capacity showed some benefit under extreme low-flow conditions, but results were limited:
    - Minor improvements in mainstem low-flow PMs.
    - Storage still depleted during prolonged dry periods, even with EdmMin, Growth, and EarlyRefill scenarios combined.

Despite these modifications, none of the operational changes fully prevented reservoir depletion during future low-flow years. For example, under EdmMinGrowth:

- Storage at Bighorn was depleted by late November.
- EarlyRefill extended this to mid-late December.
- TAUstorage delayed depletion to late December.

2.6 Modelling: Discussion and Limitations

The Tool showed overall good performance. The model is process-based and was able to reproduce hydroclimatic conditions across the watershed with relatively good fidelity and provides confidence that the model is “right for the right reasons”. As such, it remains a useful tool to quantify and characterize the hydrologic conditions at points of interest, representing the current state of water management (licencing, operations, and regulatory environment governing surface water quantity), simulate scenarios with differing land cover, climate, and water management configuration, and drive collaborative watershed decision making.

The model shows some persistent weaknesses in simulating streamflow that should be considered when evaluating model outputs. Model performance was weakest in the most arid and agriculturally dominated areas, mostly during the late summer and winter months. This is likely due to several factors, most notably the difficulty in simulating prairie pothole dynamics, the geographic heterogeneity of precipitation intensity in summer convective storms, winter conditions, and the likely anthropogenic influence on the landscape.

The model underestimates peak flow events, which is likely compounded by several factors. Forcing data likely underestimates the intensity and/or magnitude of precipitation during large events; likewise, the model may underestimate the non-linear response of large storms due to soil processes and surface runoff. Finally, peak flows may be underestimated in regulated portions of the watershed in part because the model is dogmatic in following operational management goals. Although the water management model provides a "best guess" at dam operations, it only considers the provided information and does not consider additional information which may inform how infrastructure is operated during a large event (i.e. such as precautionary actions to release higher outflows in anticipation of greater incoming/forecasted inflows). By the same token, the model may modestly over-estimate low flow periods on the mainstem. This is also likely, at least in part, due to the model's dogmatic implementation of minimum flow releases from the dams, which in practice may have been superseded by other considerations such as ice effects, dam maintenance, or other management goals.

Storage options and flow regulation results show some flexibility in the current system. Off-stream storage facilities, as currently modelled, show some ability to supplement lower flow conditions. The large reservoirs in the headwaters have considerably greater ability to achieve the same management goals and additionally are able to mitigate some peak flow events. However, this comes with several caveats. First, flood mitigation operations would require more detailed modelling and integration of flood forecasting information to properly mitigate events, including proactive lowering of reservoir levels in anticipation of large inflows and possibly maintaining additional available storage during flood season. Additionally, flood mitigation work should recognize that both major reservoirs are located relatively high in the watershed, and as such, have limited ability to mitigate high flows when the rainfall event is concentrated downstream of these facilities. Furthermore, any alteration of Bighorn or Brazeau dam operations would be contingent on operators willing to consider additional management goals in their operations. While modelling shows that in the base case there is considerable flexibility in their operations, this flexibility may very well be valuable to their business (e.g. being able to react quickly to changing power prices). Without the input of dam operators, it is uncertain how feasible changes in operations are.

Water demand is concentrated along the mainstem of the NSR between Edmonton and Pakan. Potential shortages, or unmet modelled water demand, are occasionally simulated for licences on more arid tributaries during the late summer and winter months. In all cases, unmet demand is referred to as a "potential" shortage because we cannot ascertain how each individual licensee accesses water and whether they store water in dugouts or other temporary storage infrastructure and/or have adapted their operations to only access water when it is available in-stream. On the mainstem NSR, no potential shortages are simulated in the historical base case. This reflects the considerable flow of the NSR and that there are currently no limits on water withdrawals in the basin that are implemented in the model above the physical constraint of a dry river. This modelling decision was made in consultation with regulators and WG members and reflects the lack of defined environmental flow needs studies and/or defined thresholds for the mainstem and its tributaries. This highlights a data gap that could be addressed by future studies to better identify flow thresholds and minimum flow requirements to sustain a proper functioning aquatic ecosystem.

Finally, the minimum flow management goals set in this work are set based on statistical thresholds and are completed here as a demonstration of the ability of the system and potential infrastructure to support these low flow thresholds. In the absence of available minimum flow requirement studies, these values were used. Overall, this highlights that further work would need to be completed to refine what flow requirements are necessary to maintain aquatic ecosystem health, followed by more detailing modelling with these values, in order to better understand the effectiveness and efficiency of these flow regulation options.

2.7 Economic Analysis

To complement the Tool, an economic analysis was performed to assess the economic benefit that may be likely to result from the identified/selected adaptations as outlined by the WG. The results of the economic analysis, which are based on several assumptions, are not meant to support an investment decision nor do they imply that one option is better or 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 utilized the EcoMetrics™ Methodology which identifies, quantifies, and values (in monetary terms) the environmental, economic, and social benefits to various stakeholders. Further detail on the economic analysis can be found in Appendix D.

2.7.1 EcoMetrics™ Methodology Overview

The EcoMetrics™ analysis evaluated selected categories of adaptations to identify, quantify, and value, in monetary terms, the co-benefits proposed adaptations. Not all adaptations lend themselves to an EcoMetrics™-type analysis, and some which may lend themselves to an EcoMetrics™ analysis are not yet defined enough to provide the necessary inputs to do the analysis. Therefore, this should be considered a high-level initial analysis.

The overall goal of the Roadmap is to develop and implement a number of adaptations to address identified challenges and opportunities in the area related to water quantity, water quality, water governance, drought, flooding, and other aspects. Specifics vary from adaptation to adaptation, but in general the intent is to build regional resilience, reduce risk and shortages as well as support growth through increased availability.

The analysis is from a comparative and predictive perspective. For consistency of terminology used in this report, the “outcomes” are the impacts to the region and stakeholders resulting from implementation of an adaptation(s). If the outcome is positive in terms of creating incremental value, then it is a “benefit.” In the report, benefit is used interchangeably with outcome, but with the understanding that there are cases where an outcome may have a negative impact and result in loss of value (for example, flooded agricultural land no longer usable for production). These are reflected as negative values in this report.

Outcome valuation is a combination of ecosystem service and natural asset valuation with Social Return on Investment (SROI). Ecosystem service valuation is an approach to determine the value realized in monetary terms, for stakeholders by leveraging functions and services provided by the environment, nature, and natural resources. SROI is a framework for measuring and accounting for the broad concept of social value, a measure of change that is relevant to people and organizations that experience it. This concept of value goes beyond what can be captured in pure, market-based financial terms, seeking to reduce environmental degradation and improve wellbeing by incorporating social, environmental, and economic costs and benefits into project valuation (SROI Network, 2012). For analytical purposes, SROI converts non-financial values into their financial equivalents, using both subjective and objective research to estimate those values. This is what makes SROI different from other forms of social-impact analysis, and therefore more valuable to funders and supporters.

The adaptations can be generally grouped into the following categories:

- Leveraging Land-Use Types as Nature-Based Solutions.
- Increased Storage for Various Uses.
- Increased Storage to Mitigate Drought Issues.
- Agricultural Opportunities.
- Increased Municipal Water Use Efficiency to Support Growth.

The category groupings were necessary because a number of adaptations were variations on the same activity in terms of EcoMetrics™ analysis.

2.7.2 EcoMetrics™ Results

The comprehensive benefits of the different options, which include social, economic, and environmental outcomes, were identified, quantified, and valued utilizing the EcoMetrics™ methodology. The major stakeholder groups that would benefit include academic, environmental non-governmental organizations (ENGO), government, Indigenous, industrial, municipal, utility, environment, and the general public.

Tables 2-9 through 2-12 reflect the value created, by outcome, for the four adaptation categories, as follows:

- Leveraging Land-Use Types as Nature-Based Solutions (Table 2-9).
- Increased Storage for Various Uses (Table 2-10).
- Agricultural Opportunities (Table 2-11).
- Increased Municipal Water Use Efficiency to Support Growth (Table 2-12).

The fifth category to address drought resilience (Increased Storage to Mitigate Drought Issues) is actually a different way to describe the values in the additional storage adaptation category (Table 2-10). Drought resilience is defined as value preserved per dam^3 by having water volume available in case of drought.

Hence the value created per dam^3 is the same, and is either additional value created under normal conditions, or value preserved under drought conditions.

Table 2-9: Outcome values for land cover types in dollars per acre ($/ac) (Table 1 in Appendix D).

