

# Study of Potential Water Impacts of Nuclear Power Development in Alberta

Hazen

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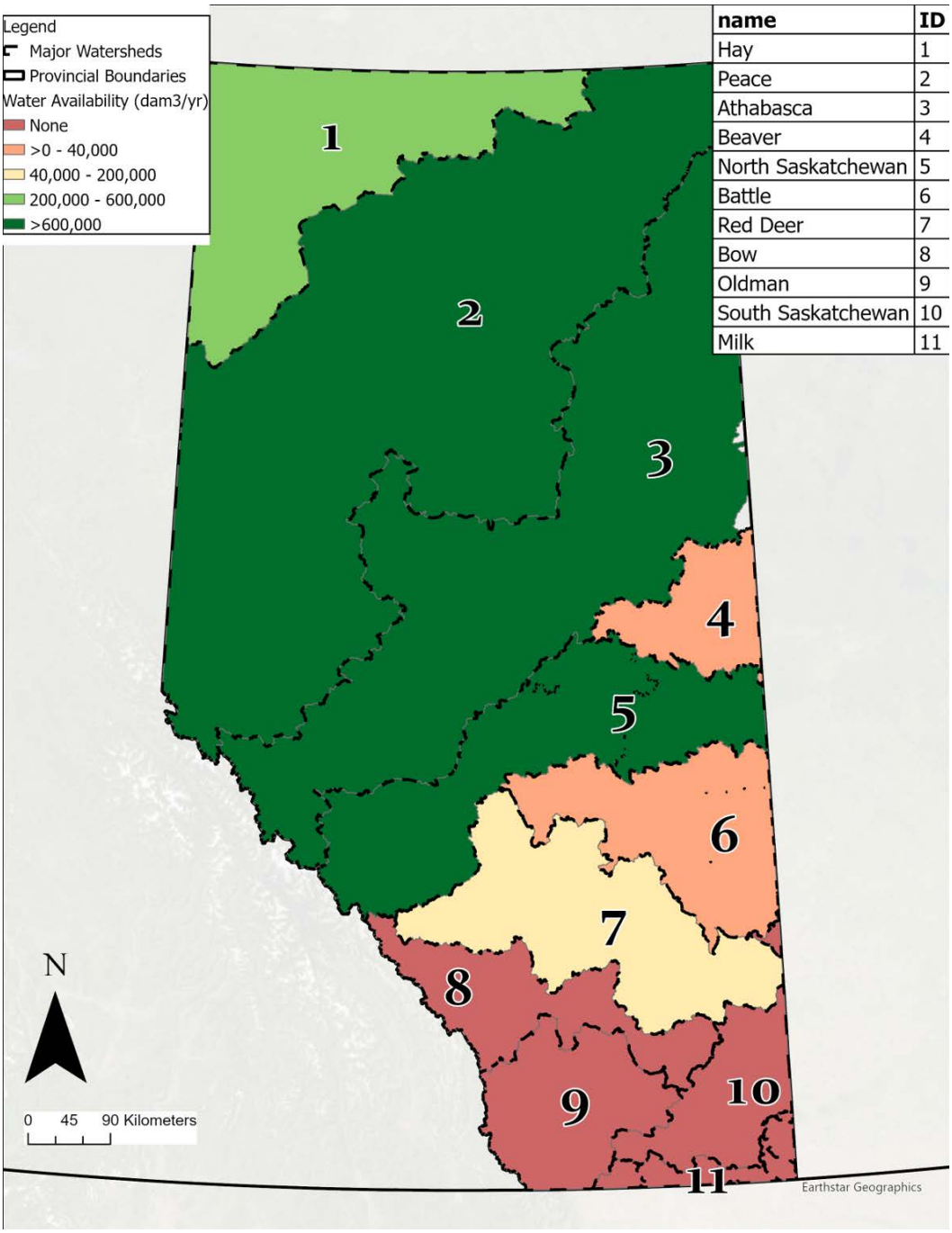
# Executive Summary

Amid a changing global energy landscape, governments, utility providers, and communities continue to consider how electricity systems can support emissions-reduction objectives while providing reliable and affordable energy over the long term. In Alberta, nuclear power generation is being explored as a potential source of both electricity and industrial steam. Provincial policy direction, public engagement, private-sector feasibility studies, and proposed projects indicate growing interest in both conventional nuclear reactors and small modular reactors (SMRs). As this interest advances, it is important to understand the potential implications of nuclear development for Alberta's water resources, as well as the constraints that regional and seasonal water availability may place on future projects.

In this report, Hazen Canada has assessed the potential cooling water requirements associated with nuclear power development in Alberta and compared those requirements to current and potential future water availability across the province. The report is intended to help policymakers, regulators, Indigenous communities, project proponents, investors, utilities, and other interested parties understand potential water-related risks, opportunities, and trade-offs associated with nuclear power development, before project siting and design decisions are finalized. It builds on Hazen Canada's previous assessments of the water implications of hydrogen development and carbon capture, utilization, and storage (CCUS) in Alberta and applies a consistent water-energy nexus perspective to nuclear power generation.

## Current and future water availability

The following figure illustrates current water availability across Alberta as of 2026 for a statistical median flow year. Major northern river systems, particularly the Peace and Athabasca rivers, generally have sufficient water available at the basin scale to accommodate the nuclear development scenarios evaluated in this study. The mainstem of the North Saskatchewan River also appears capable of supporting the assessed developments under current conditions. Conversely, water supply may constrain nuclear development in basins with lower streamflow, limited remaining allocation capacity, seasonal water availability constraints, or restrictions on new surface water licences. Nuclear development in these locations remains possible, though will require additional planning and investment to minimize the net water impacts of future facilities.




The study assessed potential growth in non-nuclear water demand alongside projected hydroclimatic changes at the 2050 and 2100 planning horizons. Incremental water demands were estimated using provincial population growth as a proxy for broader municipal and economic growth, indicating material incremental water demands in the future. On the supply side, climate projections suggest that increased precipitation may partially offset higher evaporation in some northern basins, while parts of southern Alberta may experience increasing moisture deficits. Together, these findings indicate that future water supply pressures will vary across the province and may become more pronounced in basins where current availability is already limited or where anticipated demand growth is of a similar magnitude to the water currently available for new allocations.

## Potential nuclear power water demands in Alberta

To assess the potential water demands of nuclear power in Alberta, Low, Medium, and High water use ranges were developed using the International Atomic Energy Agency's Water Management Program (WAMP) model, focusing on ongoing consumptive cooling water requirements. The ranges represent air-cooled systems, closed-loop cooling ponds, and evaporative cooling systems respectively. Reactor-specific thermal efficiencies, cooling system characteristics, and representative climatic conditions in Alberta were incorporated into the analysis. These ranges were applied to a province-wide Baseline Scenario and seven case studies to explore how reactor technology, cooling configuration, location, and operating conditions could influence future water demand.

The Baseline Scenario considers illustrative nuclear deployment pathways of 5,400 MWe by 2050 and 6,300 MWe by 2100, corresponding to annual cooling water demands across the province of approximately 102,000 to 116,000 $dam^3$ by 2050 and up to 135,000 $dam^3$ by 2100. The case studies examine industrial steam and power applications, SMRs, facility redevelopment, electricity supply for data centres, and seasonal cooling water requirements under different regional water conditions. The results show that water-related feasibility depends on cooling configuration and location, and that basin-scale availability should be supplemented by site-specific and seasonal assessments. Water availability, cooling technology, and site selection should therefore be considered together early in project planning.

## Recommendations

The following recommendations are provided for project proponents, investors, policymakers, regulators, utilities, Indigenous communities, and other decision-makers, with parallels to the recommendations presented in Hazen Canada's previous hydrogen and CCUS studies:

1. Integrate water management considerations into early-stage siting and technology screening:

    a. Potential sites should be screened concurrently for hydrologic conditions, regulatory water availability, existing allocations, seasonal reliability, water quality, intake feasibility, cumulative water demands, and applicable interprovincial or international obligations. Although this study focuses on the quantitative water demands of nuclear power generation and water availability, candidate sites for nuclear development should also be assessed for potential thermal discharge effects and impacts to aquatic ecosystems early in the planning process.

    b. Project assessments should compare air-cooled, wet-cooled, hybrid, cooling-pond, and other applicable cooling configurations using consistent criteria, including consumptive water use, total withdrawal requirements, seasonal reliability, operating performance, land requirements, and cost. Within the context of location-specific constraints and opportunities, this evaluation should recognize that minimizing water will likely involve trade-offs related to plant efficiency, land and carbon footprint, capital requirements, and operating costs.

2. Assess water availability at seasonal and operationally relevant timescales:

    a. Annual water availability estimates may not fully reflect periods during which available river flow is insufficient to meet project demand. Detailed assessments should therefore evaluate monthly, weekly, or shorter-duration conditions, as appropriate, with consideration for winter low flows, drought conditions, ice effects, intake reliability, required environmental flows,

licence priority, and potential operational restrictions. As demonstrated by Case Study #4, a basin may appear to have sufficient water on an annual basis while still experiencing seasonal constraints that could affect facility design, operation, and permitting.

3. Incorporate cumulative water demand and future uncertainty into project assessments:

    a. Potential nuclear water demands should be assessed alongside existing allocations and possible growth in other areas, including municipal, agricultural, industrial, data centre, hydrogen, and CCUS.

    b. Assessments should also consider the potential effects of changing hydroclimatic conditions on water availability and seasonal reliability over the facility's operating life. The future demand estimates presented in this report should be treated as illustrative rather than predictive because basin-level growth may differ from provincial trends and may be influenced by water reuse, efficiency improvements, water-sharing arrangements, alternative water sources, regulatory changes, and evolving development patterns.

4. Consider facility redevelopment opportunities and existing water allocations:

    a. Where non-nuclear thermal power generation or other industrial facilities are approaching retirement, decommissioning, or repurposing, proponents should evaluate whether existing water licences and associated infrastructure could support new nuclear power development.

    b. This evaluation should consider intake and discharge infrastructure, water storage and treatment systems, conveyance, and other site-specific assets. However, the transfer, assignment, amendment, or change in use of an existing water licence or allocation would remain subject to the applicable regulatory framework and should not be assumed to be available or approved without investigation.

5. Undertake early and sustained engagement with Indigenous communities:

    a. Engagement with Indigenous communities should begin before major siting and design decisions are made and should continue throughout project planning and development. Engagement should extend beyond minimum procedural Consultation requirements and provide opportunities for meaningful dialogue regarding culturally and ecologically important waters, traditional land and water uses, community priorities, cumulative effects, and potential partnership opportunities with rightsholders. Early engagement can help identify considerations that may influence site selection, technology choice, monitoring programs, mitigation measures, and long-term water management.

6. Coordinate nuclear development planning with basin-level water management initiatives:

    a. Provincial regulators should lead the coordination of information related to potential siting areas, generation loads, water requirements, development timing, and planning horizons. WPACs, utility providers, projects proponents, and other relevant stakeholders should support

this process by contributing watershed perspectives on water availability, infrastructure, demand, and project-specific inputs to inform integrated planning and decision-making.

b. Improved planning coordination would support the use of consistent assumptions, reduce duplicated efort, and facilitate the early identifcation of potential cumulative water management concerns for all water users throughout the basin. It could also help determine where WMPs, IFNs, allocation tools, monitoring programs, or regional assessments may need to be reviewed or updated to support future development planning.

# Table of Contents

**Support Acknowledgement** I

**Executive Summary** II

**Current and future water availability** II

**Potential nuclear power water demands in Alberta** IV

**Recommendations** IV

**1. Introduction and Background** 1

**1.1 Alberta Nuclear Power Generation Landscape** 1

**1.2 Project Scope and Methodology** 2

**2. Nuclear Power Context** 3

**2.1 Loop 1: Heat Generation** 6

**2.2 Loops 2 and 3: Steam Generation and Heat Rejection** 6

**3. Water Use for Nuclear Power Generation** 7

**3.1 Water-Use as a Function of Cooling System Configuration** 8

**3.1.1 Per-unit Water Demands** 8

**3.1.1.1 Operating Characteristics** 10

**3.1.1.2 Climatic Conditions** 10

**3.2 Water Temperature and Quality** 10

**4. Alberta Water Context** 12

**4.1 Hydrology** 14

**4.2 Regulatory Context** 15

**4.3 Indigenous Peoples' Participation in Water Governance** 16

**4.4 Current Water Availability** 19

**4.5 Future Water Availability and Climate Change** 22

**4.5.1 Potential Future Water Demand** 22

**4.5.2 Projected Future Changes to Water Availability** 24

**4.5.3 Future Water Availability Highlights** 26

**5. Potential Nuclear Power Deployment in Alberta 28**

**5.1 Baseline Scenario 28**

**5.1.1 2050 Horizon 30**

**5.1.2 2100 Horizon 30**

**5.2 Case Study-Based Assessment of Potential Nuclear Deployment 31**

**5.2.1 Case Study Selection 31**

**6. Potential Water Impacts of Nuclear Power in Alberta 33**

**6.1 Baseline Water Demand: Province-Wide Results 33**

**6.2 Case Study 1 - SMR in the Oil Sands to Provide Steam and Power 36**

**6.3 Case Study 2 - SMR in the Industrial Heartland to Provide Steam and Power 37**

**6.4 Case Study 3 - SMR for Power Generation in the North Saskatchewan River Basin 38**

**6.5 Case Study 4 - SMR for Power Generation in the Red Deer River Basin 40**

**6.6 Case Study 5 - SMR for Power Generation in the Battle River Basin 41**

**6.7 Case Study 6 - Meeting Data Centre Load in Alberta: Cooling Water Implications of Power Generation 43**

**6.8 Case Study 7 - Seasonality of Cooling Water Demands 44**

**7. Recommendations and Conclusions 48**

**8. Closure 51**

**9. References 52**

**10. Appendices 56**

**10.1 Appendix A – Nuclear Power Reactor Classifications 56**

**10.1.1 What is nuclear fission and how does it work? 56**

**10.1.2 Classification of nuclear reactors 56**

**10.2 Appendix B – Current and Future Water Availability in Alberta for Nuclear Power 59**

# List of Tables

**Table 1.** Common nuclear reactor classifications. 3

**Table 2.** Comparison of selected reactor technologies relevant to potential nuclear power development in Alberta. 4

**Table 3.** Per-unit water demands. 9

**Table 4.** Summary of annual flow and water availability for the river basins and sub-basins of interest, ordered by approximate water availability. 21

**Table 5.** Population growth scenario projections [43, 44] 23

**Table 6.** Total estimated incremental, annual water allocations on Alberta's river basins for non-nuclear demands, relative to the 2026 baseline. 23

**Table 7.** Qualitative highlights of future water availability, with basins organized from north to south. 26

**Table 8.** 2050 Horizon (new nuclear power generation capacity by reactor technology). 30

**Table 9.** 2050 Horizon (new nuclear power generation capacity by river basin). 30

**Table 10.** 2050 and 2100 Horizon (new nuclear power generation capacity by reactor technology). 31

**Table 11.** 2050 and 2100 Horizon (new nuclear power generation capacity by river basin). 31

**Table 12.** Baseline water use results by reactor. 34

**Table 13.** Baseline water use results by river basin. 34

**Table 14.** Estimated annual water demand for Case Study 1. 36

**Table 15.** Estimated water use as a percentage of available water in 2026. 36

**Table 16.** Estimated annual water demand for Case Study 2. 37

**Table 17.** Estimated water use as a percentage of annually available water in 2026. 37

**Table 18.** Estimated annual water demand for Case Study 3. 38

**Table 19.** Estimated annual water demand for Case Study 4. 40

**Table 20.** Estimated annual water demand for Case Study 5. 42

# List of Figures

**Figure 1.** Conceptual representation of the principal heat generation, power conversion, and heat rejection process in a nuclear power facility. 5

**Figure 2.** Map of the study area. 13

**Figure 3.** Visualization of river flows in different regions of the province, which vary seasonally and annually. The Peace River is in northern Alberta, while the North Saskatchewan River and the South Saskatchewan River are in central and southern Alberta, respectively. 14

**Figure 4.** Map of First Nations in Alberta [35]. 17

**Figure 5.** Heat map of water availability throughout Alberta as of early 2026, for a statistical median flow year. 20

**Figure 6.** High-level water availability for new allocations across the study area. The chart displays a stacked representation of water availability. 22

**Figure 7.** Median change in CMI, Evaporation, and Precipitation relative to the 2001-2020 baseline. 25

**Figure 8.** Average Alberta Internal Load Forecast. The black and green lines represent the 2024 Reference Case and High Electrification (HE) Scenarios respectively [45]. 29

**Figure 9.** Peak Alberta Internal Load Forecast. The black and green lines represent the 2024 Reference Case and High Electrification (HE) Scenarios respectively [45]. 29

**Figure 10.** Province-wide comparison between Baseline Scenario water use and estimated non-nuclear incremental demands by 2050 and 2100. 35

**Figure 11.** Hydrograph displaying the statistical lower and upper quartile streamflow of the North Saskatchewan River for the 2007-2020 period. Streamflow records at Edmonton (WSC #05DF001; red) and at Highway 759 near Wabamun (WSC #05DE010; teal). 39

**Figure 12.** Comparison between estimated water availability (in 2026) and potential water demands of a 600 MWe SMR. 41

**Figure 13.** Hydrograph displaying the lower quartile, median, and upper quartile natural streamflow of the Battle River (modelled at WSC #05FE004 for the 1912-2009 period). 42

**Figure 14.** Estimated annual water demands for 1,200 MW of power load. 43

**Figure 15.** Hydrograph displaying the estimated median (in teal) and dry flow year (in orange) and water availability (dotted line) of the Peace River for the 1991-2020 period. Streamflow records at Peace River (WSC #07HA001). 45

**Figure 16.** Estimated monthly water demand for the 1,200 MWe reactor (Case Study 7). 46

**Figure 17.** Estimated water demand (Case Study 7) as a percentage of water availability (in 2026) in the Peace River. 47

# 1. Introduction and Background

Amid the current global, political, and social climate, there is growing emphasis on reducing greenhouse gas emissions while ensuring long-term energy reliability and affordability. Consistent with these priorities, the 2025 Mandate Letter issued to the Alberta Minister of Affordability and Utilities directs the leadership of public engagement efforts and the development of a regulatory framework to enable nuclear power implementation [1]. Complementing this, the 2025 Mandate Letter issued to the Alberta Minister of Energy and Minerals calls for coordinated efforts to explore and promote small modular reactor (SMR)[1] power generation technologies, with specific emphasis on their deployment within utility grid infrastructure and heavy industrial operations [2].

As Alberta advances its exploration of nuclear power generation, the public will benefit from further dialogue on the associated environmental trade-offs, especially the potential impacts on the province's water resources, given the interconnection between water and energy within the water-energy nexus. It will be essential to examine these dynamics from the dual perspectives of both the potential water requirements of new power generation, and the limitations that regional water availability may place on future power generation development, including nuclear.

In recent years, Hazen Canada (formerly WaterSMART Solutions[2]) published reports examining the potential impacts of Alberta's evolving energy sector on the province's water resources, focusing on the hydrogen industry in 2023 [3] and amine-based carbon capture technology in 2025 [4]. These studies determined that the capacity of Alberta's river basins to support new energy developments varies by location and can be subject to seasonal constraints.

Hazen Canada has prepared this report on the potential water impacts of nuclear power development in Alberta by building on the water availability assessment and risk identification frameworks established in those prior evaluations. This report is intended for policy makers, regulators, project developers, and the interested public, with a goal to provide a better understanding of the potential impacts of the energy transition and evolving industrial sectors on our shared water resources.