Outcomes	Forest ($/ac)	Grassland ($/ac)	Riparian ($/ac)	Wetlands ($/ac)
Aesthetic Value	$1,431	$134	$775	$775
Agricultural Economy	N/A	N/A	N/A	N/A
Biological Control	$33	$45	Unavailable	$225
Carbon Sequestration Social Value	$73	$2	$73	$103
Drought Resilience	Unavailable	Unavailable	Unavailable	Unavailable
Food Provisioning	N/A	Unavailable	N/A	N/A
Habitat and Biodiversity	$2,868	$425	$1,538	$3,451
Nitrogen Retention Social Value	($36)	($34)	Unavailable	Unavailable
Nutrient Cycling	$15	$15	Unavailable	Unavailable
Phosphorus Retention Social Value	($8)	($16)	$3,444	$3,444
Pollinator Population Support	N/A	$659	N/A	N/A
Property Value	N/A	N/A	N/A	N/A
Soil Formation	$25	$1,155	$151	$893
Soil Stabilization	$301	Unavailable	$301	$2,093
Water Filtration	$974	$974	$974	$974
Water Regulation	$534	Unavailable	$482	$482
Water Supply for Population Growth	$10,406	$204	N/A	$12,682
Wildfire Risk Reduction	N/A	N/A	N/A	N/A
Total Social	**$16,616**	**$3,561**	**$7,739**	**$25,123**
Market Value of Carbon Credits	$38	$1	$38	$54
Total	**$16,654**	**$3,562**	**$7,777**	**$25,176**

Note: Brackets represent negative values.

Table 2-10: Outcome values for increased water storage (per dam³), value created or preserved (Table 2 in Appendix D).

Outcomes	Value per dam³	10,000 dam³
Enhanced Environmental Flows in Dollars per Resident ($/resident)	$7,281	$22,954,566
General Recreation in Dollars per Visitor ($/visitor)	$77	$77
Physical Health ($/visitor)	$809	$809
Population Growth in Dollars per Cubic Decameter ($/dam³) (9 persons per dam³ and $71,640 of GDP per capita)	$644,760	$2,032,713,360
Total Social	**$652,927**	**$2,055,668,812**

Table 2-11: Outcome values for agricultural opportunities (per acre) (Table 3 in Appendix D).

Outcomes	Value Per Acre
Aesthetic Value	$95
Agricultural Economy	$1,213
Biological Control	$24
Carbon Sequestration Social Value	$5
Drought Resilience	$78
Food Provisioning	$1,145
Habitat and Biodiversity	$1,823
Nitrogen Retention Social Value	($548)
Nutrient Cycling	$18
Phosphorus Retention Social Value	$324
Pollinator Population Support	$429
Property Value	$4,200
Soil Formation	$4
Soil Stabilization	($252)
Water Filtration	$170
Water Regulation	$11

Water Supply for Population Growth	$0
Wildfire Risk Reduction	$188
Total Social	**$8,926**
Market Value of Carbon Credits	$2
Total	**$8,929**

Note: Brackets represent negative values.

Table 2-12: Outcome values for enhanced municipal water use efficiency (per dam^3).

Outcomes	Value per dam^3
Enhanced Environmental Flows ($/resident)	$7,281
Population Growth ($/dam^3) (9 persons per dam^3 and $71,640 of GDP per capita)	$644,760
Total Social	**$652,041**

Values presented herein are for a single representative year, but some outcome values would be expected to recur each year if projected out beyond one year and therefore the results reflect a conservative view. Hence, the adaptations create much greater value over time.

Key findings include:

- Nature-based solutions that leverage different land cover types create value in a number of outcomes, with wetlands being the highest overall value per acre. Water retention is the most productive in terms of value created per outcome.
- Storage options provide value created or preserved mainly through supporting population which generates GDP per capita.
- Increased water available supports agriculture, and agricultural land generates value in a number of outcomes.
- Increased municipal water use efficiency essentially translates into more water to support population growth, which in turn creates more GDP. This would apply in the specific scenario where there is limited water availability as well as inability for municipalities to procure additional water licences. In this scenario, water use efficiency would translate into more water to support population growth, and in turn, create more economic growth (GDP).
- Until more details about adaptations, or details about actual implementation of various adaptations are known, some outcomes can only be valued very generally, if at all. Some outcomes do not apply to all land cover types or all adaptations. To address this lack of information, Not Available is noted. To address the applicability issue, Not Applicable (N/A) is used.

3. North Saskatchewan River Basin Water Management Roadmap

The Roadmap, outlined in Appendix E, highlights a path toward sustainable and collaborative water management in the NSRB under a changing climate and basin growth. The Roadmap is centered around four strategic drivers that reflect Alberta's evolving water management landscape, as identified and discussed by the WG:

- **Enhance the use of sustainable water management practices**: Supporting innovation and efficiency in water use across sectors through conservation, reuse, data improvements, and basin-level planning is essential to sustainable water management.
- **Conserve and restore ecosystems to maintain and improve watershed health**: Natural assets such as wetlands, riparian zones, and connected floodplains are integral to watershed function. Restoring and conserving these assets supports ecological health and resilience and contributes to Alberta's environmental objectives.
- **Maintain or improve water quality:** Protecting drinking water sources, including tributaries, lakes, and small community supplies, requires improved monitoring, data-sharing, and support for infrastructure solutions that are both environmentally sound and economically viable.
- **Advance inclusive and shared governance in water management:** Effective water management requires collaboration across governments, sectors, and communities.

The Roadmap reflects a shared commitment to sustainable and integrated water management that is responsive to Alberta's water realities. It offers clear direction for aligning provincial, municipal, and community actions while upholding environmental protection, enabling economic growth, and meeting social needs. By acting upon this direction, we can collectively strengthen water resilience in the NSRB and serve as a model for collaborative watershed stewardship.

The Roadmap, summarized in Figure 3-1, includes the sustainable water management adaptations which were deemed most promising by the WG and does not reflect the full suite of adaptations assessed through the Project. Although additional adaptations were discussed, further work is required at this time before being considered for inclusion on the Roadmap. These items are discussed as Future Considerations in Section 3.3. Additionally, complementary actions supporting basin water management are discussed in Section 3.2.

It is important to note that the Roadmap does not denote the priority or importance of any adaptation. Within the Roadmap, all adaptations are considered of equal priority and critical to sustainable water management in the NSRB.

All Roadmap adaptations were discussed within the WG, modelled using the Tool to assess their water security benefits (where possible), and assessed through the EcoMetrics™ methodology (where possible). Adaptations which could not be modelled using the decision-support tool were discussed qualitatively by the WG and are included below.

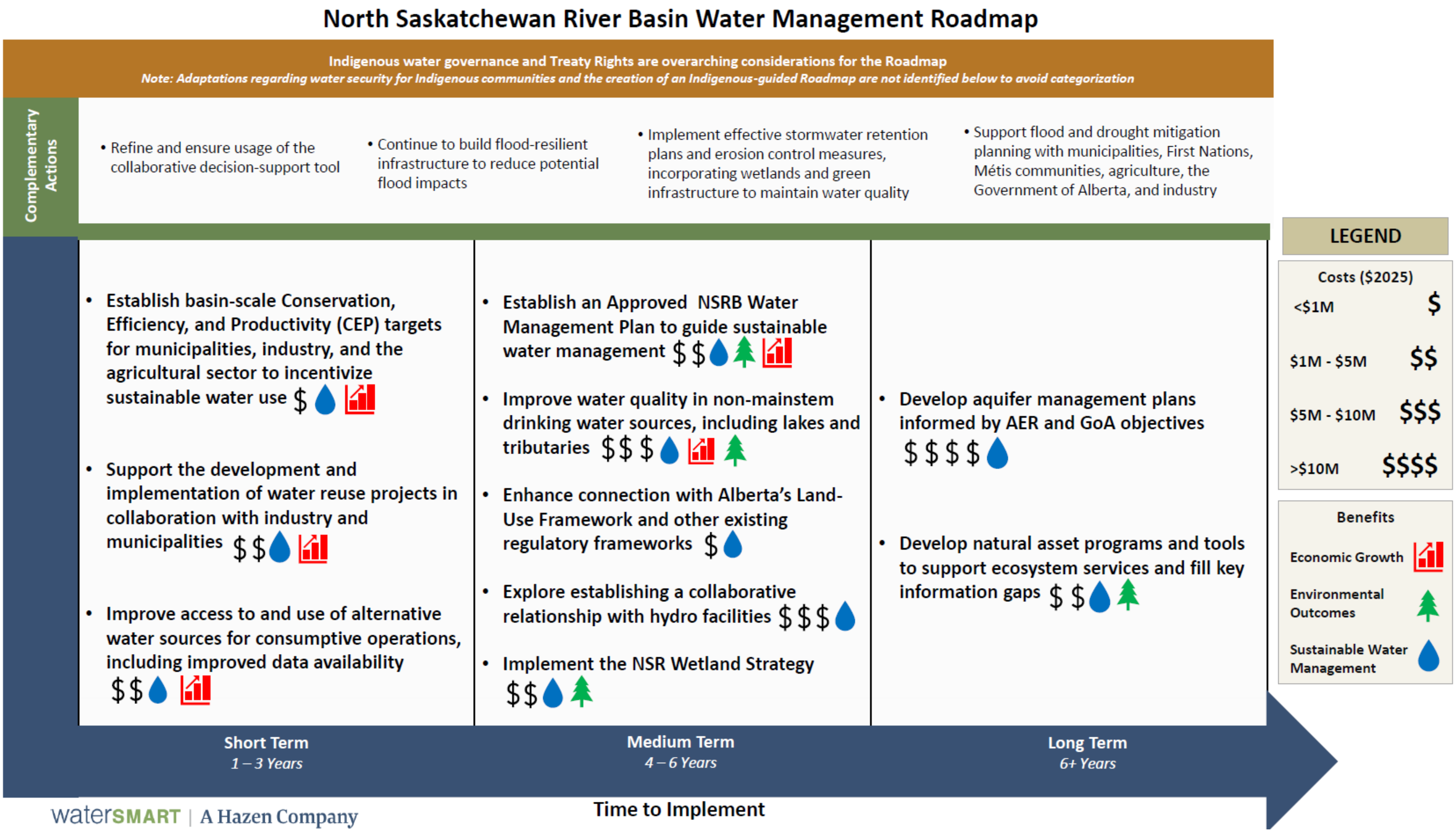

Figure 3-1: North Saskatchewan River Basin Water Management Roadmap.