## 1.1 Alberta Nuclear Power Generation Landscape

Consistent with the Provincial Mandate Letters, policy shifts and private-sector initiatives are driving the development of nuclear energy in Alberta. Following the 2021 Inter-provincial Memorandum of Understanding (MOU) [5], the Government of Alberta (GoA) established the Nuclear Energy Engagement and Advisory Panel to evaluate the province's role in the industry. This panel conducted public outreach, including online webinars in late 2025 and in-person town hall sessions in Peace River, Fort McMurray, Bonnyville, Calgary, and Edmonton in early 2026. These sessions, alongside a province-wide survey concluded in March 2026, served to compile public feedback regarding safety, waste management, and environmental stewardship [6]. The province also entered into an MOU with the Government of Canada in November 2025 to advance collaboration on nuclear energy development and committed to releasing the Alberta Nuclear Generation Strategy by 2027 [7].

Parallel to these public engagements and multi-jurisdictional collaborations, announced projects and partnerships have outlined a potential timeline for provincial nuclear development:

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[1] Small Modular Reactors refer to advanced nuclear reactors that have a power capacity of up to 300 MW(e) per unit, which is about one-third of the generating capacity of conventional nuclear power reactors [65].

[2] WaterSMART | A Hazen Company transitioned its branding to Hazen Canada on July 1, 2026. References to WaterSMART in this report reflect the company name at the time of publication of the relevant materials (i.e., prior to the brand transition).

- **Capital Power and Ontario Power Generation Partnership (2024-2025):** An agreement between Capital Power and Ontario Power Generation to assess the feasibility of grid-scale SMRs, with a target deployment window in the late 2030s [8], and a feasibility study in 2025 for approximately 600 MW in North-Central Alberta [9].
- **Peace River Nuclear Power Project:** A proposal by Energy Alberta for a large-scale facility (up to 4,800 MW) is currently undergoing an integrated impact assessment with the Impact Assessment Agency of Canada (IAAC) and the Canadian Nuclear Safety Commission (CNSC). The development's Initial Project Description indicates a fully operational target by the 2040s [10, 11].
- **Industrial Feasibility Studies (2024-2025):** Emissions Reduction Alberta (ERA) funded studies by Cenovus Energy and X-energy (in partnership with TransAlta). These assessments evaluated the use of high-temperature gas-cooled reactors, such as the SMR Xe-100, to provide low carbon steam and power for oil sands operations and existing thermal generation sites [12].

These initiatives represent a transition from conceptual exploration toward formal regulatory review and technical feasibility assessment. Given this momentum, this study establishes the hydrological baseline required for proponents and regulatory authorities to evaluate water-energy nexus interactions prior to the finalization of site-specific development plans.

## 1.2 Project Scope and Methodology

The study builds from a foundational assessment of nuclear generation technology and operational water requirements toward a detailed, scenario-based analysis of potential hydrological impacts across the province, alongside an assessment of long-term hydroclimatic projections to support infrastructure planning within the provincial energy transition framework. The following sections are included:

**Section 2:** Nuclear Power Introduction: Provides a qualitative overview of the engineering principles governing nuclear power generation and the role of water in this process.

**Section 3:** Water Use for Nuclear Power Generation: Quantifies the per-unit water requirements of nuclear power generation, leveraging the Water Allocation and Management Plan (WAMP) model developed by the International Atomic Energy Agency (IAEA).

**Section 4:** Alberta Water Context: Outlines the physical and regulatory water management systems within Alberta, leveraging baseline data from Hazen Canada's aforementioned reports. To provide a comprehensive regulatory overview, it incorporates an analysis of the constitutional and legal frameworks governing Indigenous water rights and procedural consultation obligations for project proponents.

**Section 5:** Potential Nuclear Power Deployment in Alberta: This section details the modeling parameters and growth projections used to forecast potential nuclear power development and its associated water demands in Alberta.

**Section 6:** Potential Water Impacts of Nuclear Power in Alberta: This section presents the core analytical findings through a mass-balance comparison between projected nuclear water demands and regional water availability, with consideration for potential localized impacts through basin-specific case studies.

**Section 7:** Recommendations and Conclusions: This section synthesizes the findings of the study to support long-term planning and decision-making.

# 2. Nuclear Power Context

To provide context for the water use analysis presented in this report, this section summarizes the fundamental characteristics of nuclear power generation and the technologies currently being considered for deployment in Alberta. A nuclear power facility is a thermal power plant that uses heat released through controlled nuclear fission in its reactor to produce steam, which drives a turbine-generator system to generate electricity. Nuclear power plants are typically deployed as baseload generation assets to support grid reliability, operating continuously at a relatively constant output throughout the year.

The primary fuel used in commercial nuclear reactors is uranium, which is manufactured into ceramic fuel pellets and assembled into fuel bundles within the reactor core. Fuel assemblies are arranged within the reactor core, where neutrons trigger a sustained chain reaction that releases heat. Over time, fuel assemblies generate less heat as the nuclear fuel is consumed and fewer fission reactions occur. Once their heat generation declines below operational requirements, the fuel assemblies are removed from service as spent fuel. Although the quantity of spent fuel generated is relatively small compared to many industrial waste streams, it requires specialized handling, storage, and long-term management. Note that any potential water impacts associated with nuclear fuel production and waste management are outside the scope of this report.

Nuclear reactors can be classified using different frameworks, typically based on their design principles, cooling systems, fuel types, and methods of neutron moderation. Common classification approaches are summarized in Table 1. See Appendix A – Nuclear Power Classifications for a more detailed breakdown of reactor technologies, sub-classifications, and commercial application examples.

**Table 1.** Common nuclear reactor classifications.

| Classification Type | Description | Examples |
|---|---|---|
| **Neutron moderator** | The material used in a reactor to slow down high-velocity neutrons and increase the likelihood of fission [13]. | • Light water<br>• Heavy water<br>• Graphite |
| **Fuel form** | The type, physical form, and isotopic composition of the nuclear fuel [14]. | • Natural uranium<br>• Low-enriched uranium<br>• Thorium (pre-commercial) |
| **Coolant** | The medium used to transfer heat from the reactor core to downstream energy conversion loops [14]. | • Light water<br>• Heavy water<br>• Helium<br>• Molten salt |
| **Reactor size** | The rated electrical output capacity of the reactor [14]. | • SMR<br>• Micro Modular Reactor (MMR)<br>• Conventional |
| **Neutron spectrum** | The energy (or speed) of the neutrons that sustain the fission reaction inside a reactor [15]. | • Thermal (requires moderator)<br>• Epithermal<br>• Fast (no moderator required) |

Several nuclear reactor technologies have been proposed or discussed for deployment in Alberta, including, but not limited to, the GE Vernova Hitachi BWRX-300 SMR, the Westinghouse Electric Company AP1000, the AtkinsRéalis CANDU MONARK pressurized heavy-water reactor, and X-Energy's Xe-100 SMR. These nuclear reactors differ in their design, fuel requirements, cooling approach, and intended applications. Table 2 summarizes their key characteristics.

**Table 2.** Comparison of selected reactor technologies relevant to potential nuclear power development in Alberta.

| Reactor | Neutron moderator | Fuel form | Coolant | Reactor size | Neutron spectrum |
|---|---|---|---|---|---|
| **GE Hitachi BWRX-300 [16]** | Light water | Low-enriched uranium pellets | Light water | ~300 MWe net (SMR) | Thermal |
| **Westinghouse Electric AP1000 [11]** | Light water | Low-enriched uranium assemblies | Light water | 1,200 MWe net | Thermal |
| **CANDU MONARK [11, 14]** | Heavy water | Natural uranium (37-element) bundles | Heavy water | 1,000 MWe net | Thermal |
| **X-Energy Xe-100 [17, 18]** | Graphite | High-assay low-enriched uranium (TRISO) pellets | Helium | 80 MWe net (SMR) | Thermal |

Figure 1 depicts the typical process loops of a nuclear power generation facility:

- **Loop 1:** Heat generation.
- **Loop 2:** Steam generation.
- **Loop 3:** Heat rejection.

Heat from the fission reaction is transferred between loops through heat exchangers, allowing energy, but not matter, to move from one medium to another. The configuration of Loop 1 depends on the reactor technology and coolant selected (Table 1), whereas Loop 2 remains largely consistent across reactor designs. This consistency in Loop 2 reflects that nuclear power facilities are fundamentally thermal power plants, wherein steam drives a turbine-generator to produce electricity. Loop 3 varies depending on the cooling technology employed. Additional details on these systems are provided in Sections 2.1 and 2.2.

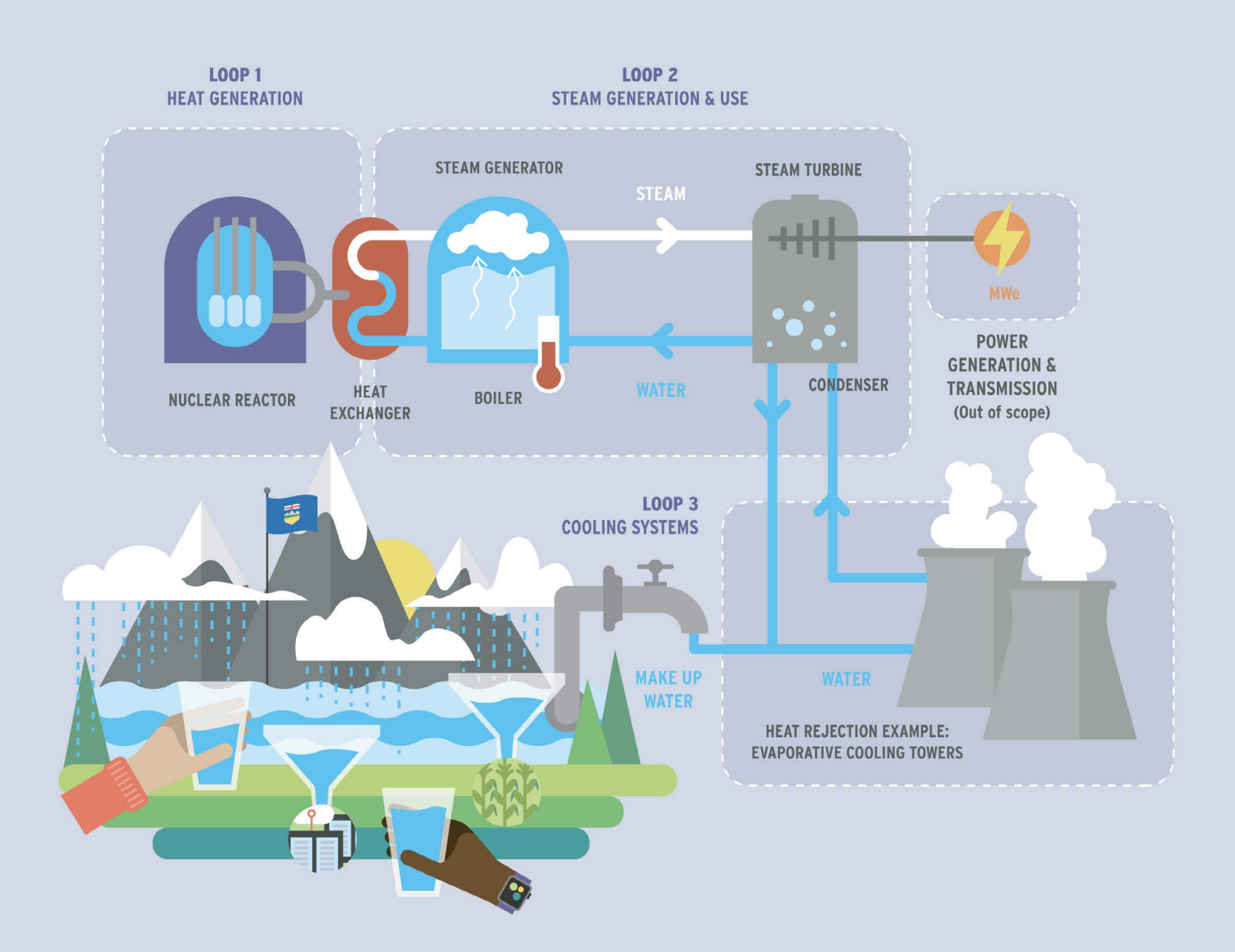



*Figure 1. Conceptual representation of the principal heat generation, power conversion, and heat rejection process in a nuclear power facility.*

## 2.1 Loop 1: Heat Generation

Within Loop 1, thermal energy is generated through a continuous, controlled reaction that releases heat within a confined area of the facility. Fuel material is arranged inside a reinforced vessel, where the controlled fission reaction occurs [19].

A circulating fluid (i.e., energy carrier) passes directly through the reactor core to absorb this thermal energy, while mechanical control mechanisms regulate the reaction rate to maintain a stable operating temperature. Depending on the reactor technology, this fluid may either transfer thermal energy to a separate steam cycle through a heat exchanger (i.e. Loop 2) or generate steam directly as part of Loop 1 (as is the case for Boiling Water Reactors). In either case, the thermal energy is ultimately used to drive a turbine generator and produce electricity [19].

**WATER THAT MAY BE IN DIRECT CONTACT** with the nuclear reactor is managed in separate, non-mixing circuits from cooling water streams. This means any water released to the environment (e.g., as steam into the air or as liquid water into a river or lake) does not come into direct contact with irradiated material [66].

## 2.2 Loops 2 and 3: Steam Generation and Heat Rejection

Although the following discussion is framed in the context of nuclear power generation, the same configuration is broadly applicable to other thermal power generation technologies, including, but not limited to, coal-fired, natural gas combined-cycle, and biomass power facilities. In all such systems, electricity is generated by converting thermal energy into mechanical work through a steam cycle (Loop 2), and the resulting waste heat must be rejected to the environment through a cooling system (Loop 3). Loop 3's process occurs in three sequential steps:

- **Step 1:** Steam Capture. Exhaust steam discharged from the Loop 2 turbine is directed into a main condenser chamber.
- **Step 2:** Heat Transfer. Loop 3 continuously circulates a cooling medium from an external source through sealed tubes inside the condenser. Thermal energy is transferred from the steam to the cooling medium, inducing rapid condensation.
- **Step 3:** Heat Rejection. The thermal energy absorbed in Loop 2 is removed on an ongoing basis, which occurs via Loop 3.

The potential water use implications throughout the nuclear power generation process, including for heat rejection, are examined in detail in Section 3.

# 3. Water Use for Nuclear Power Generation

Section 3 provides the technical basis for characterizing water demands for cooling nuclear power generation facilities. It describes how reactor thermal performance and cooling system configuration influence water withdrawals, consumptive use, and discharge requirements, and establishes the per-unit demand assumptions used to quantify and model water requirements for this study. Although not part of the scope of the assessment, additional considerations of water use for nuclear power generation, such as quality and temperature, are discussed at a high level (Section 3.2).

Depending on the type of nuclear reactor, water may play a dual role in nuclear power generation, serving both as an energy carrier and as an external thermal regulator. Within Loop 1, certain reactor types use water as a neutron moderator (Table 1). This moderator water remains within a closed system and is continuously recirculated; therefore, it does not represent ongoing water consumption. Within Loop 2 (as illustrated in Figure 1), thermal energy transferred from the reactor is used to convert liquid water into high-pressure steam. The steam then expands through a turbine as part of a Rankine thermodynamic cycle, generating electricity. Beyond its role in the power generation cycle and depending on the cooling system configuration chosen for a facility, water may also serve as the primary medium for rejecting residual heat (Loop 3).

Water is the predominant cooling medium for heat rejection in all forms of steam-cycle power generation due to a combination of thermodynamic, economic, and practical factors. Its high specific heat capacity enables water to absorb substantial quantities of thermal energy with a relatively modest rise in temperature, allowing efficient heat removal from the condenser at comparatively low circulating volumes. Water also exhibits a high latent heat of vaporization, which in recirculating cooling systems removes a large amount of heat. In addition, water has historically been generally available in most regions where power generation has been sited, resulting in low acquisition and treatment costs relative to alternative heat transfer fluids (e.g., molten salts, synthetic or mineral oils, liquid metals). The total volume of water withdrawn and consumed is generally a function of a facility's thermal efficiency and the cooling configuration selected, rather than of the underlying heat source itself .

Nuclear power generation facilities also require water during their construction and commissioning phase, primarily for excavation, concrete mixing, and construction workforce supply. Depending on facility size, these one-time demands are typically on the order of 500,000 to 1,000,000 $m^3$ and are utilized across the entire construction period, typically 4 to 5 years [20]. During operation, a nuclear facility maintains small, relatively stable volumes of water for auxiliary functions, such as safety injection reserves, sanitary and potable supply, fire protection, spent fuel storage, and chemical control systems. These auxiliary demands typically range from 10,000 to 100,000 $m^3$ per year, depending on reactor size and design [20, 21]. Because the demands associated with these functions are relatively small compared to those of the cooling system and are not expected to materially influence regional hydrology in most cases, the scope of this report focuses on the steam generation and turbine cooling system (i.e., Loops 2 and 3), where the selected cooling technology represents the principal determinant of a facility's ongoing water consumption.

[3] Facilities with higher thermal efficiencies reject less waste heat and therefore require less heat dissipation through the cooling system. Refer to Section 6.7 for more details.

## 3.1 Water-Use as a Function of Cooling System Configuration

Cooling systems are broadly categorized into four configurations: once-through cooling, recirculating (i.e., wet) cooling, air-cooled (i.e., dry) systems, and hybrid (i.e., combined wet and dry). These configurations differ in how heat rejected to the condenser in Loop 3 is ultimately transferred to the surrounding environment. Different modes of heat rejection, in turn, present distinct trade-offs between water withdrawal volumes, consumptive use, thermal discharge characteristics, land footprint, capital and operating costs, and sensitivity to ambient conditions. The suitability of a given configuration is typically dictated by site-specific hydrological availability and climatic conditions, as discussed throughout this report.

- Once-through systems withdraw large volumes of water from a surface source, pass it a single time through the condenser, and return it to the receiving water body at an elevated temperature; they are thermally efficient but withdrawal-intensive and impose thermal loads on the receiving environment [22].
- Recirculating (wet) systems reduce water withdrawal by continuously reusing water within a closed loop, dissipating heat through evaporation in a wet cooling tower or engineered cooling pond. This comes at the cost of higher net water consumption and the need for periodic blowdown and makeup water [22].
- Air-cooled (dry) systems eliminate cooling-related water use almost entirely by rejecting heat directly to the atmosphere through finned heat exchangers, but they exhibit reduced thermodynamic efficiency, higher capital costs, and a larger physical footprint than water-based systems [22].
- Hybrid configurations combining wet and dry elements are also deployed in some contexts to balance water use with thermal performance [23].

**IF A NUCLEAR POWER FACILITY** has a visible plume coming from a cooling tower, it is non-radioactive water vapour. Since Loop 3 operates independently of the reactor core, this discharge represents thermal energy released to the atmosphere as water vapour, rather than combustion by-products (e.g., exhaust or smoke). The plume becomes denser and more visible during colder weather, when the temperature differential between the saturated tower exhaust and ambient air is greatest [68].

### 3.1.1 Per-unit Water Demands

Consumptive use refers to the volume of water withdrawn from a river basin that is not directly returned following use. To evaluate the potential range of water requirements associated with nuclear power development, three cooling technologies were selected to represent Low, Medium, and High water use ranges. Note that once-through cooling was not included in the assessment because its large withdrawal requirements limits its applicability in many Alberta riverine environments. As a result, the assessment focuses on dry cooling, cooling pond, and evaporative cooling systems, which are considered more representative of the cooling approaches likely to be evaluated for nuclear development in Alberta:

- **Low:** Air-cooled (dry) systems were selected to represent the Low water use range, as heat is rejected primarily to the atmosphere through forced ambient air convection, resulting in negligible water withdrawals and consumptive use. While these systems can substantially reduce operational water withdrawals and consumptive use, they are typically associated with lower thermodynamic efficiency, higher capital costs, and larger facility footprints relative to water-cooled alternatives.

- **Medium:** Closed-loop cooling ponds were selected to represent the Medium water use range, as they require a dedicated water source and experience evaporative losses, while typically consuming less water than evaporative cooling towers.
- **High:** Evaporative cooling systems were selected to represent the High water use range, as evaporative heat rejection results in the greatest consumptive water requirements among the cooling technologies identified.

Together, these three cases capture a broad spectrum of potential cooling-related water requirements that could reasonably be expected for nuclear power facilities deployed in Alberta. They are intended to bound the range of water demands associated with the principal cooling technologies such that technology-specific differences within each case are not expected to materially affect the overall conclusions of the assessment. Technologies with intermediate water-use characteristics, including hybrid cooling systems and alternative cooling tower configurations, are expected to fall within these bounds, although they may not correspond directly to the selected Medium Use range.

Per-unit water use for each cooling technology was estimated using the IAEA WAMP. The key parameters used to evaluate the per-unit water demands are described below, as variations in these inputs produce the largest range in modelled water use outcomes[4]:

- Operating characteristics (Section 3.1.1.1).
- Climatic conditions at a potential site (Section 3.1.1.2).

By integrating these parameters, the WAMP estimates cooling-related water withdrawals and consumption, allowing for consistent comparison of per-unit water demands across cooling system configurations. Table 3 presents the resulting ranges of per-unit water demands, which reflect variation in average climatic conditions among the four study locations (i.e., the Peace River region, the Athabasca River at Fort McMurray, Alberta's Industrial Heartland, and the Wabamun area) while reactor operating parameters were kept constant for each reactor type.

**Table 3.** Per-unit water demands.

| Example Reactor | Reactor Size (MWe) | Low Use Range ($m^3$/MWh) *Air-cooled system* | Medium Use Range ($m^3$/MWh) *Closed-loop cooling ponds system* | High Use Range ($m^3$/MWh) *Evaporative cooling system* |
|---|---|---|---|---|
| AP1000 | 1,200 | 0 | 1.89 - 2.0 | 2.39 - 2.55 |
| CANDU MONARK | 1,000 | 0 | 1.89 - 2.0 | 2.39 - 2.55 |
| Xe-100 (SMR) | 80 | 0 | 1.53 - 1.62 | 1.94 - 2.07 |
| BWRX-300 (SMR) | 300 | 0 | 1.94 - 2.06 | 2.46 - 2.62 |

As noted, the negligible value reported for the low water use range is an expected outcome, as air-cooled systems reject heat directly through forced ambient air convection, eliminating the need for cooling water and associated consumptive use. In contrast, the Medium and High water use ranges represent closed-loop cooling ponds and evaporative cooling systems, respectively, both of which result in varying degrees of water consumption through evaporation.

[4] For clarity, all other parameters within the WAMP were held constant for each water use range, as their influence on model outputs is less significant than the variables highlighted in this assessment. The WAMP is a publicly available tool which readers can access and explore as desired to further explore the model's sensitivity to varying parameters.

#### 3.1.1.1 Operating Characteristics

Operating characteristics were incorporated into the WAMP model through reactor-specific thermal efficiency assumptions and cooling system design parameters. For each range, the nominal thermal efficiency and electrical generation output values reported for three of the reactor technologies (i.e., AP1000, Xe-100, and BWRX-300)[5] described in Table 2 were used to determine the corresponding quantity of residual heat requiring rejection through the cooling system (Loop 3).

Because thermal efficiency influences the magnitude of heat dissipation requirements, it is a key determinant of cooling-related water use [11, 18]. As shown in Table 3, the AP1000, BWRX-300, and CANDU MONARK reactors have broadly comparable per-unit cooling water requirements, reflecting their similar thermal efficiencies of approximately 34.5% to 35.1% [24, 11]. In comparison, the Xe-100 has a higher thermal efficiency of approximately 40% [18] and therefore produces less residual heat, requiring less cooling water per unit of electricity generated.

For recirculating cooling systems, a cycle of concentration value of three was assumed to represent typical water treatment and blowdown practices. This parameter influences makeup water requirements by controlling the concentration of dissolved solids that can accumulate within the cooling system before blowdown is required. All other operating parameters were retained at the WAMP model default values to provide a consistent basis for comparison among reactor and cooling system per-unit water demands.

#### 3.1.1.2 Climatic Conditions

The WAMP model incorporates climatic variables that influence cooling system water requirements, including ambient air temperature, source water temperature, and relative humidity. As noted, four representative Alberta locations were evaluated: the Peace River region, the Athabasca River at Fort McMurray, Alberta's Industrial Heartland, and the Wabamun area. Annual average climatic conditions for each location were used to estimate cooling-related water withdrawals and consumptive use across the reactor and cooling technologies [25, 26, 27].

As shown in Table 3, evaporative cooling systems exhibit the widest range of consumptive water demand because their performance is particularly sensitive to variations in ambient air and source water temperatures. These systems reject heat through both latent heat transfer, associated with evaporation, and sensible heat transfer, associated with changes in water and air temperature. Closed-loop cooling pond systems exhibit a slightly narrower range of consumptive water demand because they are less sensitive to short-term variations in air and source water temperatures. Their larger stored water volume provides thermal buffering, moderating changes in evaporation and cooling performance as climatic conditions vary.

## 3.2 Water Temperature and Quality

In addition to consuming water, nuclear power facilities may also influence the temperature and quality of water which is returned to the environment. While these temperature and quality considerations, and the associated management requirements, are important aspects of nuclear facility operations, they generally do not represent material water consumption. Therefore, water temperature and quality impacts are not a focus of this report; this section provides high-level context for readers, and it is not intended as a detailed evaluation of facility- and location-specific water management requirements.

[5] The CANDU MONARK design was not modelled separately, as its thermal efficiency is expected to be similar to that of the AP1000 (35 vs 35.1%) [11] and would therefore result in comparable cooling requirements.

Within a nuclear power facility, water management includes the operational and engineering controls used to monitor, treat, and regulate the condition of water prior to its discharge from Loop 3. As Loop 3 continuously absorbs thermal energy at the condenser and rejects it, the circulating water increases in temperature, while evaporation and makeup water contribute to gradual shifts in its chemical composition. At a high level, water management therefore addresses thermal characteristics, chemical composition, and radiological monitoring in an integrated manner, supported by the following controls:

- **Thermal management:** Although requirements vary by jurisdiction, facilities are subject to effluent quality regulations that establish discharge limits, including temperature, intended to protect aquatic ecosystems [20, 28].
- **Chemical management:** Water quality within the cooling system is maintained through monitoring of blowdown (i.e., the portion of cooling water periodically removed to prevent the accumulation of dissolved minerals). Prior to discharge, blowdown is treated to remove residual scale inhibitors and biocides which are applied during operation to control biological growth [29].
- **Radiological monitoring:** Because Loop 3 is isolated from the reactor core through the intervening Loop 1 and Loop 2 systems, the cooling water is not exposed to radioactive materials during normal operation. Continuous monitoring at the discharge points confirms that radiological concentrations remain consistent with ambient background levels [30].

# 4. Alberta Water Context

Section 4 has been adapted from Hazen Canada's prior studies on the potential water impacts of hydrogen (2023) and carbon capture (2025) development in Alberta. The content has been carried forward with editorial revisions for ease of reference and to provide context for readers who have not reviewed earlier studies. The content has been updated where required to align with the water management changes in effect as of March 11, 2026, following proclamation of the *Water Amendment Act,* 2025 and related amendments to the Water (Ministerial) Regulation.

Water availability in Alberta is highly variable across the province, with meaningful differences between watersheds in both the volume of water available and the degree of competition amongst users. This spatial variability influences how regulators and water users plan and manage withdrawals to meet ecological objectives while supporting communities and economic activity. In southern Alberta, rivers are often smaller and flow through more densely populated regions, which has historically increased the need to assess water-energy-food nexus trade-offs.

Water availability also varies seasonally and interannually. This temporal variability means that project proponents must assess water-supply reliability and associated risks within Alberta's existing water management and regulatory framework regardless of location. This section presents a high-level assessment of water availability along the mainstems of representative rivers within the major watersheds defined in the Alberta *Water Act* (with the Peace and Athabasca Rivers considered separately), as shown in Figure 2. Rivers were selected to represent:

- Locations relevant to the nuclear development evaluated in this report (e.g., the Peace River).
- Watersheds subject to a known allocation order that limits the issuance of new water licences (e.g., the Battle River).
- Watersheds where future water supply reliability may be more constrained due to hydrologic variability and projected growth in demand from other users (e.g., the Red Deer River).

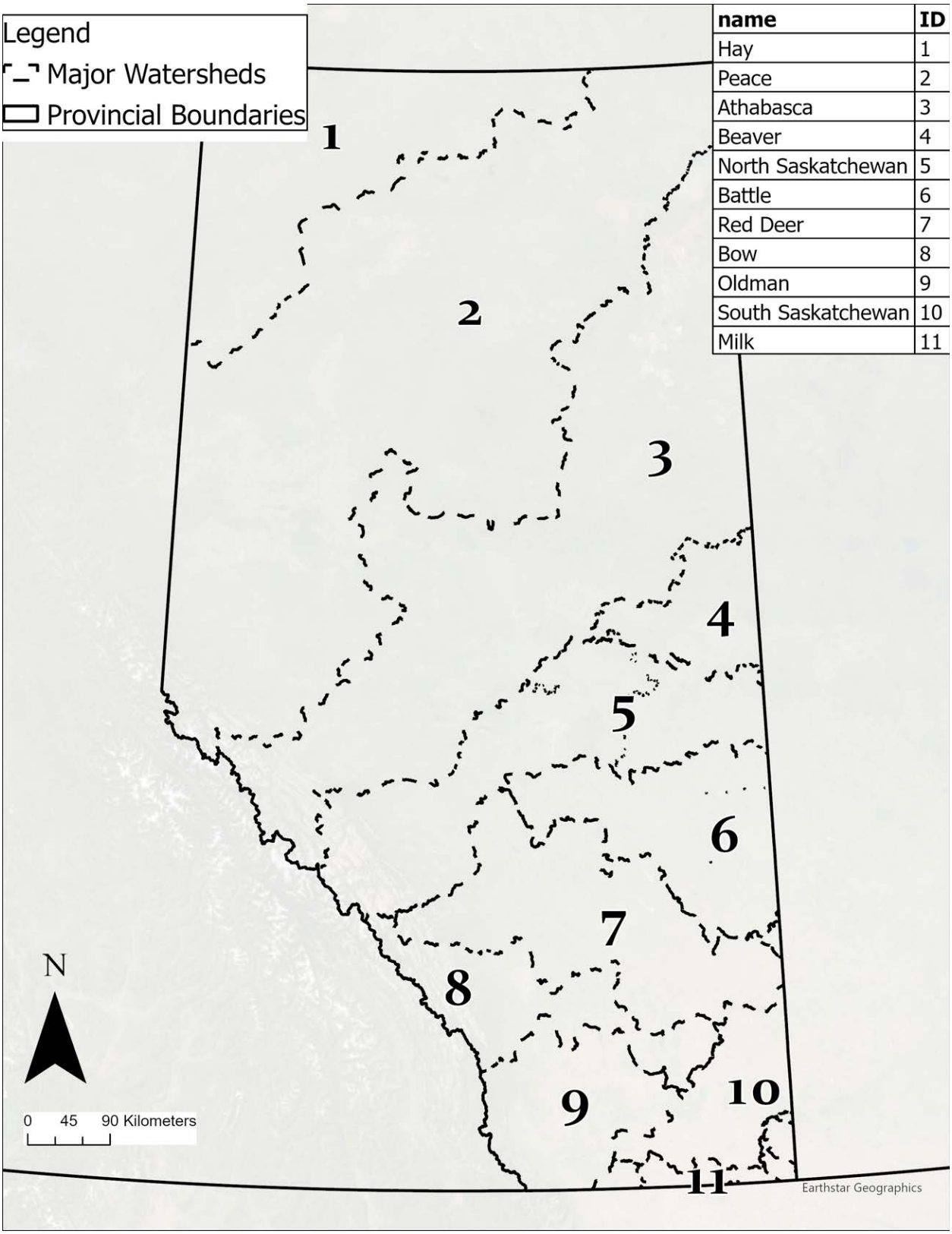



*Figure 2. Map of the study area.*

## 4.1 Hydrology

Alberta's water resources can be broadly classified into three categories: groundwater, non-flowing surface water (e.g., lakes, ponds, and sloughs), and flowing surface water (e.g., rivers, streams, and creeks). This report emphasizes flowing surface water, reflecting the comparatively greater reliance by water users in the province on rivers and streams than on groundwater or standing water bodies. Groundwater availability can vary substantially across Alberta, and limitations in existing datasets can make it difficult to confirm a dependable groundwater supply without undertaking site-specific hydrological studies and field verification.

Alberta's major river basins, as defined under the Water Act [31], originate along the eastern slopes of the Rocky Mountains, with the exception of the Beaver River Basin. Water availability within these basins exhibits pronounced seasonal variability, as streamflow typically peaks between May and July when snowmelt from the Rocky Mountains contributes substantial runoff (freshet). Streamflow generally declines between October and February as snowmelt contributions diminish, during which time glacier melt constitutes a higher proportion of total flow. This seasonal pattern is illustrated by the hydrograph shown in Figure 3 [32]. Alberta's other major river basins exhibit comparable seasonal flow regimes, with variations in the timing and magnitude of runoff and rainfall events.

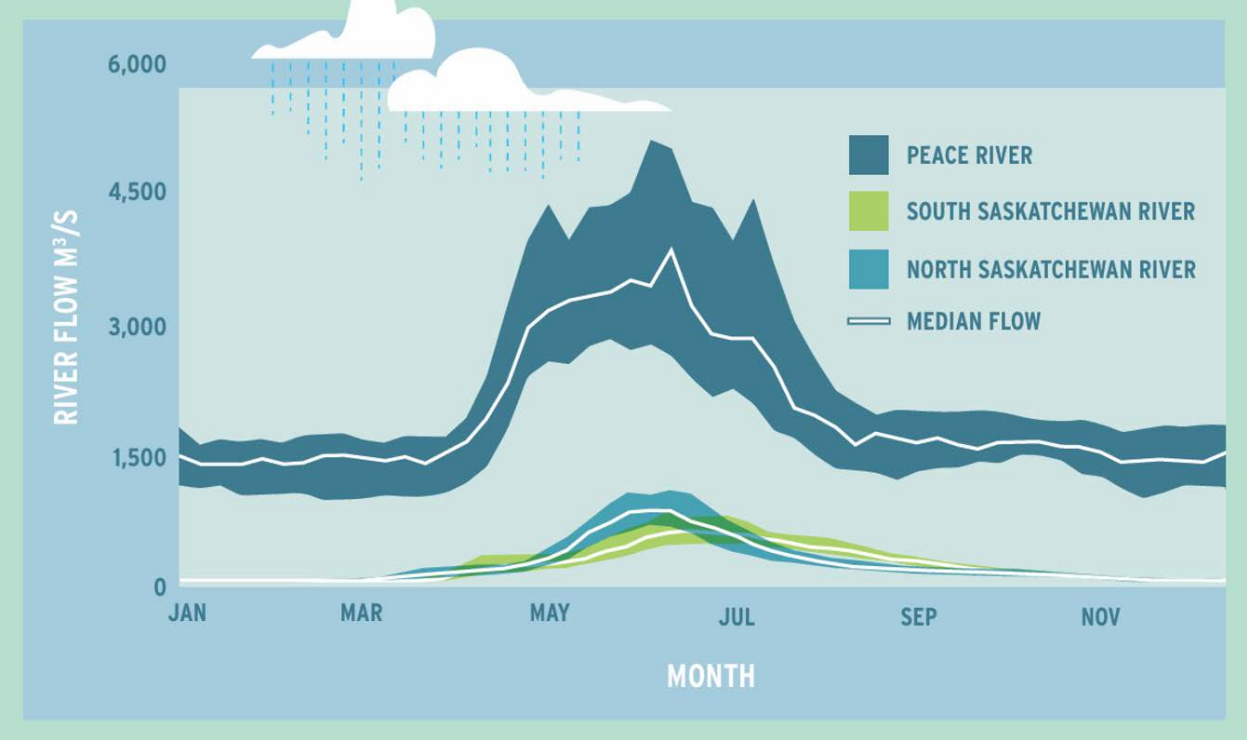



*Figure 3. Visualization of river flows in different regions of the province, which vary seasonally and annually. The Peace River is in northern Alberta, while the North Saskatchewan River and the South Saskatchewan River are in central and southern Alberta, respectively.*

In addition to seasonal variation in flow volumes, winter ice cover can present operational constraints for surface water withdrawals. Depending on the diversion infrastructure employed, ice formation may limit access to, or reliability of, surface water supplies during winter months. Additional information on the hydrologic characteristics of Alberta's river systems is provided in Appendix C of Hazen Canada's 2023 hydrogen report [3].

## 4.2 Regulatory Context

In Alberta, water resources are governed by the *Water Act*, which is intended to balance the needs of people, the environment, and industry. The *Water Act* establishes the framework for water management planning and for issuing and administering water licences, including available water diversion instruments and regulatory decision-making processes. With limited exceptions (e.g., household use, traditional agriculture, and specified Ministerial exemptions), a licence is required to divert and use water.

The *Water Act* influences water management through:

- **Diversion rights:** Licences authorize a specified diversion volume and rate (i.e., an allocation) and are issued under a priority system in which older (i.e., "Senior") licences take precedence over newer (i.e., "Junior") licences during periods of limited water supply.
    - In low-flow conditions, priorities may be called, potentially restricting diversions by junior licence holders. In practice, many licence holders rely on collaborative shortage-management approaches (e.g., water sharing Memorandums of Understanding [33]) and formal priority enforcement is uncommon.
- **Inter-basin water transfers:** Under the *Water Act*, a licence authorizing the transfer of water between major river basins may only be issued where the transfer is specifically authorized by a special Act of the Legislature or qualifies as a "lower-risk" inter-basin transfer.
    - As of March 11, 2026, Section 47 permits the Minister to authorize, by order, a licence for a "lower-risk" inter-basin transfer between adjacent major river basins, subject to the Director's invasive-species determination and compliance with prescribed diversion-rate limits and related regulatory requirements.
    - Transfers occurring within a single major river basin (i.e., intra-basin transfer) do not require the same special legislative authorization.
- **Environmental protection:** The *Water Act* includes mechanisms to determine the volume of water that should remain in a river to support environmental needs, including Water Management Plans (i.e., WMPs) that establish Water Conservation Objectives (i.e., WCOs). In the absence of WCOs, Instream Flow Needs (IFNs) may be established for individual water bodies.
- **Monitoring and reporting:** Diversion licences typically include requirements to monitor and report water quantity to Alberta Environment and Protected Areas (EPA) at defined intervals.
- **Licence transfers:** The *Water Act* includes provisions for the permanent or temporary transfer of all or part of a licence from one user to another, including (where applicable) intra-basin transfers in basins with a Cabinet-approved WMP.
    - Assignments: An assignment is a temporary arrangement to shift licence priority from one licensee to another.

The recent amendments to the *Water Act* and associated *Water (Ministerial) Regulation*, which came into force on March 11, 2026, introduced several changes to Alberta's water management framework. These changes include, but are not limited to:

- Merging of the former Peace/Slave and Athabasca major river basins into the Peace-Athabasca-Slave River Basin – Section 1(1)(ff).
- Establishing new provisions governing water reuse and return flows – Sections 1(1)(hhh.1) and 1(1)(zz.1).
- Amending the definition of water to include precipitation intercepted above the ground and captured – Section 1(1)(fff).
- Monitoring and reporting for water reuse – Sections 18(2.1) and 18 (2.2).
- Enabling "lower-risk" inter-basin transfers, as noted above – Section 47.