3.1 Water Management Adaptations

3.1.1 Establish an Approved North Saskatchewan River Basin Water Management Plan to Guide Sustainable Water Management

Description:

In Alberta, an approved Water Management Plan is a formal planning instrument developed under the authority of the *Water Act*, and can apply to all water bodies, including streams, rivers, lakes, aquifers, and wetlands. It provides strategic direction for the allocation, use, and conservation of water within a defined watershed or basin. These plans are designed to support the long-term sustainability of water resources by balancing environmental, social, and economic needs.

This adaptation calls for the creation of a formally approved, basin-wide Water Management Plan tailored to the unique context of the NSRB. The plan would offer a coordinated, science-based framework for water management and allocation decisions that would enhance clarity, consistency, and sustainability for all water users and ecosystems across the basin.

Rationale:

The NSRB is facing growing pressure from population growth, economic development, and climate variability. Water allocation decisions are currently made without a unified, long-term strategy at the basin scale. This fragmented approach can lead to inconsistent outcomes and limit the effectiveness of conservation efforts.

An approved Water Management Plan is considered a statutory plan, meaning it carries legal authority under the Alberta *Water Act* and must be considered in regulatory decisions, such as issuing water licences. Provincial approval gives the plan significant weight, ensuring that decisions align with shared long-term priorities rather than short-term or reactive interests.

Developing an approved NSRB Water Management Plan would:

- Support integrated watershed management under Alberta's *Water for Life* strategy.
- Provide greater clarity and transparency for water users, regulators, and the public.
- Identify and balance ecological and human needs, with science-based protections for instream flows and water conservation.
- Strengthen drought preparedness and water resilience in a changing climate.

Key Actions:

1. **Establish a multi-stakeholder process to scope, develop, and secure funding for the Water Management Plan:**

A representative, basin-wide planning process is essential to ensure that the plan reflects shared values and secures long-term support from governments, Indigenous communities, industry, agriculture, and environmental stewardship groups.

2. **Conduct an Instream Flow Needs (IFN) assessment for the regulated river system:**

   An IFN assessment is a science-based analysis which defines quantity and quality of water that will sustain a healthy ecosystem and river (Government of Alberta, 2011). *This science-based analysis will inform environmental flow thresholds, ensuring the Water Management Plan supports the health of aquatic ecosystems, which are a foundational requirement for sustainable water management.*

   The intent is that by managing the basin to maintain river flows above the recommended IFN, there is a low probability of negative ecological effects. IFN assessments have typically been completed using a Desktop Method for natural flows, the threshold being the greater of either:

   - *A 15% instantaneous reduction from natural flow; or*
   - *The lesser of either the natural flow or the 80% exceedance natural flow* (Government of Alberta, 2011).

   The NSRB will require an assessment for a regulated river, as the upstream Brazeau and Bighorn dams manage water flows year-round.

3. **Develop science-based Water Conservation Objectives (WCOs) through a multi-stakeholder process, with consideration of economic viability:**

   The NSRB currently has an Instream Objective (IO) on the Clearwater River. IOs refer to mandated flows that should remain in the river to address local and regional concerns stemming from low flows (Government of Alberta, 2024). *To further define environmental baselines in the NSRB, Water Conservation Objectives (WCOs) should be developed as part of the Water Management Plan.*

   A WCO is a flow threshold, identifying the quality and quantity of water required to protect the aquatic environment. WCOs are a regulatory tool to be applied to water licences approved under the Water Act. This regulatory tool can help maintain flows for healthy ecosystems, infrastructure requirements, and waste assimilation (Government of Alberta, 2024). *This is a key component of the Water Management Plan, helping to balance ecological integrity with water use needs in a transparent and justifiable way.*

4. **Apply the Surface Water Allocation Directive (SWAD) to tributaries and lakes, as appropriate, within the planning framework:**

   Alberta's SWAD is a calculation method to provide water allocation guidance to rivers, streams, lakes, and wetlands by using a cumulative basin approach (Government of Alberta, 2019). *The objective of SWAD is to minimize environmental risk by considering this cumulative allocation throughout the basin* (Government of Alberta, 2019). *SWAD is* *intended to be applied to naturalized flow, as many aquatic species require naturally changing hydrologic conditions. The NSRB mainstem is a regulated river due to the upstream dams; however integration of the directive to tributaries and lakes, as appropriate, will promote a consistent, basin-wide application of provincial policy tools and support coordinated water allocations across jurisdictions.*

5. **Develop a drought management component within the plan to promote water conservation and user education:**

   Embedding drought preparedness into the Water Management Plan can ensure that the NSRB is better equipped to respond to climate variability and water scarcity and provides a clear framework for action during low-flow periods.

   Public education helps the implementation and promotion of water conservation through informing on benefits and risks to communities and the ecosystem.

3.1.2 Establish Basin-Scale Conservation, Efficiency, and Productivity (CEP) Targets for Municipalities, Industry, and the Agricultural Sector to Incentivize Sustainable Water Use

Description:

Improving water use efficiency across sectors is a key strategy for meeting future water demand while protecting aquatic ecosystems. CEP plans allow for a long-term, achievable water strategy, setting measurable goals for reducing waste, optimizing water use, and improving resource efficiency.

This adaptation identifies the need for the development of sector-specific CEP targets for municipalities and industry within the NSRB. These targets would guide long-term planning, investment, and operational decisions, helping to reduce pressure on water supplies and improve resilience to drought and climate variability.

A collaborative and informed approach is essential to ensure that targets are realistic, meaningful, and aligned with existing regulatory, operational, and financial frameworks. By embedding CEP targets in municipal and industrial practices, the NSRB can enhance water security and drive innovation in water use and reuse.

Rationale:

Water demand is expected to increase in the NSRB due to population growth and industrial expansion. Additionally, water availability may become less predictable, as precipitation patterns may change in duration and timing due to climate variability. Improving water-use efficiency is one of the most cost-effective and immediate ways to address these challenges, particularly in municipalities and industries that are high-volume water users.

However, water efficiency gains cannot be mandated without understanding sector-specific constraints, motivations, and risks. By working closely with stakeholders to identify both barriers and opportunities, the basin can develop targeted strategies that promote efficiency without compromising economic viability or service delivery.

As shown in the economics analysis in Section 2.7.2, the potential value of enhanced municipal water use efficiency can be nearly $650,000 per dam^3 annually. With increased efficiency, each dam^3 can support more people. Using the assumption of a fixed water supply, if municipalities minimize water use, more individuals can be supported at a given GDP per capita.

Establishing CEP targets could:

- Encourage innovation and investment in water-saving technologies and practices.
- Support municipal water utilities in managing demand and reducing infrastructure costs, while securing safe drinking water.
- Enhance regional water security and climate resilience.
- Signal leadership and accountability in sustainable water management.
- Align with Alberta's *Water for Life* goals to improve efficiency and productivity by 30%.

Key Actions:

1. **Engage and consult with industry stakeholders to understand their drivers, principles, and constraints related to efficiency:**

    A sector-specific understanding will ensure CEP targets are relevant, actionable, and aligned with operational realities. Engagement will also help build trust and support for implementation of voluntary or regulatory approaches.

2. **Identify policy and regulatory barriers, opportunities, and risk tolerances across sectors:**

    This assessment will highlight where existing policies may hinder efficiency efforts or where regulatory adjustments or incentives could support innovation and adoption of CEP best practices.

3. **Explore and pilot opportunities to reduce municipal water use, including tools such as tiered utility billing:**

    Many municipalities in the NSRB are already great stewards of water conservation. For example, in 2008 the City of Edmonton implemented a Water Efficiency Fixtures Bylaw, which requires that all new homes be installed with low-flush toilets, low-flow showerheads, and low-flow faucets. Low-flush toilets can reduce water use by 30-75%, and low-flow showerheads and faucets by 15-20% (City of Edmonton, 2015). *The City of Edmonton and EPCOR have also implemented tiered billing to promote water conservation.*

    For those municipalities that have not yet implemented conservation strategies, there are many technological advancements or operational tools that may offer opportunities for improvement. Tiered pricing structures reward efficient users and encourage conservation, particularly during periods of peak demand or drought. Other opportunities may include leak detection programs, public education, and greywater reuse strategies.

4. **Engage with the agricultural sector to identify opportunities for water use efficiency gains and gain support for adoption of Best Management Practices (BMPs):**

   The agricultural sector is best positioned to identify potential opportunities for more efficient water use, or the water stewardship best practices already in use that could be shared across producers within the watershed.

   Examples of BMPs may include minimizing soil disturbance, incorporating trees or other vegetation, and nutrient management.

3.1.3 Support the Development and Implementation of Water Reuse Projects in Collaboration with Industry and Municipalities

Description:

Historically, Alberta provides water licences from natural sources such as lakes and rivers. However, there are alternative sources of water for municipal and industrial use, including through water reuse (Government of Alberta, 2024). Water reuse is the practice of treating and repurposing wastewater or process water for other beneficial uses. It offers a significant opportunity to reduce pressure on the mainstem and its tributaries. By reusing water within industrial or municipal systems, total withdrawals from the river can be reduced while still supporting economic activity and community needs.

This adaptation seeks to facilitate the planning and implementation of water reuse projects in partnership with industry and municipalities. The focus is on identifying and overcoming barriers to reuse, advancing supportive policy frameworks, and ensuring that efficiency gains can directly benefit river flows.

A basin-wide approach to water reuse can help shift the region toward a more circular and water-resilient economy, while safeguarding long-term water availability.

Rationale:

As demand for water increases and climate variability intensifies, water reuse presents an opportunity to improve basin resilience. However, uptake of reuse projects in Alberta has been limited due to regulatory uncertainty, licensing concerns, infrastructure costs, and the absence of clear incentives. The reliability of available volumes from water reuse has also been a limiting factor.

Supporting water reuse would:

- Reduce demand on surface water withdrawals from the NSR mainstem and its tributaries.
- Improve drought resilience for industry and municipalities.
- Support innovation in water technology and infrastructure.
- Align with Water for Life goals on water use efficiency and healthy aquatic ecosystems.
- Advance conservation outcomes by ensuring saved water supports environmental flows.

Key Actions:

1. **Identify policy and regulatory barriers and opportunities for water reuse in the NSRB, and provide recommendations for needed adjustments:**

   A review of Alberta's regulatory environment, including existing policies, licensing rules, wastewater standards, and reuse definitions, can clarify what changes are needed to support and scale reuse projects. The identification of barriers and opportunities is a necessary precursor to developing efficiency and reuse plans.

2. **Develop and implement efficiency and reuse plans that support river flows:**

   Strategic planning is needed to ensure that water reuse and conservation initiatives result in maintaining adequate flows and ecosystem health in the river and other waterbodies. Where needed, water reuse and conservation can help drive reductions in water withdrawals.

3. **Consult with industry to explore technological alternatives that reduce water use and increase efficiency:**

   Engaging with industrial water users will help identify practical reuse options, technology readiness, and cost-sharing models for implementation.

3.1.4 Improve Access to and Use of Alternative Water Sources for Consumptive Operations, Including Improved Data Availability

Description:

Reducing reliance on freshwater from the NSR mainstem and its tributaries is critical to ensuring long-term water availability and ecosystem health. Similar to the adaptation described in Section 3.1.3, this adaptation aims to increase the use of alternative water sources, such as municipal wastewater, saline groundwater, recycled process water, and stormwater, for industrial and other consumptive operations.

To support this shift, stakeholders must address the full range of factors that influence water sourcing decisions: availability of data, regulatory flexibility, financial feasibility, impact on net diversion, and public acceptance. By better understanding and addressing these drivers, and by showcasing successful examples, the basin can accelerate the adoption of alternative water sources, where appropriate.

This approach can help diversify the region's water supply portfolio, easing pressure on the river while maintaining economic productivity.

Rationale:

Many industrial and commercial operations do not require high-quality freshwater for all processes, yet freshwater remains the default source due to convenience, cost, or lack of alternatives. Encouraging the use of non-freshwater sources for non-potable applications can result in significant water savings.

However, uptake of alternative sources is limited by a lack of awareness, uncertainty in regulations, insufficient data on availability and quality, and potential public or stakeholder concerns. By identifying and removing these barriers, and promoting real-world examples, this adaptation supports a more sustainable and adaptive water management approach.

Improving access to and use of alternative water sources would:

- Reduce stress on surface water systems, particularly during low-flow or drought periods.
- Enhance industrial and municipal resilience through diversified water supplies.
- Promote innovation and water recycling technologies.
- Align with the goals in the Water for Life and regional water conservation strategies.
- Support long-term water security and ecological protection in the basin.

Key Actions:

1. **Explore and showcase existing operations that have reduced or eliminated their use of freshwater:**

   Case studies from operators, such as those in the Industrial Heartland, demonstrate feasibility and benefits, and can help to build confidence and interest among other operators and decision-makers in the basin. Additionally, engaging Wastewater Treatment Plants can support discussions on how to make wastewater more usable by industry.

2. **Identify policy, financial, regulatory, and social barriers to using alternative water sources:**

   Understanding the full range of constraints, such as permitting challenges, infrastructure costs, data gaps, or community perceptions, will inform strategies to understand challenges and scale up the use of alternate water sources across sectors.

3.1.5 Develop Aquifer Management Plans Informed by Alberta Energy Regulator (AER) and Government of Alberta (GoA) Objectives

Description:

Much of the analysis and mapping of Alberta's groundwater resources has been done by the Alberta Geological Survey, which has been a part of the AER over the last several decades. Groundwater is a vital but often under-monitored component of the NSRB's water supply, where some major groundwater formations in the NSR basin have even been mapped to extend well beyond the surface basin boundaries, such as the Beverly Channel from Edmonton to Cold Lake. Aquifer management plans help identify groundwater risks and opportunities, and provide a structured approach to understanding, protecting, and sustainably using groundwater resources. This may include strategies for recharge, water quality, and well protection. This adaptation supports the development of such plans, aligned with the mandates and guidance of the AER and the GoA.

Effective aquifer management requires reliable data on the quantity, quality, recharge capacity, and usage of groundwater sources, as well as how these variables interact with surface water and stormwater systems. Management plans would help define sustainable use thresholds by aquifer, and ensure groundwater is considered alongside surface water in regional planning and drought preparedness.

Rationale:

Groundwater plays an increasingly important role in supplying water to communities, industries, and ecosystems, particularly during dry periods when surface flows are low. Yet, in many parts of the NSRB, data on aquifer characteristics, quality, usage, and long-term trends remains incomplete or fragmented.

Without this information, there is a risk of over-extraction, degraded water quality, or missed opportunities to integrate groundwater into broader water management strategies. Developing aquifer-specific plans will help ensure that groundwater use is sustainable, coordinated with surface water management, and resilient in the face of climate variability and land use change.

Advancing aquifer management would:

- Improve understanding of groundwater availability, quality, and surface water interactions.
- Inform drought management and long-term water security.
- Support integrated watershed management goals.
- Provide clarity and guidance for users and regulators.
- Align with Alberta's broader objectives for sustainable groundwater use.

Key Actions:

1. **Complete an inventory of groundwater resources, including source, supply, recharge capacity, and interactions with surface and stormwater:**

   A comprehensive groundwater inventory of the NSRB will provide the foundational information needed to guide management decisions and support aquifer-specific planning.

2. **Assess gaps in groundwater data and increase reporting on groundwater use across all sectors:**

   Once an inventory is complete, expanding data collection and transparency will help identify risks, better quantify total water use, and improve understanding of groundwater availability over time.

3. **Set groundwater use objectives by aquifer:**

   These objectives will define sustainable use thresholds, inform licensing and allocation decisions, and ensure that aquifer health is protected over the long term.

3.1.6 Develop Natural Asset Programs and Tools to Support Ecosystem Services and Fill Key Information Gaps

Description:

Natural assets, such as wetlands, floodplains, riparian buffers, and beaver-modified landscapes, deliver critical ecosystem services that support watershed health, biodiversity, water quality, and climate resilience. This adaptation supports the development of programs, tools, and data frameworks to recognize, assess, and enhance the value of natural assets across the NSRB.

By improving the knowledge base on wetlands, natural infrastructure, and hydrologic functions, and by exploring various tools and programs, the basin can better manage land and water in ways that are both sustainable and cost-effective. For example, Payment for Ecosystem Services (PES) are incentives offered to communities, landowners, or agricultural producers to preserve or enhance ecosystem services.

Rationale:

Natural assets often provide water storage, filtration, erosion control, and flow regulation, benefits that reduce infrastructure costs and support climate adaptation and resiliency. However, these assets are frequently undervalued in decision-making, and information gaps persist around their extent, condition, and function.

As shown in the economics analysis in Section 2.7.2, the potential value from various nature-based solutions ranges from about $3,500/acre (for grasslands) to about $25,000/acre (for wetlands).

Building capacity to manage natural assets would:

- Support implementation of the NSWA's NSR Wetland Strategy and IWMP, a recommended approach to manage the NSRB to sustain water resources and meet the *Water for Life* strategic goals.
- Enable municipalities and landowners to integrate nature-based solutions into planning and operations.
- Advance watershed restoration priorities in a coordinated, cost-effective way.
- Improve co-existence with keystone species like beavers that contribute to ecosystem resilience.

Key Actions:

1. **Review existing data on wetlands, natural infrastructure, and groundwater recharge, and initiate studies to fill information gaps:**

   Prioritize improved data on wetland classification, function, and hydrologic contributions.

2. **Explore and potentially develop PES programs:**

   Incentivize stewardship of wetlands, riparian areas, and recharge zones through financial or programmatic support.