Other provincial statutes, regulations, policies, and technical guidance that may be relevant to a project's water supply include the *Historical Resources Act*, the *Environmental Protection and Enhancement Act*, the *Public Lands Act*, the *Wildlife Act*, the *Water (Ministerial) Regulation*, the Wastewater and Storm Drainage Regulation, the Pipeline Rules, the Alberta Wetland Policy, and the Environmental Quality Guidelines for Alberta Surface Waters.

In addition, Alberta is a party to various cross-boundary agreements, which collectively influence both the province's internal water licensing system and its obligations to downstream partners:

- The 1909 Boundary Waters Treaty and 1921 Order of the International Joint Commission set the apportioned shares of the St. Mary River and the Milk River between the United States and Canada.
- The 1969 Master Agreement on Apportionment requires Alberta to allow a volume of water to flow into Saskatchewan equal to one-half of the natural flow in each interprovincial river, which constrains the volume of water available for diversion from rivers flowing east into Saskatchewan.
- The 1997 Mackenzie River Basin Transboundary Waters Master Agreement, a multi-party agreement (Canada, British Columbia, Alberta, Saskatchewan, the Northwest Territories, and Yukon) intended to support cooperative management of water quantity and quality at interjurisdictional boundary-crossing points within the Mackenzie River Basin.

## 4.3 Indigenous Peoples' Participation in Water Governance

Since time immemorial, Indigenous Peoples have maintained deep cultural, spiritual, and stewardship relationships with water. In Canada, water-related planning, development, and regulatory decisions must consider the constitutional protection afforded to Indigenous Peoples, recognized and protected under Section 35 of the *Constitution Act*, 1982 [34]. Within Alberta, the constitutional protections interface directly with historical treaties. The majority of the province falls within the traditional territories covered by Treaties 6 (Central Alberta, signed in 1876), 7 (Southern Alberta, signed in 1877), and 8 (Northern Alberta, signed in 1899); however, portions of Alberta are also located within the boundaries of Treaties 4 and 10, as seen in Figure 4. In addition to the historical treaties covering Alberta, the province is home to distinct Métis communities and Métis rights holders whose constitutionally protected rights are recognized and affirmed under Section 35 of the *Constitution Act*, 1982.

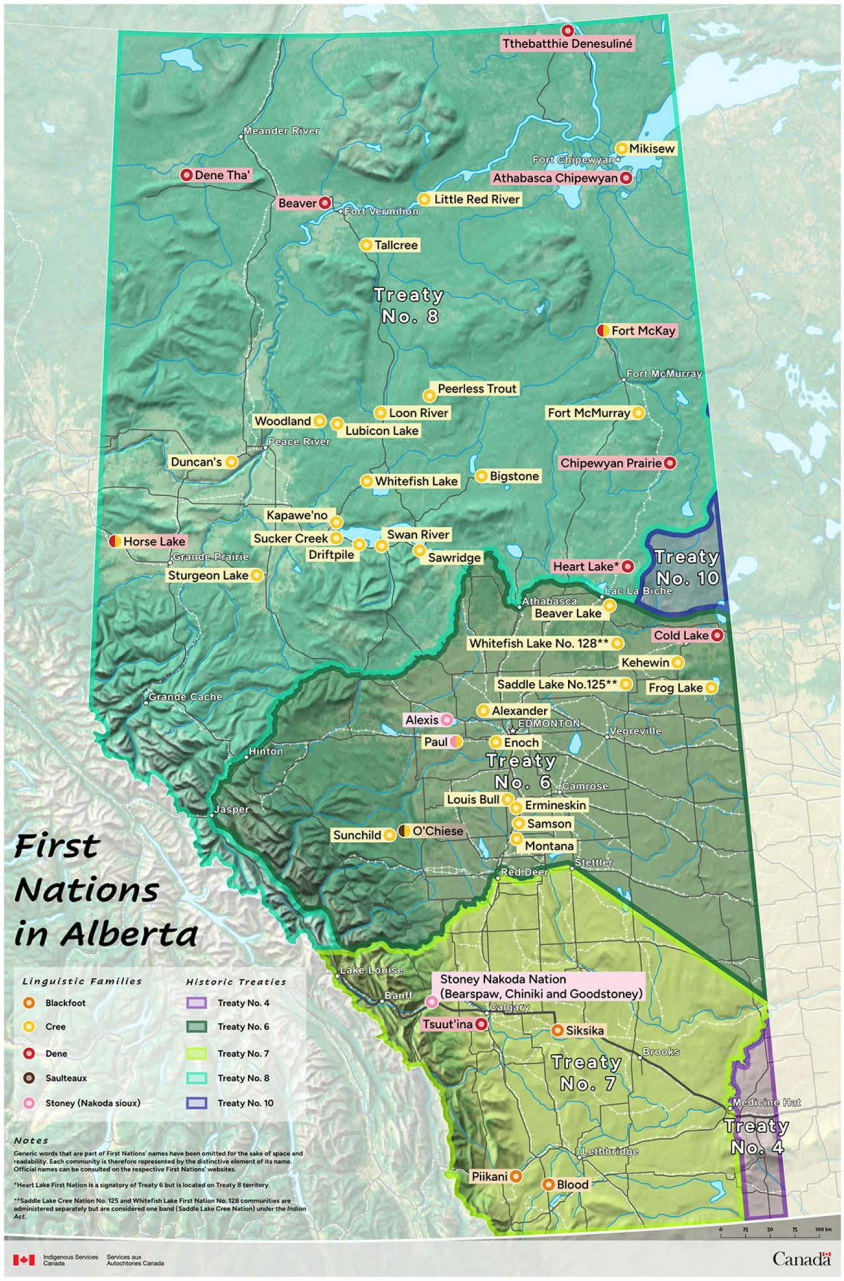



*Figure 4. Map of First Nations in Alberta [35].*

Section 35 of the *Constitution Act* recognizes and protects treaty rights, recognizing that water is inherently linked to the execution of protected rights, such as hunting, fishing, and ceremonial use. Because reserve lands are held for the use and benefit of First Nations, these communities maintain unique jurisdictional claims regarding source water protections and groundwater management [36]. While Section 35 of the *Constitution Act* and the numbered treaties do not allocate volumetric water rights for Indigenous Peoples, they do not preclude communities from applying for and holding water licences under provincial legislation. In certain cases, water allocations have also been established through negotiated settlements and statutory mechanisms (e.g., Piikani Nation's 35,000 acre-ft licence for irrigation associated with the construction of the Oldman Reservoir in southern Alberta [37, 38]).

Activities such as water licence approvals, diversions, and infrastructure development may affect the ability of Indigenous communities to exercise rights associated with traditional land use and cultural practices. Where such impacts may occur, the Crown's[6] Duty to Consult may be triggered. At the provincial level, the constitutional Duty to Consult is under the oversight of the Aboriginal Consultation Office (ACO). In Alberta, project proponents are generally required to submit their proposed activities to the ACO, which assesses whether Consultation is required and, if so, determines the appropriate level of Consultation:

- **Level 1:** Streamlined Consultation. Applies where the proposed activity is deemed to have limited potential adverse effects.
- **Level 2:** Standard Consultation. Applies where the proposed activity is deemed to have more than limited adverse effects.
- **Level 3:** Extensive Consultation. Applies where the proposed activity is deemed to have significant or complex adverse effects.

While the Crown retains responsibility for ensuring that Consultation obligations are met, project proponents may be delegated with procedural components of Consultation depending on the level of Consultation required, including information sharing, community outreach, and the documentation of concerns for consideration during regulatory review and decision-making processes, as found in the Government of Alberta's proponent guide to First Nations, Métis Settlements and Credibly Asserted Métis Communities Consultation Procedures [39, 40].

Although Consultation directed by the ACO establishes the procedural requirements that proponents must satisfy to support the Crown's assessment of Consultation adequacy, proponents should consider these requirements one component of broader engagement. Early and sustained engagement can support trust and relationship building, improve understanding of community-specific interests, values, and priorities, and create opportunities for partnerships that provide mutually defined benefits.

Increasingly, federal policy and legislation are recognizing a more direct role for Indigenous Nations and Communities in the governance and management of water resources on their lands. On June 16, 2026, the federal government introduced Bill C-37[7]. Among other provisions, the bill proposes to establish legally enforceable drinking water protections on First Nation lands and explicitly recognizes First Nations' rights to self-government, including jurisdiction over water on, in, and under their lands.

[6] The Crown is represented by whichever level of government is making the decision that could affect Indigenous or Treaty rights.

[7] Bill C-37 has received first reading as of August 2026.

## 4.4 Current Water Availability

As introduced in Section 4.2, water availability in Alberta is governed by the Water Act, with management tools and instruments varying by basin. The regulatory context of a given water body, whether defined by a Water Allocation Order, a prescriptive WMP approved by Cabinet, or the application of the Surface Water Allocation Directive (SWAD), determines the volume of water available for new licences and the conditions under which diversion may be authorized. Notably, the Bow, Oldman, and South Saskatchewan River Basin Water Allocation Order (2007) closed the sub-basins to new water diversion licence applications. Notwithstanding this closure, the Oldman River Basin Water Allocation Order (2003) preserves a limited reserve of water upstream of the Oldman Dam for designated uses.

The volume of water available for new consumptive demands was estimated for each river within the study area. This assessment reflects estimated water usage as of May 2026, incorporating assumptions regarding historical water availability and existing licensed allocations across the relevant river basins. It is important to note that these results are not intended to substitute for a detailed, site-specific water supply risk assessment; project proponents are strongly encouraged to undertake such an analysis prior to proposing or advancing new developments. River flow data was sourced from Water Survey of Canada (WSC) hydrometric gauge stations, and existing water allocation use data, including seasonality, was obtained from EPA and Watershed Planning and Advisory Council (WPAC) publications. The applicable regulatory framework for each basin, including, where relevant, the WMP, was applied to estimate water availability.

To characterize the interannual variability inherent in Alberta's river systems, two statistical flow scenarios were selected: a median flow year (50th percentile) and a dry flow year (25th percentile). Both scenarios were derived from the 30-year historical streamflow record spanning 1991 to 2020. Figure 5 displays the results of the water availability analysis in each basin across the province. The colour-scaling indicates how much water is available for new allocations on an annual basis, based on the statistical median flow year[8].

[8] Figure 5 presents a generalized representation of water availability and does not reflect seasonal variations in streamflow.

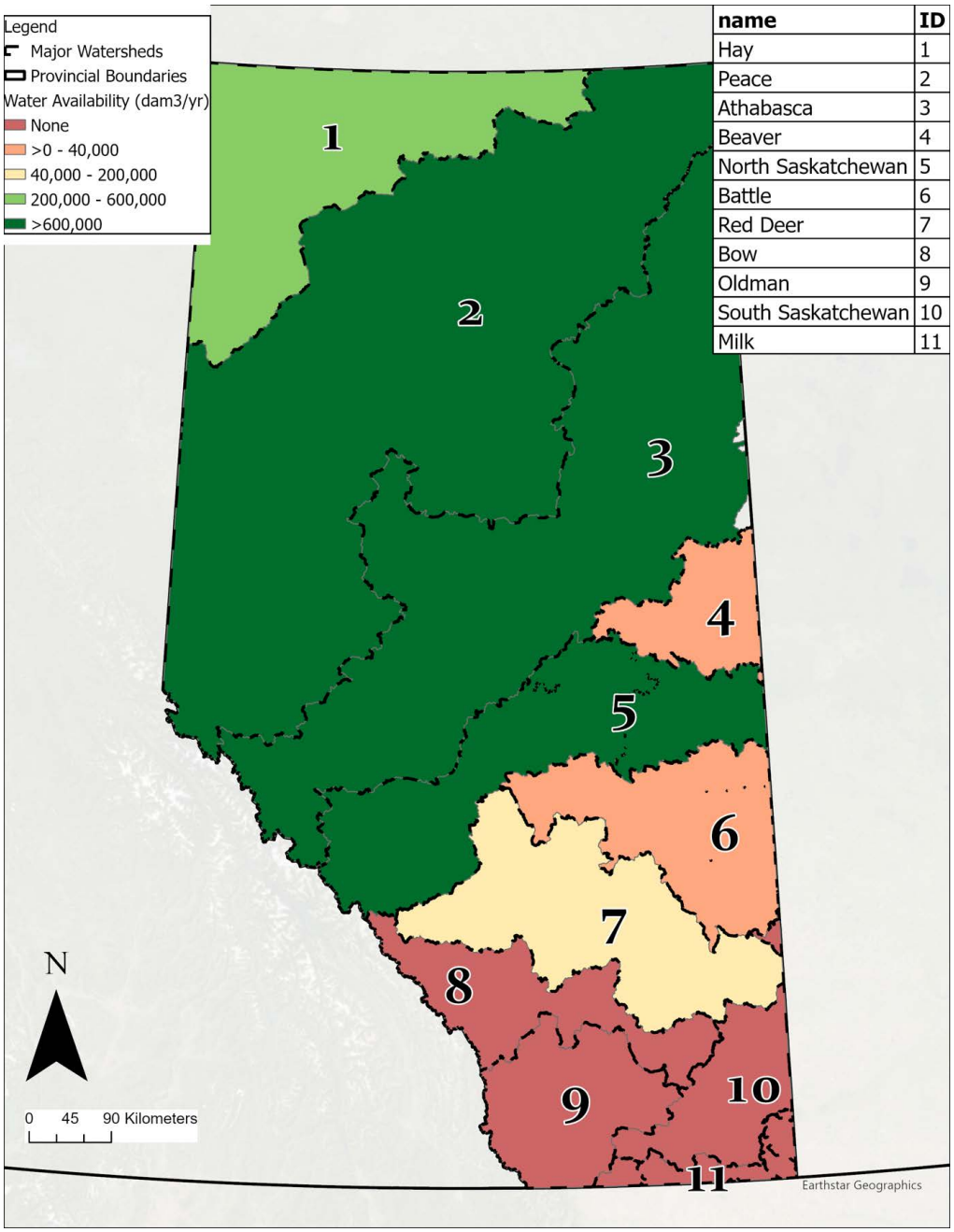



*Figure 5. Heat map of water availability throughout Alberta as of early 2026, for a statistical median flow year.*

Compared to previous Hazen Canada assessments [3, 4], some differences in the spatial distribution of water availability are evident. These changes primarily reflect differences in the scope and methodology of the analysis. Whereas previous studies evaluated potential future water availability under projected 2050 conditions, the present assessment represents water availability as of 2026, while also accounting for more recent publicly available information. In addition, refinements have been incorporated where basin-specific information regarding the timing and seasonality of water use has become available to better characterize seasonal allocation patterns (e.g., North Saskatchewan River Water Management Roadmap project [41]).

Table 4 was prepared to accompany Figure 5. For both the median and dry year scenarios, Table 4 compares approximate annual river flows with the volume estimated to be available for new allocations, with rivers ranked in descending order of water availability (i.e., annually available volume). Although northern Alberta river basins generally support greater annual water availability than southern basins, water availability assessments should be undertaken at the relevant watershed and sub-basin scale, as conditions can vary considerably among individual rivers and tributaries.

**Table 4.** Summary of annual flow and water availability for the river basins and sub-basins of interest, ordered by approximate water availability.

| Basin | Sub-basin | Approximate annual flow ($dam^3/yr$) | | Approximate current water availability for new licences ($dam^3/yr$) | |
|---|---|---|---|---|---|
| | | Median Year | Dry Year | Median Year | Dry Year |
| Peace - Slave - Athabasca | Confluence of the Peace and Athabasca | 80,769,000 | 66,549,000 | 11,930,000 | 9,797,000 |
| | Peace | 60,047,000 | 50,124,000 | 8,973,000 | 7,485,000 |
| | Athabasca | 20,722,000 | 16,425,000 | 2,957,000 | 2,312,000 |
| North Saskatchewan | North Saskatchewan | 6,099,000 | 4,997,000 | 732,000 | 600,000 |
| Hay | Hay | 1,969,000 | 1,074,000 | 294,000 | 160,000 |
| Milk | Milk* | 294,000 | 243,000 | 64,300 | 49,000 |
| South Saskatchewan | Red Deer** | 1,584,000 | 1,149,000 | 61,000 | 61,000 |
| Beaver | Beaver | 357,000 | 197,00 | 35,000 | 12,000 |
| North Saskatchewan | Battle | 153,000 | 103,000 | 3,320 | 3,320 |
| South Saskatchewan | Bow | 3,627,000 | 2,858,000 | 0 | 0 |
| | Oldman<br>-----<br>Upper Oldman*** | 2,999,000 | 2,072,000 | 0<br>-----<br>0 | 0<br>-----<br>0 |
| | South Saskatchewan | 6,713,000 | 5,189,000 | 0 | 0 |

*Under the Milk River WMP, water is reserved under the WMP for very specific uses, which do not include nuclear power generation.

**The water availability indicated for the Red Deer River Basin is inclusive of the MD of Acadia & Special Areas Irrigation Project water licence application for 170,000 $dam^3/yr$ and the allocation limits established in the South Saskatchewan River Basin WMP (i.e., 600,000 $dam^3/yr$).

***Although the Oldman River Basin Water Allocation Order, which has priority over the closure of the South Saskatchewan River Basin, reserves up to 11,000 acre-ft/yr (approximately 13,560 $dam^3/yr$) of water available for allocations in the Upper Oldman River Basin each year, the Government of Alberta's recent Request for Proposal Number 27TDRWCE817 "Security of Water Supply in Alberta: A 100 Year Plan" notes that this volume has been fully allocated as of Spring 2026 [42].

Figure 6 presents the estimated water availability from Table 4 in descending order of available volume. These annual estimates should be considered alongside seasonal and interannual variability, which may affect the timing and reliability of water availability.

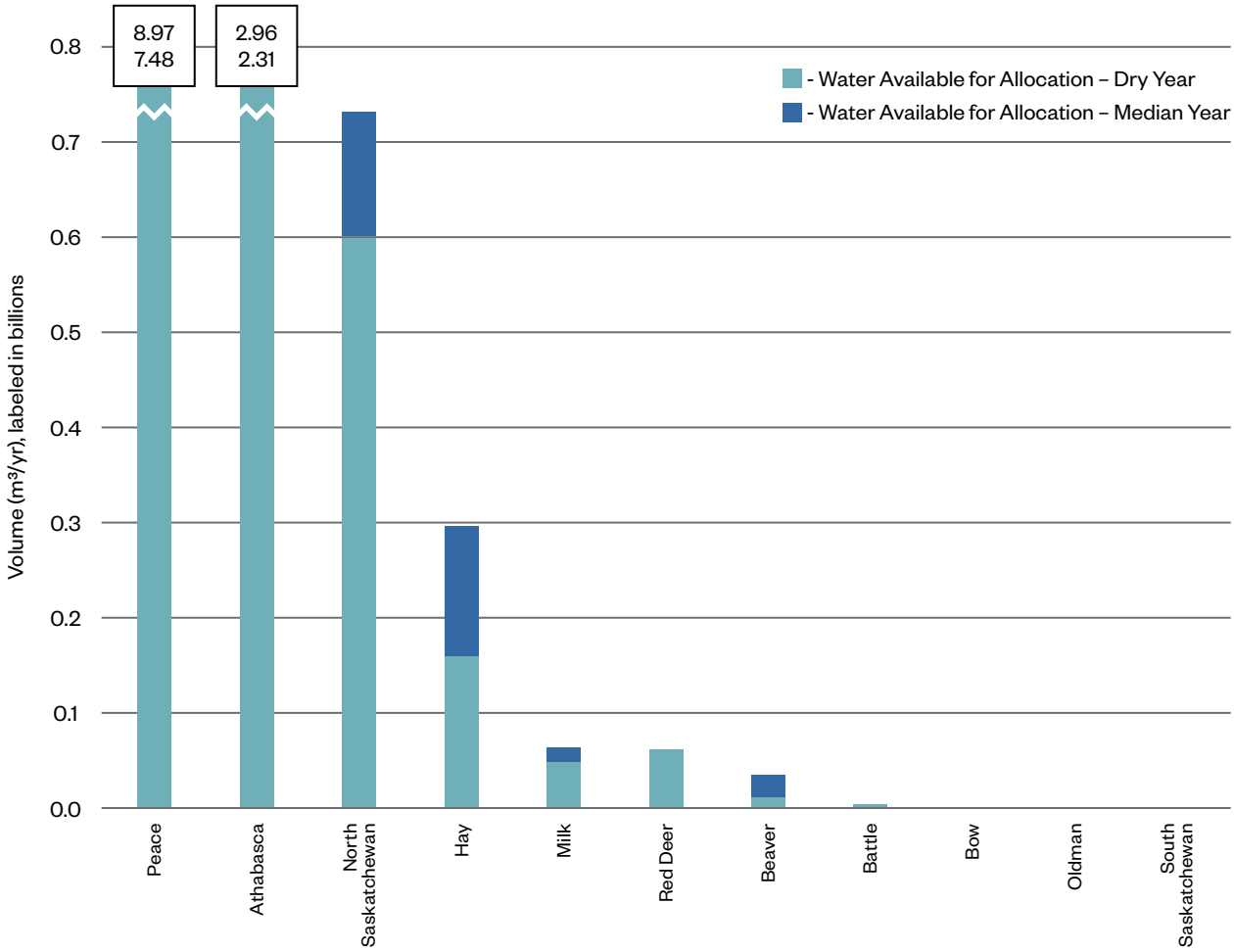



*Figure 6. High-level water availability for new allocations across the study area. The chart displays a stacked representation of water availability.*

## 4.5 Future Water Availability and Climate Change

Future water availability risks were evaluated by comparing anticipated increases in water demand in Alberta against potential climate change driven trends across two planning horizons, 2050 and 2100. Given the uncertainty associated with future climate projections, hydrologic response, water management decisions, and allocation patterns, this assessment does not attempt to quantify future water availability volumes and future river streamflow. Instead, it identifies river basins that may be more vulnerable to increasing water stress under potential future conditions.

### 4.5.1 Potential Future Water Demand

Basin-wide water demand for the 2050 and 2100 planning horizons was projected by scaling incremental consumptive demands proportional to provincial population growth. Population growth was selected as a water demand proxy as it broadly correlates with economic output and offers greater long-term data availability than other socioeconomic

indicators. Table 5 summarizes the low, medium, and high population growth forecasts considered in this analysis. For the 2050 horizon, projected water demands were correlated to the Government of Alberta's medium population growth estimate of 1.3% per year [43]. Extending the analysis to the 2100 horizon required additional consideration, as provincial population estimates do not project beyond 2050, and national population projections extend only to 2075 [44]. The medium-growth trajectory (i.e., M1) published by Statistics Canada's Demography Division on January 2026 was extrapolated from 2075 to 2100 and applied at the provincial scale.

**Table 5.** Population growth scenario projections [43, 44]

| Growth case | 2050 Horizon (Annual % growth) | 2100 Horizon (Annual % growth) |
|---|---|---|
| Low | 0.73% | 0.06% |
| Medium | 1.30% | 0.66% |
| High | 1.79% | 1.28% |

Table 6 presents the estimated incremental demand for new consumptive uses across the study area under the medium population growth scenario at the 2050 and 2100 planning horizons, derived by multiplying the cumulative growth percentage with estimated water use by basin in 2026. The Bow, Oldman, and South Saskatchewan River Basins were excluded from the assessment because they are closed to new water allocations, and any future water demand growth will need to be serviced from existing allocations (e.g., via transfers, intensification, reuse, etc.). As basin-wide water demands increase, available water for new licences will in turn decline across all river basins, with the extent of this reduction varying by existing allocation levels, regulatory constraints, and projected climate-driven changes in streamflow (Section 4.5.2).

**Table 6.** Total estimated incremental, annual water allocations on Alberta's river basins for non-nuclear demands, relative to the 2026 baseline.

| Basin | Sub-basin | Estimated annual water allocations in 2026 ($dam^3/yr$) | Estimated Incremental water demand ($dam^3/yr$) | |
|---|---|---|---|---|
| | | | By 2050 | By 2100 |
| Peace - Slave - Athabasca | Confluence of the Peace and Athabasca | 185,600 | 70,800 | 170,600 |
| | Peace | 34,000 | 13,000 | 31,300 |
| | Athabasca | 151,600 | 57,800 | 139,300 |
| North Saskatchewan | North Saskatchewan | 45,900 | 17,500 | 42,200 |
| Hay | Hay | 794 | 300 | 730 |
| Milk | Milk | 16,800 | 6,400 | 15,400 |
| South Saskatchewan | Red Deer | 538,700 | 123,700 | 298,200 |
| Beaver | Beaver | 18,900 | 7,200 | 17,400 |
| North Saskatchewan | Battle | 3,300 | 1,200 | 3,000 |

*The water allocation for the Red Deer River Basin is inclusive of the administratively complete Municipal District of Acadia & Special Areas Irrigation Project water licence application for 170,000 $dam^3/yr$.

Note that these estimates should not be interpreted as indicating that all projected water demand could be met under current water availability conditions (e.g., Red Deer River Basin). The actual growth in water demand will be influenced by region-specific factors, including municipal growth patterns, industrial investment, irrigation development, energy-sector activity, water sharing between users, widespread water recycling, and changes in water-use efficiency. As a result, future demand within individual river basins may increase or decrease at rates that differ from the provincial average considered in this study. Furthermore, where projected water demand growth exceeds current water availability estimates, future development would need to be supported by water demand management, alternative water supplies, or other adaptive measures.

### 4.5.2 Projected Future Changes to Water Availability

As part of the 2025 Study of Water Impacts of CCUS Development in Alberta, Hazen Canada prepared a provincial-scale climate change model to estimate potential water availability across Alberta's major river basins (HUC2 scale) under two future climate scenarios (SSP2-4.5 and SSP-8.5). That analysis applied the Raven Hydrological Modelling Framework with spatially distributed climate forcings, expressing water availability as the difference between precipitation and potential evapotranspiration over a continuous 2021–2081 projection window.

The present assessment (Appendix B) builds on this foundation while introducing several methodological refinements. Rather than applying a process-based hydrological framework, water availability is characterized through a statistical water balance based on the Climate Moisture Index (CMI)[9], evaluated across four discrete 20-year normals (i.e., 2021–2040, 2041–2060, 2061–2080, and 2081–2100) to align with standard climate reporting periods. The analysis is also resolved at the more granular HUC10 sub-basin scale, with upstream flow-path routing applied so that each sub-basin reflects the aggregated climate conditions of its full contributing area.

The key results from this analysis, shown in Figure 7, indicate increases to both precipitation and evaporation across Alberta relative to the 2001-2020 baseline, with distinct regional patterns. In northern Alberta, projected precipitation increases are generally sufficient to produce positive shifts in CMI as a proxy for water availability, while central basins remain comparatively stable. In contrast, southern basins, including the Milk, South Saskatchewan, and Red Deer basins are projected to experience evaporation increases that exceed precipitation gains, resulting in larger moisture deficits. These regional contrasts become more pronounced in later-century projections and under higher emissions scenarios, particularly SSP-8.5.

The results should be interpreted within the context of several limitations:

- The analysis is confined to Alberta and does not account for transboundary inflows originating in British Columbia or Montana, potentially underestimating water availability in basins such as the Peace, St. Mary, and Milk rivers.
- The water balance was evaluated using annual precipitation and evaporation totals and does not capture seasonal fluctuations in streamflow.
- The assessment does not incorporate land cover effects, hydrologic connectivity, or prairie pothole dynamics, nor water withdrawals, reservoir operations, or other flow regulation practices.

[9] CMI represents the annual sum of net moisture deficit (i.e., precipitation minus evaporation).

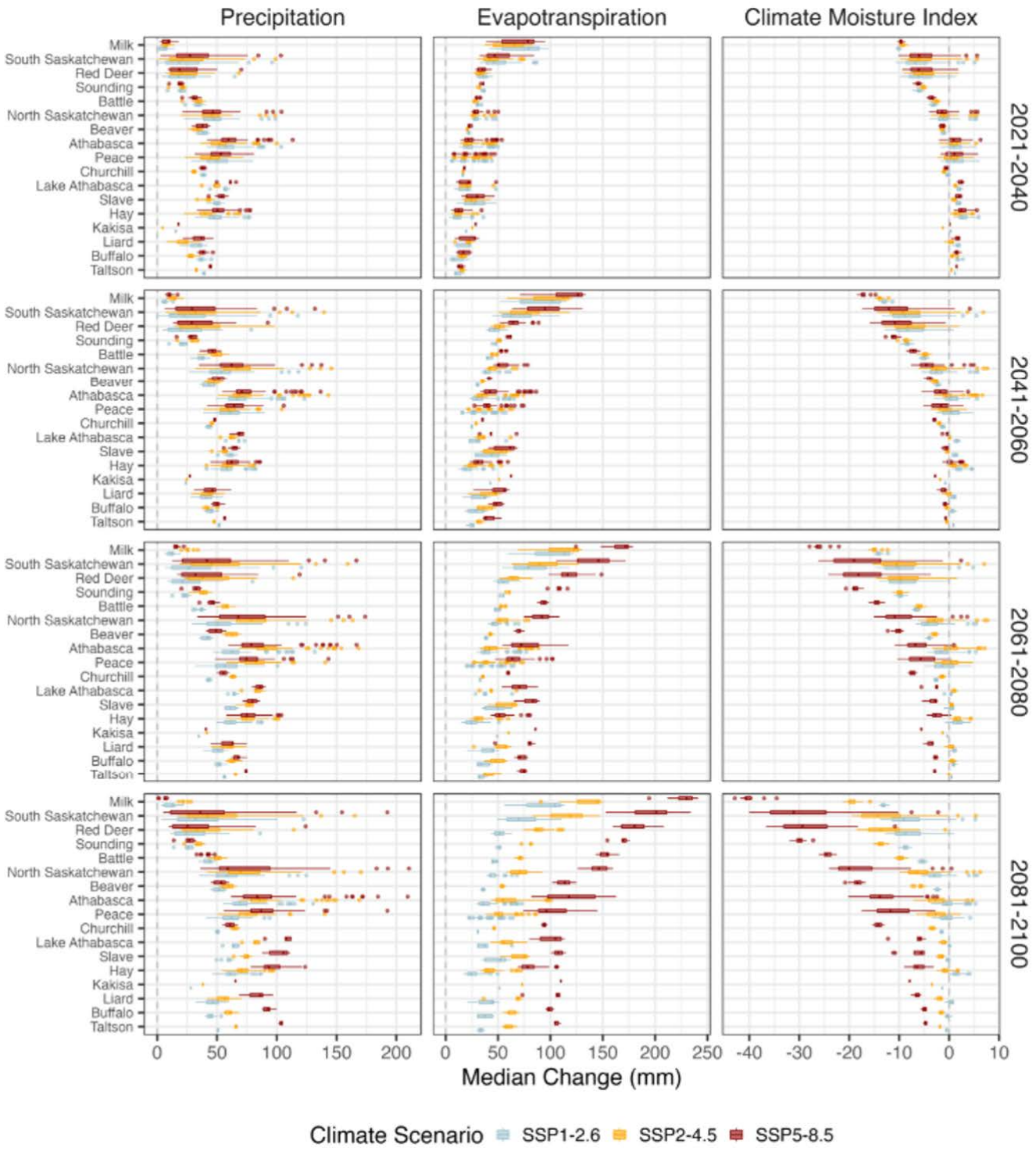



*Figure 7. Median change in CMI, Evaporation, and Precipitation relative to the 2001-2020 baseline.*

### 4.5.3 Future Water Availability Highlights

As previously discussed, this assessment does not attempt to predict future streamflows or quantify future water availability due to uncertainties related to climate conditions, hydrologic response, water management decisions, and allocation patterns. Table 7 provides a qualitative summary of potential future water availability conditions across Alberta's major river basins, based on the projected balance between precipitation and evaporation relative to the 2001-2020 baseline period. These summaries are intended to characterize broad hydrologic patterns and relative basin responses under future climate scenarios, and to provide context for the estimated incremental water demands discussed in Section 4.5.1. Note that the incremental water demand estimates should not be interpreted as a fixed projection, since basin-specific growth will depend on local development patterns and potential changes in practices like water reuse, alternative water supply sourcing, and water use efficiency, among others.

**Table 7.** Qualitative highlights of future water availability, with basins organized from north to south.

| Basin | Sub-basin | Hydroclimatic Progression and Trends (2050 and 2100 Horizons) | Approximate current (2026) water availability for new licences ($dam^3/yr$) | | Estimated Incremental water demand ($dam^3/yr$) | | Qualitative Highlights |
|---|---|---|---|---|---|---|---|
| | | | Median Year | Dry Year | By 2050 | By 2100 | |
| Hay | Hay | Projected increases in precipitation generally keep pace with increases in evaporation through mid-century. By late century, precipitation is projected to increase by approximately 20-30% under SSP5-8.5, supporting continued water availability relative to many southern Alberta basins. | 294,000 | 160,000 | 300 | 730 | Current water availability is large relative to projected incremental demand in 2050 and 2100. Future allocation risk appears low. |
| Peace - Slave - Athabasca | Peace | Precipitation is projected to increase more substantially than in southern Alberta throughout the projection period. These increases generally offset higher evaporation rates, contributing to continued water availability through 2100. | 8,973,000 | 7,485,000 | 13,000 | 31,300 | Current water availability is large relative to projected incremental demand in 2050 and 2100. Future allocation risk appears low at the major basin scale, but conditions in tributaries should still be assessed. |
| Peace - Slave - Athabasca | Athabasca | Increased precipitation in upstream headwater regions contributes to relatively consistent water availability through both mid- and late-century periods. While evaporation is projected to increase over time, gains in upstream precipitation help maintain basin-scale moisture conditions. | 2,957,000 | 2,312,000 | 57,800 | 139,300 | Current water availability is large relative to projected incremental demand in 2050 and 2100. Future allocation risk appears low at the major basin scale, but conditions in tributaries should still be assessed. |
| Beaver | Beaver | Moderate increases in precipitation are projected across the basin, alongside rising evaporation. These competing influences suggest a gradual downward shift in basin moisture conditions through the latter half of the century, particularly under higher-emission scenarios. The basin was not identified among those with the most pronounced projected changes. | 35,000 | 12,000 | 7,200 | 17,400 | Current water availability is of a similar order of magnitude to projected incremental water demand in 2050 and 2100, indicating a moderate to high risk to future allocation, especially during dry years. In the context of nuclear power generation, proposed projects within this basin should consider low water use cooling technologies to reduce potential water supply constraints in the future. |
| North Saskatchewan | North Saskatchewan | Projected increases in precipitation and evaporation remain broadly comparable through mid-century, resulting in relatively stable basin conditions. Contributions from upstream headwaters help support long-term water availability despite increasing evaporative losses. | 732,000 | 600,000 | 17,500 | 42,200 | Findings from the North Saskatchewan River Basin Water Management Roadmap indicate that the mainstem may support additional population and industrial growth, pending the determination of IFNs [41]:<br>• Headwater contributions and control structures (e.g., Bighorn Dam) provide some resilience to future climate change.<br>• Tributaries (such as Sturgeon and Vermilion Rivers) are at risk of impact from climate pressures and cannot sustain economic and population growth demands. |
| North Saskatchewan | Battle | Limited headwater contributions and rising evaporation are projected to have a greater influence on basin moisture conditions over time. Relative to other Alberta basins, the Battle Basin exhibits a greater potential for reductions in water availability under future climate scenarios. | 3,320 | 3,320 | 1,200 | 3,000 | Current water availability is of a similar order of magnitude to projected incremental water demand in 2050 and 2100, indicating a moderate to high risk to future allocation, especially during dry years. In the context of nuclear power generation, proposed projects within this basin should consider low water use cooling technologies to reduce potential water supply constraints. |

| Basin | Sub-basin | Hydroclimatic Progression and Trends (2050 and 2100 Horizons) | Approximate current (2026) water availability for new licences ($dam^3/yr$) | | Estimated Incremental water demand ($dam^3/yr$) | | Qualitative Highlights |
|---|---|---|---|---|---|---|---|
| | | | Median Year | Dry Year | By 2050 | By 2100 | |
| South Saskatchewan | Red Deer | Projected increases in evaporation are expected to exceed precipitation gains, contributing to a gradual reduction in basin moisture availability over time. While some increases in precipitation may occur in the headwater regions, these gains are generally not projected to fully offset increasing evaporative losses across the basin. | 61,000 | 61,000 | 123,700 | 298,200 | Current water availability is lower than the projected incremental water demand in 2050 and 2100. Future allocation risk appears high at the major basin scale. In the context of nuclear power generation, proposed projects within this basin should consider low water use cooling technologies to reduce potential water supply constraints. |
| South Saskatchewan | Bow | Modest precipitation increases are projected in portions of the headwaters; however, rising evaporation is expected to influence overall basin moisture conditions. As a result, future hydrologic conditions may become more variable across the basin, particularly under higher-emission scenarios. | 0 | 0 | 0 | 0 | The Bow River Basin is closed to new surface water allocations. Future water requirements for new projects would likely be met through the transfer of existing allocations and the use of alternative water sources. In the context of nuclear power generation, proposed projects within this basin should consider low water use cooling technologies to reduce potential water supply constraints. |
| South Saskatchewan | Oldman | Limited precipitation increases relative to rising evaporation are projected to influence basin moisture conditions through the century. This response is broadly consistent with projected changes across much of southern Alberta, where evaporative demand is expected to increase over time. | 0 | 0 | 0 | 0 | While water has been reserved for future development within the Oldman River Basin, much of this reservation has already been committed to identified projects and users. Water requirements for new projects would likely be met through the transfer of existing allocations and the use of alternative water sources. In the context of nuclear power generation, proposed projects within this basin should consider low water use cooling technologies to reduce potential water supply constraints. |
| South Saskatchewan | South Saskatchewan | Projected increases in evaporation are expected to exceed precipitation gains through time, contributing to progressively lower moisture availability by late century, particularly under SSP5-8.5. | 0 | 0 | 0 | 0 | The South Saskatchewan River Basin is closed to new surface water allocations. Future water requirements for new projects would likely be met through the transfer of existing allocations and the use of alternative water sources. In the context of nuclear power generation, proposed projects within this basin should consider low water use cooling technologies to reduce potential water supply constraints. |
| Milk | Milk | The basin is projected to exhibit some of the lowest Climate Moisture Index values in the province. Mid-century moisture deficits are projected to approach approximately -50 mm/year, increasing to approximately -65 mm/year by 2070 and -120 mm/year by 2100 under SSP5-8.5. These projections indicate a continuing trend toward lower moisture availability relative to other Alberta basins. | 64,300 | 49,000 | 6,400 | 15,400 | Current water availability is of a similar order of magnitude to projected incremental water demand in 2050 and 2100, indicating a moderate to high risk to future allocation, especially during dry years.<br><br>Water availability for new allocations is reserved under the WMP for very specific uses, which do not include nuclear power generation. In the context of nuclear power generation, proposed projects within this basin should consider low water use cooling technologies to reduce potential water supply constraints. |

# 5. Potential Nuclear Power Deployment in Alberta

This section presents the nuclear deployment scenarios considered in this study, including the assumptions and analytical approach used to evaluate their potential water demands. The objective is not to predict nor endorse future development, but rather to explore hypothetically representative deployment pathways and the range of potential water demands associated with nuclear energy generation in the province. These hypothetical, "what if?" scenarios examine the implications of alternative future nuclear power deployment conditions to support planning and decision-making.