3. **Assess hydrologic factors such as floodplain connection, stream restoration, and wetland hydrology to guide future restoration:**

    Use these assessments to identify priority areas for investment in natural infrastructure.

4. **Improve beaver co-existence by assessing and addressing barriers and conducting demonstration projects in both the mainstem and tributaries:**

    Show practical examples of flow devices, infrastructure protection, and the hydrologic benefits of beaver-modified systems, which may include increased water storage, new habitat, and reduced erosion.

3.1.7 Implement the NSR Wetland Strategy

Description:

The NSR Wetland Strategy, developed by the NSWA, outlines a framework for protecting, restoring, and enhancing wetlands as part of a healthy and functioning watershed. This adaptation focuses on advancing the implementation phase of the strategy by identifying and acting on priority areas for restoration, enhancement, or conservation.

Wetlands provide critical services for flood mitigation, drought resilience, water quality improvement, and biodiversity. By aligning wetland strategy implementation with land-use planning and conservation investments, this initiative strengthens ecological infrastructure across the basin.

Rationale:

Wetlands have been significantly reduced in many parts of the NSRB due to agriculture, urban development, and drainage. Implementing the NSR Wetland Strategy supports regional and provincial commitments under Alberta's Wetland Policy, advances the goals of the IWMP, and improves watershed resilience to a changing climate.

As shown in the economics analysis in Section 2.7.2, the potential value associated with wetlands is about $25,000/acre.

Benefits of this implementation could include:

- Protection of remaining high-value wetlands and their ecosystem services.
- Strategic restoration in areas where wetland functions have been lost.
- Targeted investments in wetland construction or enhancement to improve water quality, flood storage, and wildlife habitat.
- Long-term cost savings through nature-based infrastructure solutions.

Key Actions:

1. **Identify priority catchments for wetland ecosystem restoration or construction opportunities:**

Use watershed and land-use data to guide targeted action in degraded or flood-prone areas.

2. **Review data to identify 'Highest Value' wetlands, establishing clear criteria and potential protective measures:**

   Develop a framework to define, identify, and protect ecologically significant wetlands through planning and policy tools.

3. **Conduct education and outreach on the NSR Wetland Strategy:**

   Education and outreach on the Wetland Strategy would create support and collaboration for wetland restoration and construction in the basin.

3.1.8 Improve Water Quality in Non-Mainstem Drinking Water Sources, Including Lakes and Tributaries

Description:

While much attention is paid to the NSR mainstem, many rural communities rely on tributaries, lakes, groundwater, and other non-mainstem sources for drinking water. These sources are often more vulnerable to contamination due to lower flows, smaller catchment areas, and fewer treatment options.

This adaptation focuses on protecting and improving water quality in these critical but sometimes overlooked sources. It emphasizes enhanced monitoring and assessment, and implementing targeted infrastructure upgrades, particularly in communities with ageing or insufficient wastewater systems. A strong foundation of data and local prioritization will support cost-effective and equitable solutions to ensure safe, reliable drinking water for all.

Rationale:

Tributaries and lakes serve as essential water sources for some communities in the NSRB, particularly outside of major urban centers. These systems are often more sensitive to nutrient loading, bacteria, and other pollutants that can stem from lower flows, outdated wastewater infrastructure, stormwater runoff, or land use impacts.

Current monitoring in many of these areas is limited or inconsistent, making it difficult to assess trends, identify risks, or target mitigation. Addressing these gaps and upgrading infrastructure where needed will not only improve drinking water quality but also support ecosystem health and long-term community resilience.

Improving water quality in non-mainstem sources could:

- Support the health and safety of rural and smaller communities.
- Protect vulnerable aquatic ecosystems.
- Enhance long-term source water security in the face of climate variability.
- Align with regional water quality objectives and Alberta's *Water for Life* goals.

- Reduce future treatment costs and public health risks.

Key Actions:

1. **Identify water quality and quantity data gaps, especially in under-monitored areas such as the eastern portion of the watershed:**

    Filling these data gaps will allow for better tracking of conditions, identification of risks, and informed decision-making.

2. **Improve monitoring, assessment, and reporting for non-mainstem drinking water sources:**

    Once data gaps are identified, establishing enhanced and consistent monitoring across priority water bodies will help establish baselines, detect issues early, and support community planning.

3. **Identify monitoring criteria and determine priority areas for assessing impacts from wastewater lagoons:**

    Criteria may include proximity to drinking water intakes, known nutrient issues, or lagoon system age and condition.

4. **Pursue enhanced wastewater treatment solutions for prioritized smaller communities that discharge into tributaries, considering economic viability and local need:**

    Identify existing water and wastewater treatment infrastructure on non-mainstem water sources and consider priority areas for new infrastructure. Tailored, cost-effective upgrades (e.g., lagoon retrofits, decentralized treatment) can yield high environmental and public health returns while acknowledging the financial capacity of small communities.

3.1.9 Improve Water Security for Indigenous Communities, Ensuring Adequate and Safe Water is Available for Drinking, Household, Community Needs, and Emergency Services

Description:

The NSRB is located within Treaty 6 and a portion of Treaty 8 territory, where water security is foundational to community health, resilience, and cultural continuity. This adaptation seeks to strengthen water security for Indigenous communities in the NSRB by supporting access to safe, sufficient water for all essential uses, including drinking water, household needs, cultural practices, and emergency services.

Improving water security requires a collaborative approach that respects Indigenous leadership, knowledge, and priorities. Supporting Indigenous-led monitoring, reporting, education, and training builds long-term capacity and empowers communities to manage water in ways that align with their own values, governance systems, and lived experience.

Rationale:

Many Indigenous communities continue to face water insecurity, including boil water advisories, infrastructure gaps, or insufficient access to emergency water supplies for firefighting. Addressing these challenges is not only a matter of public health but of reconciliation, equity, and respect for Indigenous rights and responsibilities as stewards of the land and water.

Supporting Indigenous-led approaches ensures that water monitoring, assessment, and education are responsive to community-identified concerns and grounded in Traditional Knowledge. Collaborative, capacity-building efforts also foster shared understanding and advance more inclusive and effective watershed management.

Improving water security for Indigenous communities would:

- Address longstanding disparities in access to clean and reliable water.
- Support self-determination in water governance and monitoring.
- Incorporate Indigenous knowledge into broader watershed planning.
- Strengthen community resilience to emergencies and climate change.
- Fulfill principles of partnership and reconciliation embedded in Alberta's *Water for Life* strategy and national commitments.

Key Actions:

1. **Collaborate with First Nations and Métis communities to develop or enhance Indigenous-led monitoring and reporting of water and ecosystems, in accordance with community needs:**

    Collaboration may include open discussions and site visits to identify areas of community concern and data gaps. This action may also include training, equipment support, data-sharing protocols, and ensuring Indigenous knowledge is meaningfully incorporated into monitoring frameworks. Further engagement with First Nations and Métis communities is crucial to ensure this action is aligned with community needs.

2. **Assist with education and training on water health and water use, in collaboration with First Nations leaders and Elders:**

    Programs may focus on youth engagement, household water use, climate impacts, or source water protection that are guided by community priorities and traditional teachings. Education and training are central, as equipment and process-related problems are the cause of the majority of boil water advisories (Environment and Climate Change Canada, 2025). *Further engagement with First Nations and Métis communities is crucial to ensure this action is aligned with community needs.*

3.1.10 Create an Indigenous-Guided Future Roadmap for Water in the North Saskatchewan River Basin

Description:

This adaptation supports the development of a forward-looking, Indigenous-guided Roadmap for water in the NSRB. The Roadmap would articulate shared priorities, responsibilities, and visions for water protection, governance, and use that is centered on Indigenous rights, knowledge systems, and leadership.

Creating such a Roadmap requires respectful, sustained engagement with First Nations and Métis communities to co-develop a process that reflects their values, histories, and relationships with water. It also includes identifying opportunities to incorporate Indigenous considerations into existing water models, such as the Tool.

Rationale:

Indigenous Peoples in the NSRB have stewarded the land and water since time immemorial. Their Traditional Knowledge, spiritual relationships with water, and lived experience offer essential insights for sustainable water management, particularly in the face of climate change, increasing land use pressures, and water scarcity.

Yet, many existing water governance frameworks and regulations have not meaningfully included Indigenous perspectives or decision-making. An Indigenous-guided Roadmap would help reframe water planning to reflect Indigenous laws, protocols, and aspirations, while fostering collaboration with non-Indigenous governments and institutions.

Creating this roadmap would:

- Honour Indigenous rights and responsibilities related to water.
- Support self-determination and autonomy in water governance, considering Indigenous priorities, responsibilities, and vision.
- Build long-term, trust-based relationships between Indigenous and non-Indigenous partners.
- Enhance the cultural, ecological, and technical foundations of water planning in the basin.
- Align with reconciliation commitments and policy frameworks such as Alberta's *Water for Life* strategy and the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP).

Key Actions:

1. **Pursue opportunities to engage with First Nations and Métis communities and explore the potential for an Indigenous-guided Roadmap in the NSRB:**

   Engagement would be based on respectful dialogue, listening, and co-creation of process. Early discussions would clarify community interest, participants, desired outcomes, and culturally appropriate approaches to collaboration.