The analysis is structured around two complementary approaches:

- **"Baseline" Scenario:** A plausible nuclear deployment pathway that incorporates announced nuclear developments and their potential contribution to Alberta's electricity system within the 2050 and 2100 planning horizons.
- **Case studies:** A series of conceptual deployment configurations evaluated independently of the Baseline Scenario. These case studies illustrate how different reactor technologies, desired facility power output, and regional siting opportunities could influence water demands.

The Baseline Scenario and case studies were informed by available data, forecasts, announced deployment plans, and discussions with strategic partners, thereby incorporating the collective experience of a broad and well-informed cross-section of government and industry stakeholders. The water demands associated with both the Baseline Scenario and the individual case studies are evaluated in Section 6.

## 5.1 Baseline Scenario

Future electricity demand in Alberta was projected using preliminary assumptions from the Alberta Electric System Operator's (AESO) 2026 Long-Term Outlook (LTO) Plan Assumptions and Scenarios Matrix[10], recognizing the uncertainty associated with long-term forecasting in an evolving electricity landscape [45]. Under the preliminary 2026 LTO current measures scenario (i.e., 2026 CM), the Alberta Internal Load (AIL) is expected to grow materially from 2025 to 2050, reflecting higher electricity demand associated with large loads (i.e., data centres, hydrogen production, CCUS, and project-specific loads) and overall electrification of transportation and buildings. During this period, the AIL is projected to increase from approximately 10.3 GW to 14.8 GW, while peak demand is projected to grow from approximately 12.8 GW to 19.3 GW. These trajectories are illustrated by the blue lines in Figure 8 and Figure 9 respectively, which are excerpted from the AESO's Plan Assumptions and Scenarios Matrix.

[10] At the time of this assessment, the AESO's 2026 Long-Term Outlook Plan Assumptions and Scenarios Matrix remained subject to stakeholder review. Any updates incorporated by the AESO following the close of the comment period on August 7, 2026 are not reflected in this analysis.

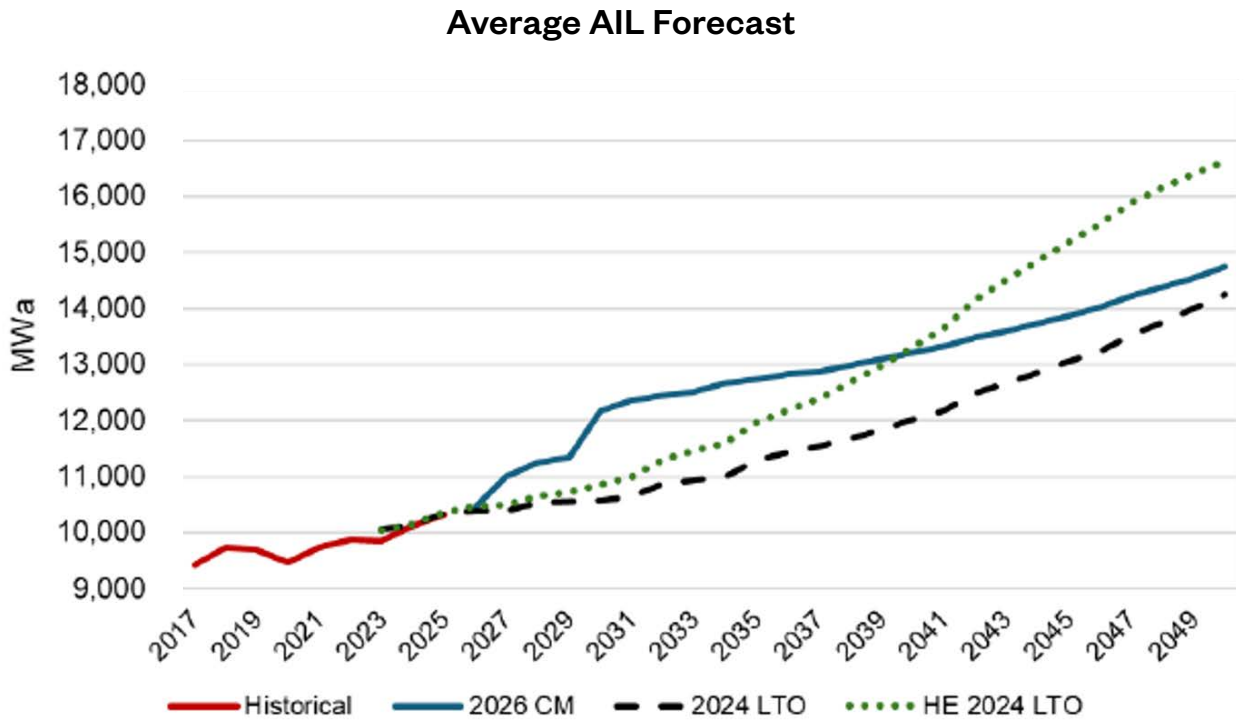



*Figure 8. Average Alberta Internal Load Forecast. The black and green lines represent the 2024 Reference Case and High Electrification (HE) Scenarios respectively [45].*

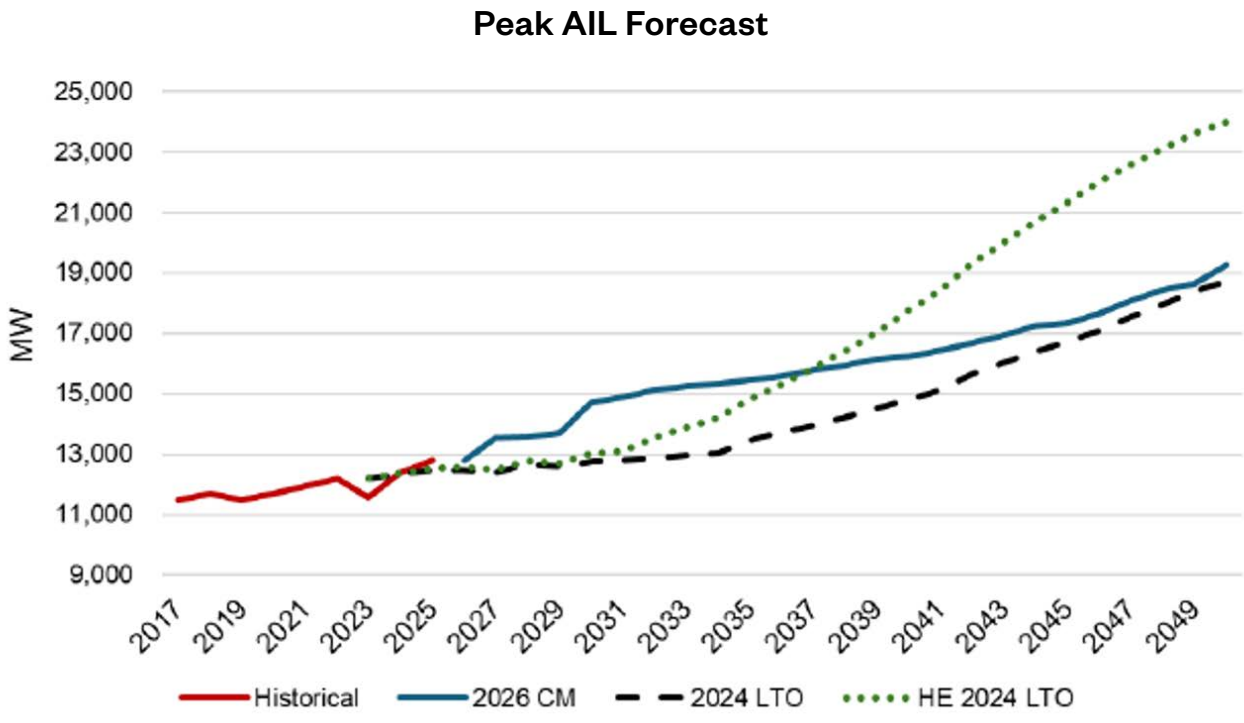



*Figure 9. Peak Alberta Internal Load Forecast. The black and green lines represent the 2024 Reference Case and High Electrification (HE) Scenarios respectively [45].*

Although electricity demand growth could be expected to moderate from 2050 to 2100 compared to the 2025 to 2050 period due to post-electrification saturation of different sectors of the economy, the combination of gradual load increases and replacement needs of existing generation assets is expected to create opportunities for new generating capacity over the same period. These conditions support consideration of nuclear generation as a potential long-term contributor to Alberta's future electricity supply. Sub-sections 5.1.1 and 5.1.2 describe the core assumptions underlying the Baseline Scenario for the 2050 and 2100 planning horizons respectively.

### 5.1.1 2050 Horizon

The 2050 Baseline Scenario incorporates two announced nuclear developments in Alberta that could be operational within the assessment horizon. These include the proposed 4,800 MW Peace River Nuclear Project by Energy Alberta and a potential 600 MW SMR project being evaluated by Capital Power and Ontario Power Generation in north-central Alberta (North Saskatchewan River Basin - Wabamun Area). For the purposes of this analysis, both developments were assumed to be operating by 2050, reflecting their successful advances through planning, licensing, and construction. The associated generating capacities are summarized in Table 8 and Table 9.

**Table 8.** 2050 Horizon (new nuclear power generation capacity by reactor technology).

| Potential Deployment | Capacity (MW) |
|---|---|
| Peace River Nuclear Project<br>Assumed AP-1000 reactor | 4,800 |
| SMR Additions to the grid<br>Assumed BWRX-300 reactor | 600 |
| **Total** | **5,400** |

**Table 9.** 2050 Horizon (new nuclear power generation capacity by river basin).

| River Basin | Capacity (MW) |
|---|---|
| Peace<br>Assumed AP-1000 reactor | 4,800 |
| North Saskatchewan<br>Assumed BWRX-300 reactor | 600 |
| **Total** | **5,400** |

### 5.1.2 2100 Horizon

As the AESO 2026 Long-term Outlook (LTO) does not project beyond 2050, an alternative assumption was developed to represent conditions during the second half of the century. In 2024, the Canadian Nuclear Association (CNA) commissioned a study to evaluate Canada's future electricity requirements and potential nuclear development pathways through 2050. The study developed three national build case scenarios, including a high-build case in which nuclear generation supplies approximately 45% of new electricity demand. This assessment adopts the high-build case as a representative upper-bound assumption for Alberta and applies this target beyond 2050 to inform the 2100 Baseline Scenario [46].

Under an illustrative assumption that the AIL continues to grow at a CAGR of 1.0%[11] between 2050 and 2100, load would increase from approximately 14.8 GW in 2050 to 24.3 GW by 2100. Relative to 2025 demand levels, this represents approximately 14 GW of incremental load over the 2025 - 2100 period. Applying the CNA high-build assumption of 45% of incremental electricity demand being supplied by nuclear generation results in a total nuclear capacity requirement of approximately 6.3 GW by 2100. Because the 2050 Baseline Scenario already includes 5.4 GW of nuclear capacity (Section 5.1.1), an additional 900 MW[12] was assumed to be added between

[11] A post-2050 CAGR of 1.0% was assumed for illustrative purposes to reflect a gradual moderation in electricity demand growth relative to the accelerated electrification period preceding 2050.

[12] The 900 MW of additional generation capacity was allocated equally among the Peace, Athabasca, and North Saskatchewan River Basins (i.e., 300 MW per basin) for the purposes of this assessment. This simplifying assumption was adopted to evaluate potential water demand implications across multiple regions, in the absence of specific project siting information.

2050 and 2100 to maintain this proportional contribution to future load growth. This additional capacity was modelled as a BWRX-300 reactor[13], as seen in Table 10 and Table 11.

**Table 10.** 2050 and 2100 Horizon (new nuclear power generation capacity by reactor technology).

| Potential Deployment | Capacity (MW) |
|---|---|
| Peace River Nuclear Project<br>Assumed AP-1000 reactor | 4,800 |
| SMR Additions to the grid<br>Assumed BWRX-300 reactor | 1,500 |
| **Total** | **6,300** |

**Table 11.** 2050 and 2100 Horizon (new nuclear power generation capacity by river basin).

| River Basin | Capacity (MW) |
|---|---|
| Peace<br>Assumed AP-1000 and BWRX-300 reactors | 5,100 |
| North Saskatchewan<br>Assumed BWRX-300 reactor | 900 |
| Athabasca<br>Assumed BWRX-300 reactor | 300 |
| **Total** | **6,300** |

## 5.2 Case Study-Based Assessment of Potential Nuclear Deployment

The case studies introduced in this section explore individual, hypothetical scenarios derived from the Low, Medium, and High water use ranges described in Section 3. As noted, the purpose of the case studies is to assess how alternative nuclear power deployment assumptions could influence water demand and water availability constraints across a range of spatial and temporal scales, including province-wide, location-specific, and seasonal analyses. Collectively, the case studies support informed decision-making by helping project developers, policymakers, regulators, and the public consider potential risks, opportunities, and trade-offs associated with different nuclear power development pathways.

### 5.2.1 Case Study Selection

The case studies were developed to examine four thematic areas relevant to nuclear deployment and water management considerations in Alberta. For consistency, all scenarios assume constant full-power operation throughout the year; actual water demands may be lower where generation output varies over time due to actual capacity factors, outage schedules, maintenance periods and load following operation:

- **Case Studies 1 and 2: Industrial heat and steam supply**
    - The assessment assumes the deployment of two Xe-100 SMRs in the Lower Athabasca River Basin (Case Study 1) and North Saskatchewan River Basin (Case Study 2). Each reactor is assumed to produce 200 MWth of heat and 80 MWe[14] of electricity (i.e., thermal efficiency of 40%). Present-day (2026) water availability was selected to isolate demand-related considerations from the additional uncertainty associated with projecting future hydrologic conditions, as discussed in Section 4.5. Water availability was estimated using aggregated weekly flow data, while applicable constraints from WMPs and instream flow needs were also considered.

[13] Ontario Power Generation recently selected the BWRX-300 SMR for the Darlington New Nuclear Project [61]. Accordingly, this assessment uses the technology as a Canadian reference for potential future SMR deployment, including in Alberta, where Capital Power (in collaboration with Ontario Power Generation) is evaluating the feasibility of SMR developments [67].

[14] MW thermal (MWth) measures the rate of heat energy produced or consumed by a system, while MW electric (MWe) describes the final usable electricity produced after conversion losses.

- **Case Studies 3, 4, and 5: Grid-scale electricity generation**
  - The assessment evaluates deployment of two BWRX-300 SMRs, providing a combined generating capacity of 600 MWe. Three representative locations were considered: the North Saskatchewan, Red Deer River, and Battle River Basins.
  - The North Saskatchewan River and Red Deer River Basins case studies represent a facility on land that has not been used for power generation purposes or require a new water allocation.
  - The Battle River Basin case study represents the redevelopment of an existing natural gas-fired power generation facility as a 600 MWe SMR. The case study assumes that an existing water allocation associated with the facility remains available to support the redeveloped site. The case study highlights that facility redevelopment opportunities may offer advantages to new projects through access to existing infrastructure, electrical transmission networks, water management systems, and licensed water allocations. These characteristics may reduce the extent of new infrastructure required and potentially improve overall project feasibility.
  - Water demands were evaluated relative to 2026 water availability conditions. Water availability was estimated from aggregated weekly flow data, while WMP and IFN constraints were considered where relevant. For the Battle River Basin, existing licensed water allocations for power generation were also considered, reflecting the likelihood that a hypothetical SMR facility could rely on the transfer or repurposing of existing allocations for power generation.
- **Case Study 6: Data centre power supply**
  - The assessment compares the cooling water requirements of BWRX-300 SMRs and NGCC facilities to supply power for 1,200 MW of data centre load, consistent with the AESO's interim large-load connection framework as of August 2026 [47]. The analysis is conducted at a provincial scale and considers only power generation cooling demands, excluding water use associated with data centre operations[15]. SMR water demand estimates are based on the applicable Industrial Heartland location water use range (as discussed in Section 3.1), while NGCC water use ranges were obtained from published literature for the cooling technologies evaluated.
  - This comparison is intended solely to illustrate differences in cooling water requirements and should not be interpreted as a broader comparison of overall environmental performance between different power generation technologies. Future evaluation of generation technologies should also consider factors such as lifecycle greenhouse gas emissions, air quality impacts, fuel supply requirements, waste management, land use, reliability, and other environmental, technical, and economic considerations.
- **Case Study 7: Water availability and seasonal constraints**
  - The assessment evaluates the seasonal evaporative cooling water requirements of a 1,200 MWe (AP-1000) nuclear reactor at the proposed Peace River Nuclear Project location. Monthly water demands were estimated using the WAMP under average monthly temperature conditions and compared to the Peace River's monthly water availability under median and lower-quartile flow conditions to explore the interaction between seasonal cooling demands and water availability.

[15] This assumption is supported by the growing adoption of closed-loop and other low-water cooling technologies in modern data centres, which substantially reduce direct consumptive water requirements compared to traditional evaporative cooling systems. The water use dynamics of data centres offer a topic for future study.

- Note that the results of this case study **do not** represent project-specific engineering, design, or operational forecasts. Rather, they demonstrate how seasonal temperature may influence cooling water requirements of a nuclear power generation project.

Collectively, these case studies illustrate how deployment objectives, technology selection, and site-specific conditions can influence the magnitude and timing of water requirements associated with nuclear energy development in Alberta.

Note that the water demand calculations presented for all case studies assume continuous full-power operation throughout the year. In practice, annual and seasonal water requirements will be influenced by facility-specific operating conditions, including capacity factors, planned and unplanned outage schedules, maintenance activities, and load-following operation. These factors can substantially affect the timing and magnitude of water withdrawals and consumptive use by reducing water demands during periods of reduced generation or plant shutdown. As a result, the estimated water demands presented in this assessment should be considered an upper-bound scenario, as actual water requirements may be lower depending on facility operating characteristics. Site-specific assessments should account for these operational considerations when evaluating water supply requirements and potential impacts on water resources.

# 6. Potential Water Impacts of Nuclear Power in Alberta

This section presents the results of the Baseline Scenario and case study assessments introduced in Section 5. The results are organized by deployment scenario and focus on the estimated water demands associated with nuclear power generation, comparisons to available water supplies where applicable, and the implications of technology, location, and cooling system selection on water use. As noted, the results reflect hypothetical, indicative scenarios, and are not intended as predictions of future outcomes. As discussed in Section 4.5, future water availability and streamflow were not quantified due to uncertainties related to climate, hydrologic response, water management, and allocation patterns.

## 6.1 Baseline Water Demand: Province-Wide Results

Table 12 and Table 13 present the estimated baseline water use results based on the per-unit water demand ranges established for different nuclear technologies in Section 3.1. The scenario assumes development of the Peace River Nuclear Project and one 600-MWe SMR project by 2050, with a further 900 MWe of SMR capacity added between 2050 and 2100.

The Peace River Nuclear Project has publicly indicated its intent to use evaporative cooling; consequently, its estimated Low, Medium, and High water use ranges reflect the range of potential water demands associated with an evaporative cooling system (i.e., High use per-unit water demand).