2. **Explore with First Nations and Métis communities the potential to update the Tool with Indigenous considerations:**

    This may include identifying areas where Traditional Knowledge can inform Tool assumptions, inputs, or interpretation through PMs - ensuring the Tool better reflects the holistic and place-based understanding of water systems held by Indigenous communities.

3.1.11 Enhance Connection with Alberta's Land-Use Framework and Other Existing Regulatory Frameworks

Description:

Effective water management in the NSRB requires strong alignment between watershed planning and Alberta's land-use and regulatory systems. This adaptation supports better integration of the NSWA's IWMP with Alberta's Land-use Framework, regional and sub-regional plans, municipal development strategies, and related regulatory tools.

The IWMP, developed by the NSWA in collaboration with stakeholders, provides a science-based, consensus-driven roadmap for protecting water quality and quantity, aquatic ecosystem health, and sustainable land and water use. Embedding the IWMP more deeply into existing land-use and regulatory frameworks will improve consistency, coordination, and effectiveness of water management actions across the basin.

Rationale:

Land use is one of the most significant drivers of watershed health, impacting the basin through water use and runoff water quality. While the Alberta Land-Use Framework highlights watershed protection as a key strategy, decisions around urban growth, industrial development, agriculture, and infrastructure are often made with limited integration of watershed-scale planning or hydrologic science.

Stronger connections between land-use and water management planning will support cumulative effects management, ensure long-term water security, and prevent unintended degradation of water resources. The IWMP provides a critical foundation for this work, aligning well with provincial strategies like *Water for Life* and offering practical recommendations that can inform regional plans under the Land-Use Framework. Specifically, Goal 5 of the IWMP identifies that watershed management should be incorporated into land-use planning processes at all scales.

Enhancing integration with existing plans and frameworks would:

- Operationalize key actions in the NSWA IWMP across land-use and regulatory decisions.
- Ensure that regional planning incorporates water quality, surface water, and groundwater objectives.
- Support cross-jurisdictional coordination and reduce duplication.
- Advance cumulative effects management and improve source water protection.

- Promote more resilient and sustainable watershed outcomes.

Key Actions:

1. **Connect the regulatory tools and approaches of the Land-Use Framework, alongside regional, sub-regional, provincial, and municipal plans and align with the NSWA IWMP to develop a regional plan to enhance basin water management:**

    Identify opportunities to align water-related goals and implementation mechanisms across planning systems to support coordinated, basin-wide outcomes.

2. **Support ongoing implementation of the NSR Surface Water Quality Management Framework and regional Cumulative Effects management efforts:**

    Ensure these frameworks inform land-use and water allocation decisions and are integrated with broader watershed management activities.

3. **Incorporate groundwater use guidelines into land-use planning:**

    Ensure that groundwater considerations, such as aquifer recharge, quality, connectivity to surface water, and sustainable withdrawal, are reflected in zoning, permitting, and development planning.

3.1.12 Explore Establishing a Collaborative Relationship with Hydro Facilities, in Support of Shared Understanding

Description:

Hydroelectric facilities in the NSRB play a significant role in shaping river flow patterns and seasonal water availability. This adaptation seeks to explore the potential for a water management operating agreement with hydro operators, most notably TransAlta, which manages the Brazeau and Bighorn dams in the headwaters, to align operations with broader watershed goals related to water supply, ecosystem health, and community needs.

Such an agreement would build on existing water management practices by encouraging coordinated operations that support both hydropower production and basin-wide water security, particularly considering growing climate variability and demand pressures. It would also strengthen transparency and collaboration between the hydropower industry, the GoA, municipalities, and all other relevant stakeholders, ensuring operational decisions consider multiple values and risks.

Rationale and Modelling Considerations:

As climate variability alters flow regimes and intensifies drought conditions, understanding and managing the relationship between hydroelectric operations and river flows is increasingly critical. Reservoir management and flow regulation by hydropower operators have the ability to both positively and negatively affect water availability, ecosystem resilience, flood and drought preparedness and mitigation, and other water uses. Municipalities, industry and aquatic biota have come to rely upon the current hydrologic regime that is maintained by reservoir management.

A cooperative water management operating agreement could:

- Improve transparency and shared understanding of operational constraints and opportunities.
- Support more predictable and optimized water flows to meet ecological, municipal, agricultural, and industrial needs.
- Align hydropower operations with Alberta's *Water for Life* goals and the NSWA IWMP.
- Strengthen adaptive capacity in the face of climate change.

This adaptation is not meant to override the mandates of hydroelectric facilities but is about working collaboratively to find operational alignments that benefit the whole basin.

Key Actions:

1. **Collaborate with TransAlta, the GoA, and municipalities to understand their operations and support overall basin water security:**

   Build shared knowledge of flow management practices, licensing conditions, and reservoir operations to identify synergies and trade-offs in water use and timing.

2. **Collaborate with TransAlta to understand electrical demand patterns and the impacts of climate change on hydropower generation:**

   Explore opportunities to adapt operations where possible to enhance flow stability and support downstream needs, while maintaining energy reliability.

3.2 Complementary Actions Supporting Water Management

In addition to the strategic Roadmap adaptations outlined in Section 3.1, several important actions are already underway across the NSRB that contribute significantly to sustainable water management. These complementary actions have not been included as core Roadmap adaptations because they are progressing through existing policies, infrastructure projects, and collaborative initiatives. However, they remain essential components of a functioning, resilient, and sustainable water management system.

Many of these efforts are particularly evident within the Edmonton Metropolitan Region and serve as models that can inform and support basin-wide progress:

1. **Refine and ensure usage of the Tool:**

The Tool built as part of the Roadmap project should continue to be a tool used by water users and partners across the NSRB. The Tool will require periodic updates and improvements to meet the needs of users and to reflect new conditions in the basin.

Particularly, the minimum flow management goals identified and implemented in the Tool were set based on statistical thresholds in the absence of available minimum flow studies in the basin. This was used as a proxy to estimate low flows and therefore potential impacts to ecosystem health. As identified in Section 3.1.1, further work is required to refine flow requirements for ecosystem health in the basin. The WG identified a need to establish Instream Flow Needs and Water Conservation Objectives as part of an approved Water Management Plan. Such assessments could be reflected in the Tool to better understand the impacts of adaptations.

2. **Continue to build flood-resilient infrastructure to reduce potential flood impacts:**

The need for flood-resilient infrastructure is a recognized and ongoing need that is being addressed by municipalities, utilities, and industry as part of standard infrastructure planning and asset management.

In the Edmonton region, for example, municipalities have incorporated flood risk assessments into their capital planning cycles, leading to the construction of protective berms around essential facilities and floodplain setback policies for new developments. These efforts, often embedded in regular operations, reflect a growing emphasis on climate risk reduction and service continuity.

3. **Implement effective stormwater retention plans and erosion control measures, incorporating wetlands and green infrastructure to maintain water quality:**

These practices are increasingly embedded in municipal and industrial planning frameworks as a standard approach to managing runoff and protecting aquatic health.

The City of Edmonton has prioritized Low-Impact Development (LID) and constructed stormwater wetlands to manage peak flows and improve water quality. Other LID examples in Edmonton include the addition of bioretention gardens and basins, soil cells, and absorbent landscaping. LIDs provide benefits to flood and runoff reduction, increases vegetation, and filters pollutants.

Surrounding municipalities are using erosion control measures and vegetated buffers to protect tributaries and riparian zones as part of land development and agricultural drainage improvements.

4. **Support flood and drought mitigation planning with municipalities, First Nations, Métis communities, agriculture, the GoA, and industry:**

Ongoing work through regional partnerships, such as the EMRB, NSWA, and EPA, supports coordinated drought and flood preparedness planning. This includes scenario planning, public education, and resource-sharing across jurisdictions and sectors.

These initiatives, while not new, are critical enablers of long-term watershed health and resilience. Their continued advancement complements and reinforces the Roadmap's strategic adaptations, ensuring that emerging priorities are built on a strong foundation of coordinated, proactive water management.

3.3 Future Considerations

In addition to the strategic Roadmap adaptations outlined in Section 3.1 and the complementary actions outlined in Section 3.2, several other adaptations were considered for potential future implementation, but ultimately not included as core objectives in the current Roadmap. These items may be actioned in the future and therefore have been retained as important outcomes from WG discussions.

1. **Re-operationalize Sundance Pond storage:**

Consideration was given to exploring the feasibility of re-operationalizing water storage options within the NSRB to increase water availability and security and conducting a cost-benefit analysis of doing so. A key location considered was the Sundance Pond, located adjacent to Wabamun Lake.

Using the Tool, an off-stream storage of 42,000 dam^3 was modelled at the Sundance location (CurrentConditions_Historical_Sundance). In this adaptation, water from the NSR mainstem upstream of Edmonton is pumped to the reservoir up to a rate of 7 m^3/s when the river flow in Edmonton is above 150 m^3/s. Water is released from the reservoir to the mainstem when the river flow in Edmonton is below 10% of the seasonal flow (Q10).