**Table 12.** Baseline water use results by reactor.

**2050 Horizon**

| Potential Deployment | Capacity (MWe) | Low Use ($dam^3/yr$) | Medium Use ($dam^3/yr$) | High Use ($dam^3/yr$) |
|---|---|---|---|---|
| Peace River Nuclear Project | 4,800 | 101,756 | 101,756 | 101,756 |
| SMR Additions to the grid | 600 | - | 10,802 | 13,772 |
| **Total** | **5,400** | **101,756** | **112,558** | **115,529** |

**2100 Horizon**

| Potential Deployment | Capacity (MWe) | Low Use ($dam^3/yr$) | Medium Use ($dam^3/yr$) | High Use ($dam^3/yr$) |
|---|---|---|---|---|
| Peace River Nuclear Project | 4,800 | 101,756 | 101,756 | 101,756 |
| SMR Additions to the grid | 1,500 | - | 26,465 | 33,648 |
| **Total** | **6,300** | **101,756** | **128,221** | **135,404** |

**Table 13.** Baseline water use results by river basin.

**2050 Horizon**

| Basin | Total annual water demand ($m^3/yr$) | | |
|---|---|---|---|
| | Low Use ($dam^3/yr$) | Medium Use ($dam^3/yr$) | High Use ($dam^3/yr$) |
| Peace | 101,756 | 101,756 | 101,756 |
| Athabasca | - | - | - |
| North Saskatchewan | - | 10,802 | 13,772 |
| **Total** | **101,756** | **112,558** | **115,529** |

**2100 Horizon**

| Basin | Total annual water demand ($m^3/yr$) | | |
|---|---|---|---|
| | Low Use ($dam^3/yr$) | Medium Use ($dam^3/yr$) | High Use ($dam^3/yr$) |
| Peace | 101,756,160 | 106,977 | 108,381 |
| Athabasca | - | 5,221 | 6,625 |
| North Saskatchewan | - | 16,023 | 20,398 |
| **Total** | **101,756** | **128,221** | **135,404** |

Overall, the Baseline Scenario indicates that nuclear-related cooling water demands could be concentrated within the Peace River Basin under both assessment horizons, reflecting the assumed deployment of the Peace River Nuclear Project and its use of evaporative cooling. Additional SMR deployment increases total annual water demand from approximately 113,000 to 116,000 $dam^3$/year in 2050, to between 128,000 and 135,000 $dam^3$/year in 2100 under the Medium and High Water Use ranges. Figure 10 compares the potential Baseline Scenario water demand against projected increases in demand across Alberta (modelled in **Table 6**).

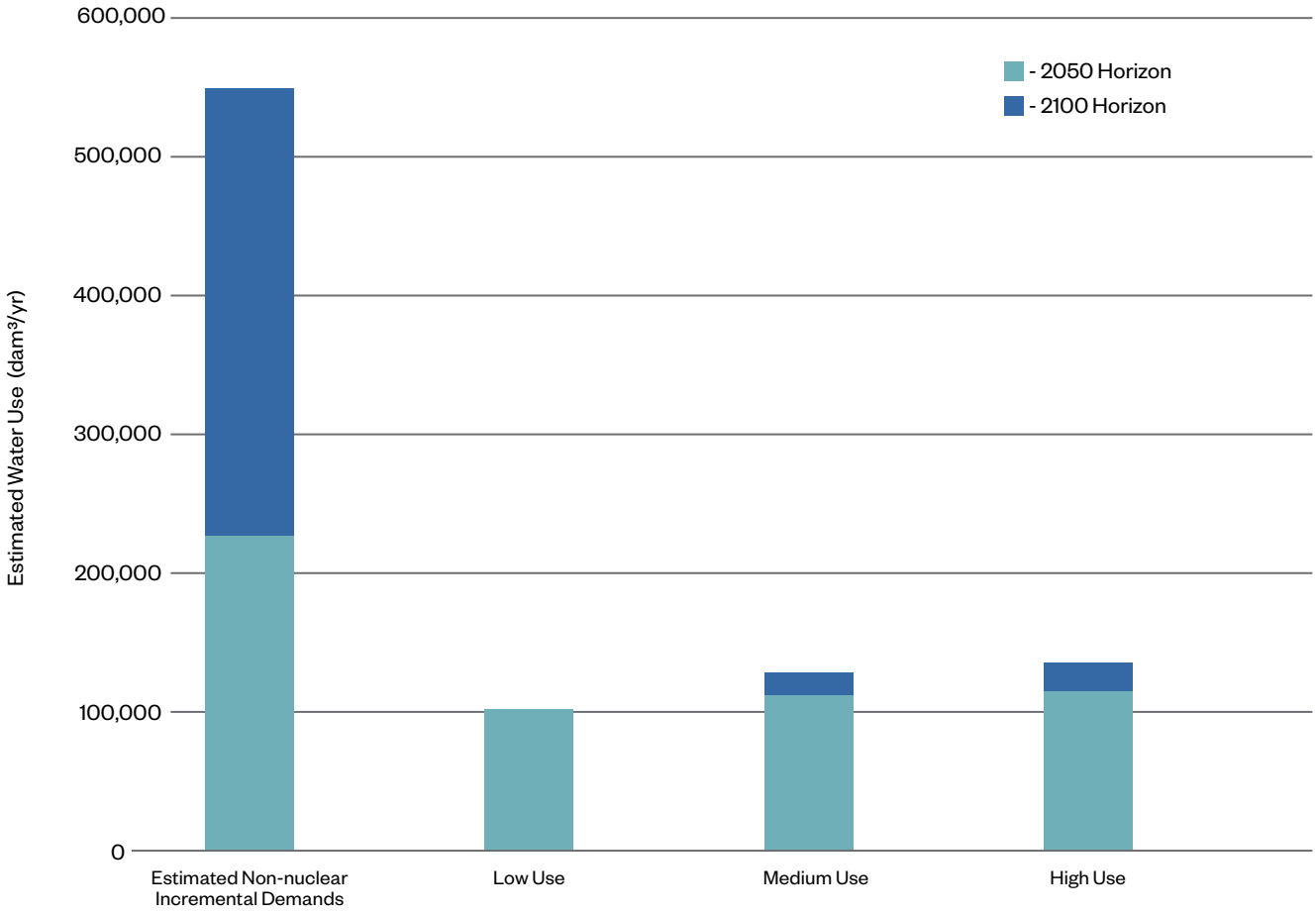



*Figure 10. Province-wide comparison between Baseline Scenario water use and estimated non-nuclear incremental demands by 2050 and 2100.*

These Baseline Scenario water demands are of a similar order of magnitude to, though significantly lower than, the anticipated growth in water use within the province's river basins (per Section 4.5.1). It is important to recognize that the development of additional power generation capacity would introduce water demands under a range of generation pathways, with requirements varying according to the technology, cooling system, facility design, and operating conditions. Nuclear development therefore represents one of several potential contributors to future water demand in Alberta and reinforces the importance of considering regional water availability, existing allocation pressures, and long-term growth across all water-using sectors (i.e., within the context of the water-energy nexus).

## 6.2 Case Study 1 - SMR in the Oil Sands to Provide Steam and Power

This case study evaluates the deployment of two Xe-100 SMRs to provide process heat and electricity for oil sands operations within the Athabasca River Basin. The Athabasca River Basin supports oil sands production, where water is required for extraction and processing activities. Table 14 summarizes the estimated annual water demand for the Case Study 1 oil sands deployment scenario.

**Table 14.** Estimated annual water demand for Case Study 1.

| Hours in a year (h) | Total Power-Capacity (MWe) | Total Energy (MWh) | Low Use ($dam^3/yr$) | Medium Use ($dam^3/yr$) | High Use ($dam^3/yr$) |
|---|---|---|---|---|---|
| 8,760 | 160 | 1,401,600 | - | 2,149 | 2,717 |

The Athabasca River mainstem generally exhibits high water availability due to its extensive tributary network and annual flow volumes which are large relative to both basin water demands and other river basins in Alberta. Consistent with these characteristics, the estimated water demands associated with the deployment of two Xe-100 reactors represent a small proportion of available water under both median and dry-year conditions, as shown in Table 15.

**Table 15.** Estimated water use as a percentage of annually available water in 2026.

| Case Study Water Use Demand | Low | Medium | High |
|---|---|---|---|
| Estimated annual water use ($dam^3/yr$) | 0 | 2,149 | 2,717 |
| Water available in a dry flow year before nuclear demands ($dam^3/yr$) | 2,312,000 | | |
| Equivalent use percentage of total water available | 0% | 0.09% | 0.12% |
| Water available in a median flow year before nuclear demands ($dam^3/yr$) | 2,957,000 | | |
| Equivalent use percentage of total water available | 0% | 0.07% | 0.09% |

From an annual water availability perspective, the results suggest that the SMR water demands evaluated in this case study are unlikely to represent a significant constraint on deployment within the basin. Additionally, future SMR developments may not necessarily require a net new water allocation. Depending on project location and ownership arrangements, water requirements could potentially be met through the transfer, acquisition, or repurposing of existing licensed allocations. Note that periods of reduced streamflow, regulatory restrictions, or competing water demands may influence the availability of water at specific times of the year, even where annual supplies appear sufficient. For additional discussion of how seasonal water demands interact with seasonal water availability, refer to Case Study 7.

## 6.3 Case Study 2 - SMR in the Industrial Heartland to Provide Steam and Power

This case study evaluates the deployment of two Xe-100 SMRs to provide process heat and electricity to industrial operations in the Alberta Industrial Heartland. The Alberta Industrial Heartland is a major industrial hub northeast of Edmonton that hosts petrochemical, refining, fertilizer, hydrogen, and other energy-intensive industries. These facilities rely on water from the North Saskatchewan River for cooling, steam generation, and as raw process input (e.g., process solvent).

Table 16 summarizes the estimated annual water demand for the Case Study 2 deployment scenario. Estimated water demands are slightly higher than those presented in Case Study 1 despite the use of the same reactor technology, reflecting regional differences in climatic conditions as discussed in Section 3.1.1. In particular, the warmer ambient temperatures at the Industrial Heartland result in increased cooling-related water requirements and correspondingly higher overall water demands.

**Table 16.** Estimated annual water demand for Case Study 2.

| Hours in a year (h) | Total Power-Capacity (MWe) | Total Energy (MWh) | Low Use ($dam^3/yr$) | Medium Use ($dam^3/yr$) | High Use ($dam^3/yr$) |
|---|---|---|---|---|---|
| 8,760 | 160 | 1,401,600 | - | 2,240 | 2,843 |

The North Saskatchewan River Basin generally exhibits moderate to high water availability, supported by substantial river flows and flow regulation provided by the Bighorn and Brazeau dams west of Edmonton. Consistent with these characteristics, the estimated water demands associated with the deployment of two Xe-100 reactors represent a small proportion of available water under both median and dry-year conditions, as shown in Table 17.

**Table 17.** Estimated water use as a percentage of annual available water[16].

| Case Study Water Use Demand | Low | Medium | High |
|---|---|---|---|
| Estimated annual water use ($dam^3/yr$) | 0 | 2,240 | 2,843 |
| Water available in a dry flow year before nuclear demands ($dam^3/yr$) | 600,000 | | |
| Equivalent use percentage of total water available | 0% | 0.37% | 0.47% |
| Water available in a median flow year before nuclear demands ($dam^3/yr$) | 732,000 | | |
| Equivalent use percentage of total water available | 0% | 0.31% | 0.38% |

Although water availability in the basin is lower than in the Athabasca River Basin, the results suggest that the reactor water demands evaluated in this case study are minor relative to overall basin water availability on an annual basis. This finding is consistent with the conclusions of the North Saskatchewan River Water Management Roadmap Project, completed by the North Saskatchewan Watershed Alliance in collaboration with Hazen Canada.

[16] The North Saskatchewan River Basin is not subject to a Cabinet-approved Water Management Plan or basin-specific allocation framework. Because river flows are regulated by the Bighorn and Brazeau reservoirs, the Standard Water Allocation Decision (SWAD) framework does not directly represent basin hydrology. Therefore, a modified SWAD approach was applied to account for higher winter flows and reduced spring peak flows relative to natural conditions.

The Roadmap project identified the mainstem of the North Saskatchewan River as capable of supporting additional population and industrial growth under current conditions. Nevertheless, project proponents should undertake site-specific water availability assessments to evaluate long-term water security, including potential future changes in hydrologic conditions, water demand, water management practices, and regulatory requirements. For additional discussion of current and future water availability in the basin, readers are encouraged to consult the North Saskatchewan River Water Management Roadmap Project [41].

## 6.4 Case Study 3 - SMR for Power Generation in the North Saskatchewan River Basin

This case study evaluates the deployment of two BWRX-300 SMRs for electricity generation within the North Saskatchewan River Basin. Unlike Case Study 2, which evaluates SMRs supplying both electricity and process steam for industrial use, this case study assumes that the full generating capacity is dedicated to electricity supplied to the provincial electricity grid, and it assumes a larger electrical output.

The case study represents a potential future pathway for utility-scale nuclear deployment in Alberta, building on existing interest in SMR development and the suitability of the region for large-scale power generation. Each reactor is assumed to provide 300 MWe of electrical output, resulting in a combined generating capacity of 600 MWe. Table 18 summarizes the estimated annual water demand for the Case Study 3 deployment. Estimated water demands reflect the climatic conditions near the Industrial Heartland as discussed in Section 3.1.1.

**Table 18.** Estimated annual water demand for Case Study 3.

| Hours in a year (h) | Total Power-Capacity (MWe) | Total Energy (MWh) | Low Use ($dam^3/yr$) | Medium Use ($dam^3/yr$) | High Use ($dam^3/yr$) |
|---|---|---|---|---|---|
| 8,760 | 600 | 5,256,000 | - | 10,802 | 13,772 |

To provide context for the estimated annual water demand, Figure 11 illustrates the hydrograph of the North Saskatchewan River at two points: Highway 759 near Wabamun (in teal) and Edmonton (in red). Although upstream dams on the North Saskatchewan River moderate seasonal variability relative to other rivers in Alberta, seasonal variability remains an important consideration in modelling water availability.

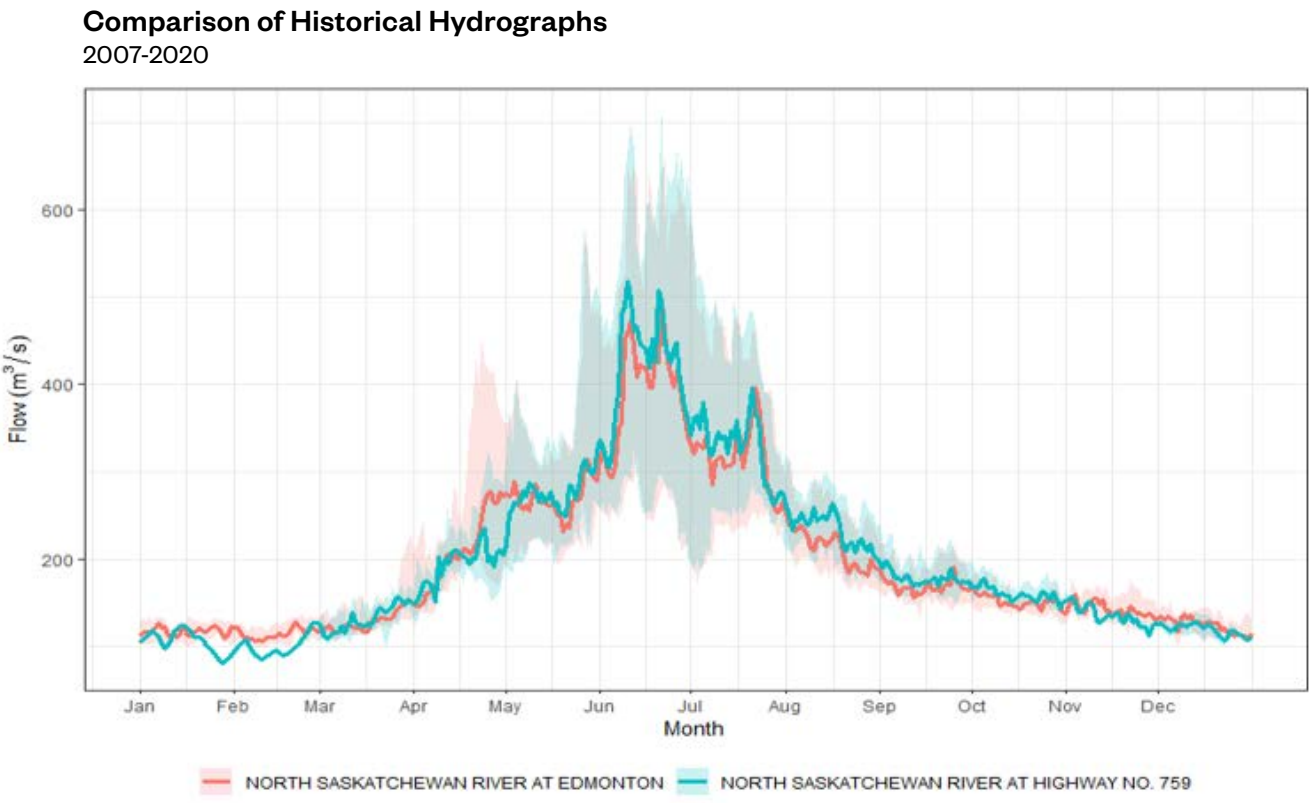



*Figure 11. Hydrograph displaying the statistical lower and upper quartile streamflow of the North Saskatchewan River for the 2007-2020 period. Streamflow records at Edmonton (WSC #05DF001; red) and at Highway 759 near Wabamun (WSC #05DE010; teal).*

As seen in Figure 11, streamflow characteristics near the Wabamun area are broadly comparable to those observed further downstream at Edmonton, resulting in a similar magnitude of water potentially available for new allocations (see Table 4). On an annual basis, streamflow in the North Saskatchewan River is expected to be sufficient to support the water demands presented in Table 18. As discussed in Case Study 2, recent basin-scale assessments of the North Saskatchewan River Basin have identified capacity to accommodate additional growth under current conditions. Nevertheless, project proponents should undertake site-specific water availability assessments to evaluate local conditions and future uncertainties that may influence long-term water availability [41].

## 6.5 Case Study 4 - SMR for Power Generation in the Red Deer River Basin

Like Case Study 3, Case Study 4 involves the deployment of two BWRX-300 SMRs for generating 600 MWe of electricity; however, in Case Study 4 the location is within the Red Deer River Basin. Table 19 summarizes the estimated annual water demand for the Case Study 4 deployment. Given the broadly similar climatic conditions between the North Saskatchewan River Basin (at the Industrial Heartland) and the Red Deer River Basin, climatic input parameters developed for Case Study 3 were considered sufficiently representative for this screening-level assessment. As such, the resulting water demands for a 600 MWe SMR deployment are the same in Case Study 3 and 4.

**Table 19.** Estimated annual water demand for Case Study 4.

| Hours in a year (h) | Total Power-Capacity (MWe) | Total Energy (MWh) | Low Use ($dam^3/yr$) | Medium Use ($dam^3/yr$) | High Use ($dam^3/yr$) |
|---|---|---|---|---|---|
| 8,760 | 600 | 5,256,000 | - | 10,802 | 13,772 |

The Red Deer River Basin WMP establishes an allocation limit of 600,000 $dam^3/yr$. As of May 2026, approximately 369,000 $dam^3/yr$ had been allocated, leaving about 231,000 $dam^3/yr$ available for future allocation. In addition, new applications representing approximately 170,000 $dam^3/yr$ are awaiting a final allocation decision. If these applications are approved, the available volume remaining within the WMP allocation limit would decrease to approximately 61,000 $dam^3/yr$. While this remaining volume exceeds the annual water demand estimated in Table 19, water availability during low streamflow periods may still limit water supply security at certain times of the year. To explore this seasonal variability risk, Figure 12 illustrates the estimated monthly water availability near the mouth of the Red Deer River Basin during a dry flow year alongside the potential water demand associated with the Case Study 4 SMR deployment. Water demand was assumed to remain constant throughout the year.