The Sundance storage adaptation shows limited hydrological effects compared to the reference case scenario (CurrentConditions_Historical_EstUse). Of note, the Sundance storage is able to reduce the Assimilative Capacity PM by over 20% and is able to approximately mitigate the Assimilative Capacity degradation of the Growth scenario (CurrentConditions_Historical_SundanceGrowth). However, as summarized in Table 3-2, there is no impact to Potential System Storage as the storage services the mainstem, where low flows are of limited concern.

The impacts of the Sundance storage are most evident during a dry year, where late-season flows are supplemented to maintain flows above the Q10. Figure 3-3 provides an example of the NSR near Pakan in 2009, where the reference case flows drop below 110 m^3/s in early September, and the Sundance storage is able to supplement flows up to approximately 130 m^3/s by releasing stored water. This continues until mid-October when the additional storage is depleted.

Due to the limited hydrological effects discussed above, the WG removed this adaptation from the Roadmap at this time. However, the WG identified that further work, including hydrological modelling and a cost-benefit analysis, is necessary before concluding that storage is not required in the basin.

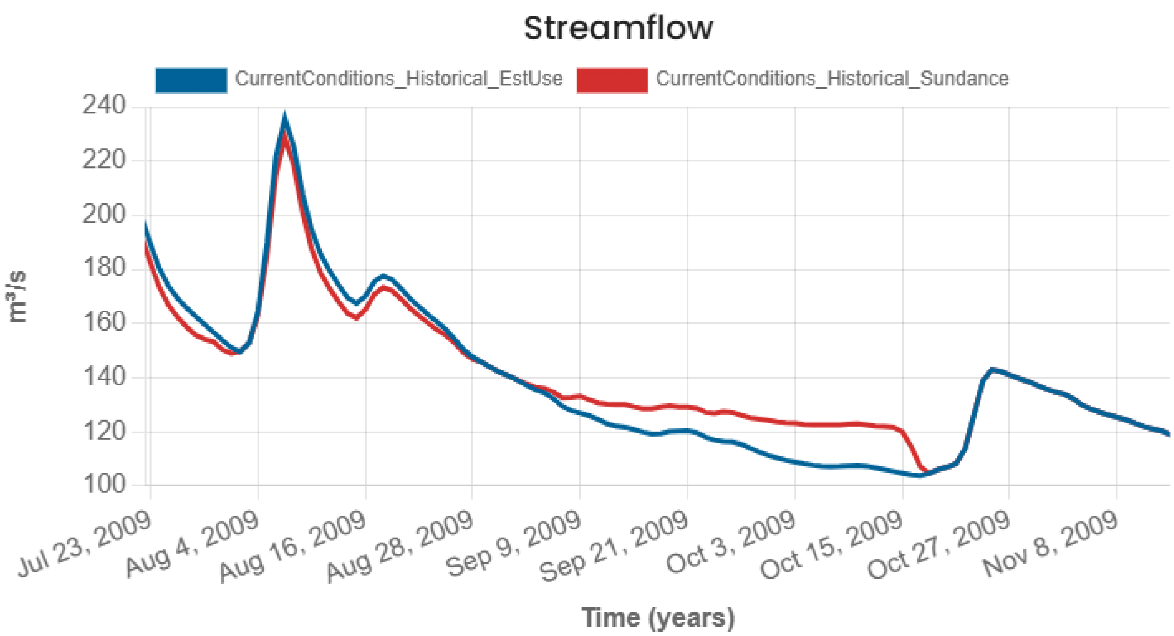

Figure 3-2: Daily stream flow of reference case and Sundance storage scenarios (NSR near Pakan) (From Decision-Support Tool).

Table 3-1: Performance Measures for the reference case and Sundance storage scenarios (1991 - 2020) (From Decision-Support Tool).

Scenario	Apportionment (%)	Assimilative Capacity (Days)	Edmonton Peak Flows (Days)	Headwater Fish Habitat (Days)	High Summer Water Temperature (%)	Loading Potential (Days)	Potential System Shortage (dam^3)	St. Albert Peak Flows (Days)	Tributary Low Flows (%)	Vermillion Low Flows (%)
CurrentConditions_Historical_EstUse	98.38	37.54	0.00	92.93	89.06	21.79	54.31	1.71	8.43	20.57
CurrentConditions_Historical_SundanceGrowth	97.23	37.04	0.00	92.93	89.63	20.32	77.81	1.71	8.43	20.57
CurrentConditions_Historical_Sundance	98.38	29.71	0.00	92.93	89.17	21.11	54.31	1.71	8.43	20.57

2. **Initiate intra-basin water transfers from the mainstem to the Vermilion River:**

While the Tool indicates that the mainstem of the NSR will contain enough water for growth and climate adaptation, tributaries such as the Vermilion River are anticipated to experience water shortages. For example, the Tool estimates a mean annual flow of 2.26 m^3/s and peak annual flow of 19.71 m^3/s near Vermilion Park Lake, considering 1991 – 2020 data. The WG therefore considered the possibility of augmenting water levels in the Vermilion River by using an intra-basin water transfer from the mainstem NSR to the Vermilion River.

While an economic analysis was not completed for this adaptation, it is anticipated that conveying water from the mainstem to the Vermilion River would be expensive, likely requiring extensive pipelines and energy to convey the water. In addition, intra-basin water transfers can have significant ecological impacts due to the transfer of invasive species, native species, water chemistry, and pathogens, significantly reducing the potential benefits as a water shortage response. The WG indicated that the Roadmap should instead focus on managing the Vermilion River, and other tributaries, through natural infrastructure.

3. **Construct off-stream storage upstream of the City of Edmonton:**

The WG considered the potential benefits to basin hydrology of constructing off-stream storage upstream of the City of Edmonton, such as one of the sites mentioned in the *Provincial Inventory of Potential Water Storage Sites and Diversion Scenarios*, published in September 2005 as a component of the *Water for Life* strategy (MPE, 2008). Examples of storage sites completed in the study are outlined in Table 3-3.

Table 3-2: Water storage options upstream of Edmonton, as identified in MPE's 2008 Assessment of Potential Water Storage Sites and Diversion Scenarios.

Project Name	Location	Purpose	Reservoir Volume (dam^3)
Baptiste River – Sunchild Storage Area	Baptiste	Water Security	123,400
Brazeau – O'Chiese Damsite	Brazeau	Water Security	51,800

Like other WG discussions relating to additional built storage, there appears no pressing need to augment storage in the NSRB. The WG stated a strong preference for the sustainable use of existing resources rather than resorting to construction of additional infrastructure. Additionally, results from the hydrological model show relatively little benefit to off stream storage in time of low flow.

4. **Design a hydrologic model in collaboration with Indigenous communities:**

The current Roadmap is constructed within the framework of Western science and culture, and is not well informed by the knowledge, traditions, and expertise of the Indigenous people whose traditional territories and gathering places coincide with the NSRB. To create a hydrologic model which would incorporate and reflect this knowledge and culture, consideration was given to conducting a literature review of Indigenous hydrological knowledge, co-designing a process to include Indigenous data layers within the existing hydrologic model, and retaining an Indigenous hydrologist or modeler to support model adjustments.

While the WG had some limited involvement from a few Indigenous people, it was felt overall that identifying specific adaptations and actions in the absence of meaningful engagement with First Nations and Métis peoples was not an appropriate way to respect and involve Indigenous people. The ideas from the WG could be used in future work with First Nations and Métis people, ideally in projects that are led, shaped, and informed by Indigenous and Métis people.

4. Implementation and Support for a North Saskatchewan River Basin Water Management Roadmap

Successful implementation of the Roadmap is crucial to maintaining water security in the NSRB. To provide a reference point for project proponents, the timing, benefits, and costs have been identified for each adaptation. The WG used the following assumptions to characterize these items:

- Timing to implementation:
    - Short-term: One to three years.
    - Medium-term: Four to six years.
    - Long-term: Over six years.
- Identified benefits included increased economic growth, environmental outcomes, and sustainable water management as compared to current conditions. Benefits were identified throughout WG discussions.
- While a detailed cost analysis was not completed for the Roadmap, assumptions were made about costs (in 2025 dollars) based on professional judgement and adaptations were broken down into the following high-level categories:
    - Low: Under $1M to implement.
    - Medium-low: Between $1M - $5M to implement.
    - Medium-high: Between $5M - $10M to implement.
    - High: Over $10M to implement.

4.1 Knowledge and Mobilization

The primary purpose of the Roadmap is to provide strategies which ensure water management in the basin is done in a strategic, proactive and sustainable way, enabling continued growth and development. The responsible use of our water resources is critical to ensure we have enough high-quality water in the future to support anthropocentric and environmental needs.

A key next step identified in the final WG is to establish a communications group for the purposes of:

- Developing a marketing and awareness plan to engage key decision makers and advocate for the Roadmap.
- Distilling Roadmap information into 1-pagers and presentations, optimizing utility across various audiences.
- Creating a dashboard to delegate adaptation tasks and monitor implementation.

The Roadmap is a starting point. This section summarizes the benefits, costs, and timing for each adaptation to be progressed further. The vision is that this can be used as a guide for proponents to promote each adaptation.

1. Establish an Approved NSRB Water Management Plan to guide sustainable water management:
    - Timing: The implementation of this adaptation is anticipated to take place over a period of four to six years.
    - Benefits: Benefits include greater water management clarity and transparency for users, balanced ecological and human needs, increased drought preparedness, and support for economic growth.
    - Costs: It is anticipated that the cost to implement is between $1M - $5M.
2. Establish basin-scale CEP targets for municipalities, industry, and the agricultural sector to incentivize sustainable water use:
    - Timing: The implementation of this adaptation is anticipated to take place over a period of one to three years.
    - Benefits: Benefits include increased innovation for economic growth, and greater water security and climate resilience for environmental health.
    - Costs: It is anticipated that the cost to establish CEP targets is below $1M, however implementation of initiatives for sectors to achieve these targets will be greater.
3. Support the development and implementation of water reuse projects in collaboration with industry and municipalities:
    - Timing: The implementation of this adaptation is anticipated to take place over a period of one to three years.
    - Benefits: Benefits include reduced surface water withdrawals for a healthier environment and improved drought resiliency and increased innovation in water technology and infrastructure for economic growth.
    - Costs: It is anticipated that the cost to implement is between $1M and $5M.
4. Improve access to and use of alternative water sources for consumptive operations, including improved data availability:

- Timing: The implementation of this adaptation is anticipated to take place over a period of one to three years.
- Benefits: Benefits include enhanced industrial and municipal resiliency, innovative water recycling technology applications, and long-term water security.
- Costs: It is anticipated that the cost to implement is between $1M and $5M.

5. Develop aquifer management plans informed by AER and GoA objectives:
    - Timing: The implementation of this adaptation is anticipated to take place over a period of more than six years.
    - Benefits: Benefits include improved understanding of groundwater, better informed drought management practices, and enhanced transparency and guidance for users.
    - Costs: It is anticipated that the cost to implement is over $10M.
6. Develop natural asset programs and tools to support ecosystem services and fill key information gaps:
    - Timing: The implementation of this adaptation is anticipated to take place over a period of more than six years.
    - Benefits: Benefits include advancing watershed restoration, improved co-existence with other species, and enhanced integration of nature-based solutions for cost-effective water management.
    - Costs: It is anticipated that the cost to implement is between $5M and $10M.
7. Implement the NSR Wetland Strategy:
    - Timing: The implementation of this adaptation is anticipated to take place over a period of four to six years.
    - Benefits: Benefits include protecting high-value wetlands, restoring and investing in existing wetlands, and improved natural assets.
    - Costs: It is anticipated that the cost to implement is between $1M and $5M.

As an initial step to implement the NSR Wetland Strategy, the NSWA is completing a Wetland Restoration Opportunities Mapping Project to characterize hydrologic conditions which can be used to prioritize areas for wetland restoration and conservation. This project leverages the Tool to characterize the hydrologic function of the basin and to perform a flood frequency analysis, including utilization of the same climate scenarios as the Roadmap Project. Initial findings suggest wetlands in the tributaries are most impacted due to dry conditions and are of higher priority for restoration and conservation. This work is expected to be completed in 2025.

8. Improve water quality in non-mainstem drinking water sources, including lakes and tributaries:
    - Timing: The implementation of this adaptation is anticipated to take place over a period of four to six years.
    - Benefits: Benefits include improved health and safety of rural and small communities, long-term water security, and reduced water treatment costs.
    - Costs: It is anticipated that the cost to implement is between $5M and $10M.
9. Improve water security for Indigenous communities, ensuring adequate and safe water is available for drinking, household, community needs, and emergency services:
    - Timing: The implementation of this adaptation is anticipated to take place over a period of four to six years.
    - Benefits: Benefits include reducing disparities in access to clean and reliable water, improved community resilience, supporting self-sufficiency in water governance, and incorporating and learning from the breadth of Indigenous knowledge into watershed planning.
    - Costs: It is anticipated that the cost to implement is between $5M and $10M.
10. Create an Indigenous-guided future Roadmap for water in the NSRB:
    - Timing: The implementation of this adaptation is anticipated to take place over a period of one to three years.
    - Benefits: Benefits include building long-term and trust-based relationships between Indigenous and non-Indigenous partners, furthering reconciliation commitments, and supporting autonomy in water governance.
    - Costs: It is anticipated that the cost to implement is between $1M and $5M.
11. Enhance connection with Alberta's Land-Use Framework and other existing regulatory frameworks:
    - Timing: The implementation of this adaptation is anticipated to take place over a period of four to six years.
    - Benefits: Benefits include improved regional planning, enhanced cross-jurisdictional cooperation, and increased basin resilience and sustainability.
    - Costs: It is anticipated that the cost to implement is below $1M.
12. Explore establishing a collaborative relationship with hydro facilities:
    - Timing: The implementation of this adaptation is anticipated to take place over a period of four to six years.

- Benefits: Benefits include increased adaptive capacity towards climate change, improved ability to meet water needs, and greater transparency in hydro operations.
- Costs: It is anticipated that the cost to implement is between $5M and $10M.

5. Closing Remarks

The results of this Project highlight the need for collaborative and adaptive water management across the NSRB, as climate change and future growth and development increase pressure on water availability within the system. The adaptations identified on the NSRB Roadmap demonstrate how water security and economic growth can be facilitated together through collaborative action. The strategies and adaptations put forward on the Roadmap demonstrate how basin-wide approaches can be leveraged to improve collaborative and sustainable water management in the NSRB.

The Project aimed at creating a Roadmap to enable water users and managers to:

- Establish a shared understanding of water availability, basin operations, needs, and concerns.
- Demonstrate how economic growth and development can be supported within the basin.
- Identify complementary and mutually beneficial water management opportunities.
- Have conversations and build connections on water security across different sectors.

The Roadmap was developed through the collaboration of knowledgeable and experienced water users and managers from across the NSRB. Through the collaborative process, many opportunities were identified to implement and improve sustainable water management practices, conserve and restore ecosystems, maintain and improve water quality, and advance inclusive water governance in the basin. It is important to note that the Roadmap adaptations have not been prioritized, as implementation of all identified strategies build upon each other and are crucial for watershed security.

To implement and improve sustainable water management practices, the WG identified the following Roadmap adaptations:

- **Establish an Approved NSRB Water Management Plan** to guide sustainable water management.
- **Establish basin-scale CEP targets** for municipalities, industry, and the agricultural sector to incentivize sustainable water use.
- **Support the development and implementation of water reuse projects** in collaboration with industry and municipalities.
- **Improve access to and use of alternative water sources** for consumptive operations, including improved data availability.
- **Develop aquifer management plans** informed by AER and GoA objectives.

To conserve and restore natural ecosystems, the WG identified the following adaptations:

- **Develop natural asset programs** and tools to support ecosystem services and fill key information gaps.
- **Implement the NSR Wetland Strategy** to support implementation of the Alberta Wetland Policy in the NSRB.

To improve and maintain water quality in the basin, the WG identified the following adaptations:

- **Improve water quality in non-mainstem drinking water sources**, including lakes and tributaries.
- **Improve water security for Indigenous communities**, ensuring adequate and safe water is available for drinking, households, community needs, and emergency services.

To advance inclusive and shared water governance in the basin, the WG identified the following adaptations:

- **Create an Indigenous-guided future Roadmap** for water in the NSRB.
- **Enhance connection with Alberta's Land-Use Framework** and other existing regulatory frameworks.
- **Explore establishing a collaborative relationship with hydropower facilities**.

In addition to the Roadmap, the WG identified complementary actions to support water management in the basin. These are the water management actions that are already underway in the basin and are critical components towards creating a resilient watershed. The WG also considered other possible water management strategies for future consideration, such as intra-basin transfers and off-stream storage opportunities. Further steps to integrate Indigenous Traditional Knowledge into the Tool were considered and the WG decided that further study and engagement is required on this item. For this reason, these strategies have been discussed as part of this Project; however, these items are not Roadmap adaptations.

A substantial amount of time and knowledge was given to this Project by the WG. The excitement and commitment to the collaborative process was remarkable, and the expertise and experience in the basin was vital to the creation of the Roadmap and the Tool. The Project Team is deeply grateful to the people and groups who helped create this Roadmap. The full list of funders and participants can be found in Appendix B.

This Roadmap offers a strong basis to collectively strengthen water resilience in the NSRB and serve as a model for collaborative watershed stewardship. Our hope is that the GoA, municipalities, Indigenous communities, industry, agricultural groups, and environmental stewardship groups consider the Roadmap and find opportunities to progress these water management strategies. We thank you for the opportunity to help guide this collaborative work and are grateful for the time and effort of the many participants in this process. We are inspired by your knowledge and dedication to the NSRB and are excited to see the Roadmap implemented for increased sustainability and resilience in the basin.

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Appendix A: Terms of Reference

Appendix B: Project Funders and Contributors

Appendix C: Modelling Report (MacHydro)

List of Units

Abbreviation	Definition
m	Meters
km^2	Squared kilometers
°C	Degrees Celsius
mm/day	Millimeters per day
ft	Feet
cfs	Cubic feet per second
m^3/s	Cubic meters per second
m^3/year	Cubic meters per year
%	Percent
dam^3	Cubic decameters

**Note: units are in order of appearance in Appendix C.*

Appendix D: EcoMetrics^{TM} Report

Appendix E: NSRB Water Management Roadmap (NSWA)