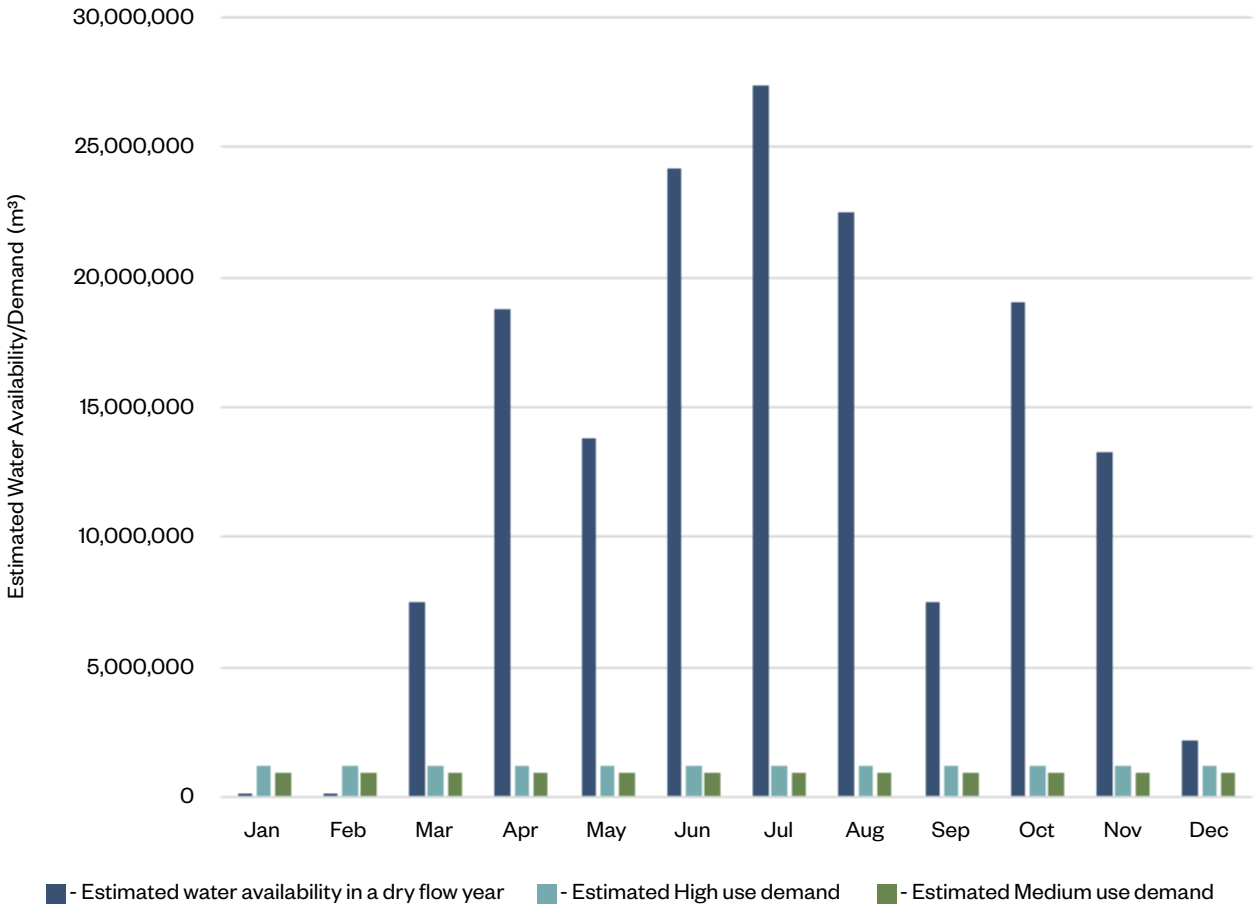



*Figure 12. Comparison between estimated water availability (in 2026) and potential water demands of a 600 MWe SMR.*

During the winter months, streamflow is lower, and available water may be insufficient to fully meet the cooling water requirements (i.e., Medium and High Use ranges) of a project of this scale. In contrast, higher summer streamflow would generally provide sufficient water availability to meet projected water demands.

The presence of low winter streamflow does not, in itself, preclude the Red Deer River Basin as a potential development location. Under such conditions, project proponents could explore supplementing river withdrawals through alternative sources such as groundwater, treated municipal effluent, water reuse systems, or off-stream storage. Alternatively, proponents could consider cooling technologies with lower water requirements, such as air-cooled systems (i.e., Low Use). However, these systems may involve trade-offs, including reduced thermodynamic efficiency, higher capital costs, and larger physical footprints compared to water-cooled alternatives. For additional discussion on seasonal water demands, refer to Case Study 7.

## 6.6 Case Study 5 - SMR for Power Generation in the Battle River Basin

This case study considers the hypothetical deployment of a 600 MWe SMR facility within the Battle River Basin as a redevelopment of an existing combined-cycle natural gas-fired power plant. Consistent with the approach used in Case Study 4, climatic conditions in the Battle River Basin were assumed to be broadly comparable to those of

the North Saskatchewan River Basin in Case Study 3. Consequently, the estimated water demand for the 600 MWe reactor is unchanged. Table 20 summarizes the estimated annual water demand for the assumed deployment.

**Table 20.** Estimated annual water demand for Case Study 5.

| Hours in a year (h) | Total Power-Capacity (MWe) | Total Energy (MWh) | Low Use ($dam^3/yr$) | Medium Use ($dam^3/yr$) | High Use ($dam^3/yr$) |
|---|---|---|---|---|---|
| 8,760 | 600 | 5,256,000 | - | 10,802 | 13,772 |

Unlike the major river systems considered in previous case studies, the Battle River is a comparatively small watershed, lacking Rocky Mountain headwaters and with lower average streamflow and more pronounced seasonal variability, as seen in Figure 13.

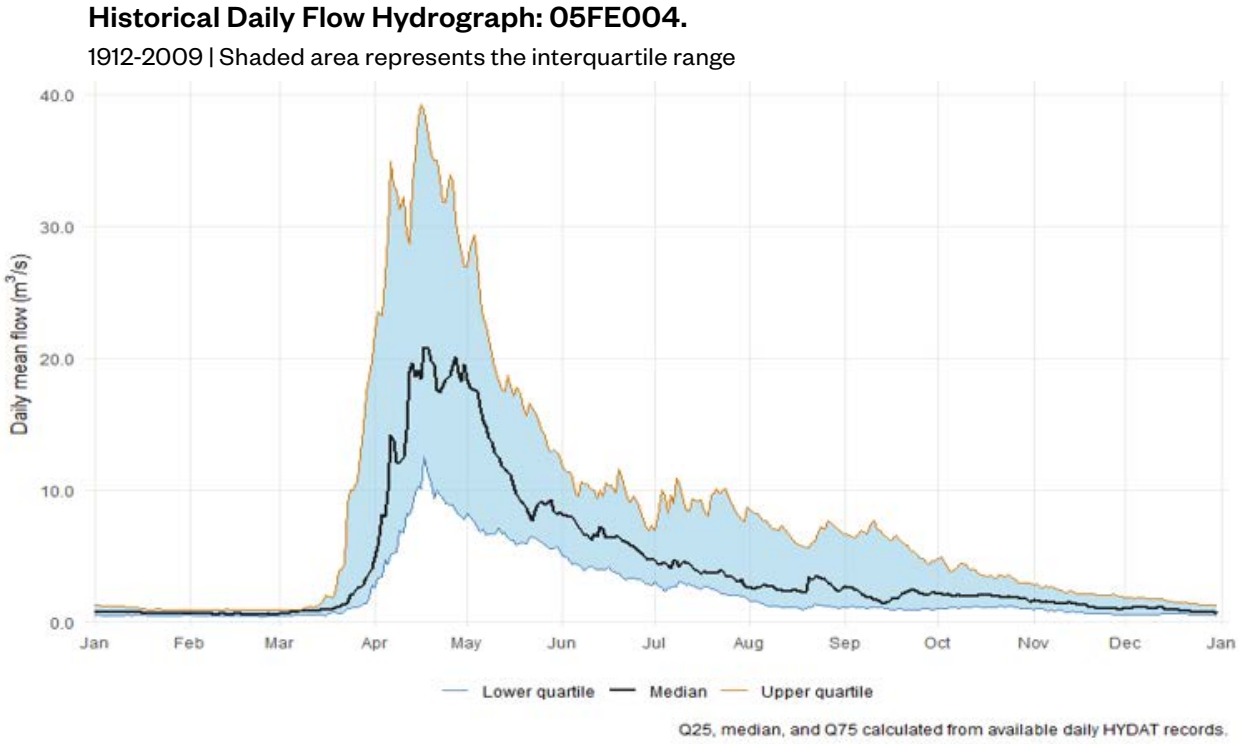



*Figure 13. Hydrograph displaying the lower quartile, median, and upper quartile natural streamflow of the Battle River (modelled at WSC #05FE004 for the 1912-2009 period).*

The Battle River Basin WMP establishes an annual allocation limit of 57,500 $dam^3/yr$. As of May 2026, approximately 54,200 $dam^3/yr$ has been allocated, leaving roughly 3,300 $dam^3/yr$ available for new allocations. This remaining volume is below the estimated annual cooling water requirements associated with the Medium and High use ranges presented in Table 20.

While this analysis indicates securing a new water allocation for a nuclear development may be challenging under current allocation conditions, the Battle River Basin currently has approximately 691,000 $dam^3/yr$ licenced for power generation, with a consumptive and losses portion of approximately 13,820 $dam^3/yr$. As existing power generation facilities near the end of their operational life, the associated licensed water allocations may present opportunities for redevelopment using SMRs of this scale. Depending on the specific circumstances of the project, water requirements could potentially be met through the repurposing of an existing licence through an amendment by the current licence holder, or the transfer of existing licensed allocations to another potential user subject to applicable regulatory approvals.

## 6.7 Case Study 6 - Meeting Data Centre Load in Alberta: Cooling Water Implications of Power Generation

A province-wide case study was developed to quantify the potential cooling water requirements associated with new electricity demand from data centre load in Alberta, based on a comparative assessment of hypothetical BWRX-300 SMR and NGCC generation facilities. Notably, many modern data centres are increasingly adopting closed-loop liquid cooling and other low-water cooling technologies to reduce on-site water consumption. While these approaches can substantially reduce or even eliminate cooling-related water use at the data centre facility, they generally require greater mechanical cooling and electricity consumption than evaporative cooling systems. Consequently, reductions in water use at the data centre may be partially offset by increased electricity demand and, depending on the generation source, higher cooling-related water requirements associated with power production.

NGCC power generation was compared to nuclear power generation as it is generally viewed as a readily deployable source of new generation capacity in Alberta, owing to its comparatively short development and construction timelines relative to nuclear power. NGCC water use ranges were drawn from published literature for each cooling configuration considered [48, 49]:

- **High use** (closed-loop wet mechanical-draft cooling towers): 1.52 m³/MWh.
- **Medium use** (closed-loop cooling ponds): 1.17 m³/MWh.
- **Low use** (air-cooled condenser): 0 m³/MWh.

The Low, Medium, and High water use ranges for the BWRX-300 reactor in Central Alberta (Industrial Heartland area) were used as a proxy for province-wide conditions. Figure 14 presents the estimated annual cooling water demand for 1,200 MW of continuous load (as defined in Section 5.2.1) across both thermal generation technologies and their respective Water Use ranges. Any potential hybrid of NGCC and SMR deployment serving the same load would fall within the envelope defined by these extremes, scaled to the share of each technology. While nuclear power facilities are expected to use more water than NGCC on a per-unit basis, meeting the projected electricity load associated with data centres will require incremental generation capacity, and thus water consumption, regardless of power source.

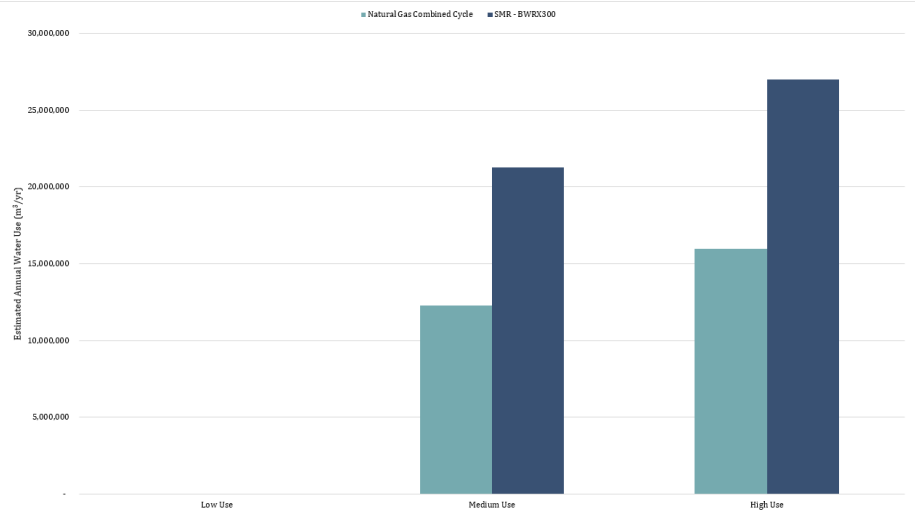



*Figure 14. Estimated annual water demands for 1,200 MW of power load.*

The higher net thermal efficiency of NGCC facilities (i.e., greater than 50%) [50] results in lower cooling water use per unit of electricity generated relative to the BWRX-300 SMR. This efficiency advantage stems from the combined-cycle configuration, in which a Brayton cycle gas turbine and a Rankine cycle steam turbine operate in series. Exhaust heat from the gas turbine is recovered in a heat recovery steam generator to drive a secondary steam cycle, rather than being rejected directly to the environment. Extracting useful work from two thermodynamic cycles reduces the fraction of primary energy that must be dissipated as waste heat, which in turn lowers the cooling water demand per unit of electrical output.

By contrast, single-cycle thermal generation technologies, such as conventional coal-fired plants and simple-cycle gas turbines, operate on a single thermodynamic cycle and exhibit net thermal efficiencies broadly comparable to the BWRX-300 SMR (approximately 34.5%) [24]. As a result, cooling water requirements for these technologies are expected to be of a similar order of magnitude to those of the SMR when equipped with equivalent cooling configurations. As noted in Section 5.2.1, water use is only one component of the overall impacts of power generation technologies which should be considered when planning future developments.

## 6.8 Case Study 7 - Seasonality of Cooling Water Demands

This case study examines how seasonal temperature conditions (i.e., both ambient air and water temperatures) may influence cooling water requirements for a nuclear power generation facility by evaluating a 1,200 MWe AP1000 reactor at the proposed Peace River Nuclear Power Project location. The estimated water demands presented herein reflect cooling water requirements only and do not include one-time water demands associated with facility construction, nor water requirements for auxiliary functions and non-cooling uses, as discussed in Section 3.1. These results are intended as an illustrative evaluation of seasonal demand variability and **should not** be interpreted as project-specific forecasts for the Peace River Nuclear Power Project.

Figure 15 illustrates the statistical median and dry flow years of the Peace River near the Town of Peace River (in teal and orange respectively), together with the corresponding estimated water availability (dotted line). The figure provides a screening-level comparison of seasonal water availability under representative hydrologic conditions and highlights how available water volumes vary throughout the year. As Alberta's largest river by flow, the Peace River supports relatively high levels of water availability. Upstream reservoir operations in British Columbia also moderate seasonal variability and result in higher winter streamflow compared to natural flow conditions.

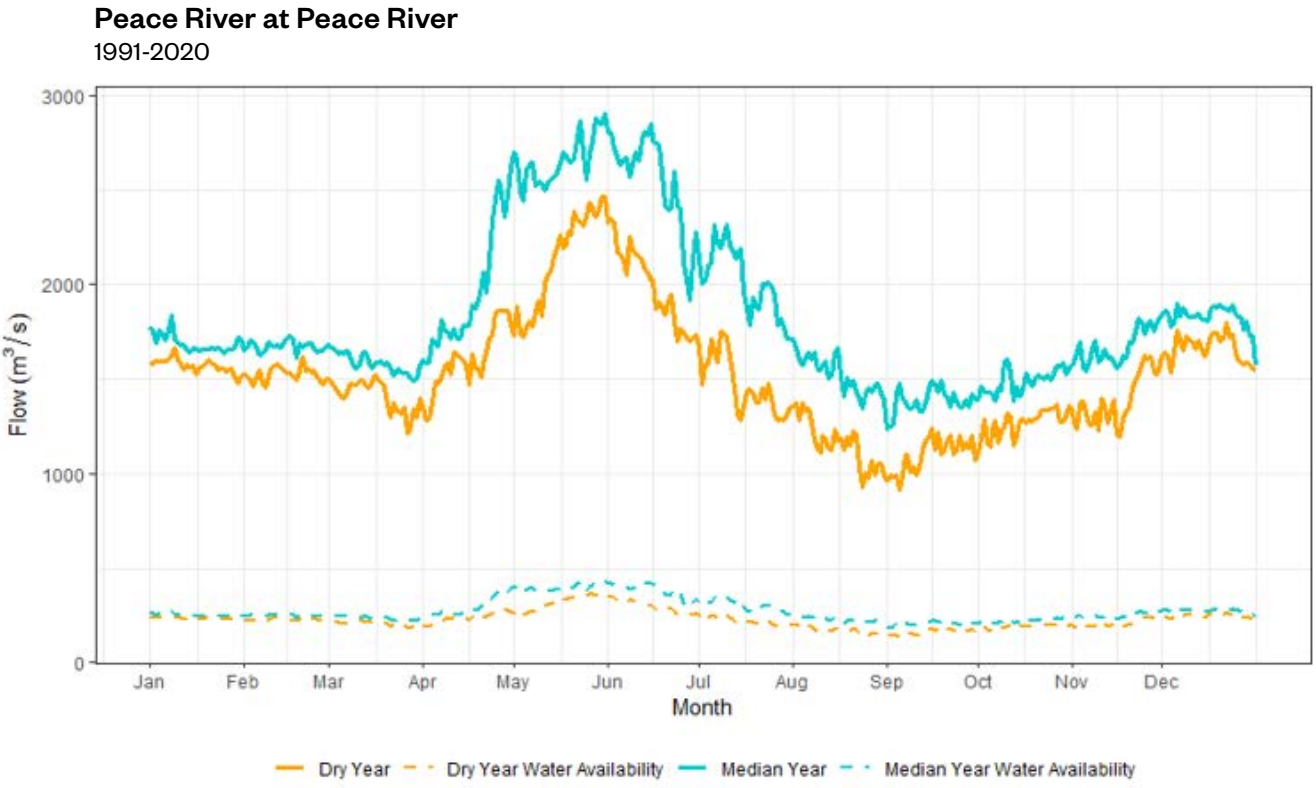



*Figure 15. Hydrograph displaying the estimated median (in teal) and dry flow year (in orange) and water availability (dotted line) of the Peace River for the 1991-2020 period. Streamflow records at Peace River (WSC #07HA001).*

Assuming evaporative cooling (i.e., the High Use demand range) and average climatic conditions near the site, the modelled water demand for the 1,200 MWe reactor evaluated in this case study is approximately 25.44 million m³/yr. This is equivalent to an average withdrawal rate of approximately 0.8 m³/s if water is used uniformly throughout the year. This demand is small relative to the water potentially available for allocation under the median and dry flow years shown in Figure 15. For reference, the dry flow year water availability generally ranges from 180 to 360 m³/s, whereas the reactor demand would be approximately 0.8 m³/s.

However, cooling water requirements are not uniform, instead varying seasonally in response to changing ambient air and source water temperatures. Figure 16 presents the monthly average river and air temperatures near the site (purple and red dotted lines, respectively). These variables were used as input parameters in the WAMP, the results of which are shown using the blue bars in Figure 16.

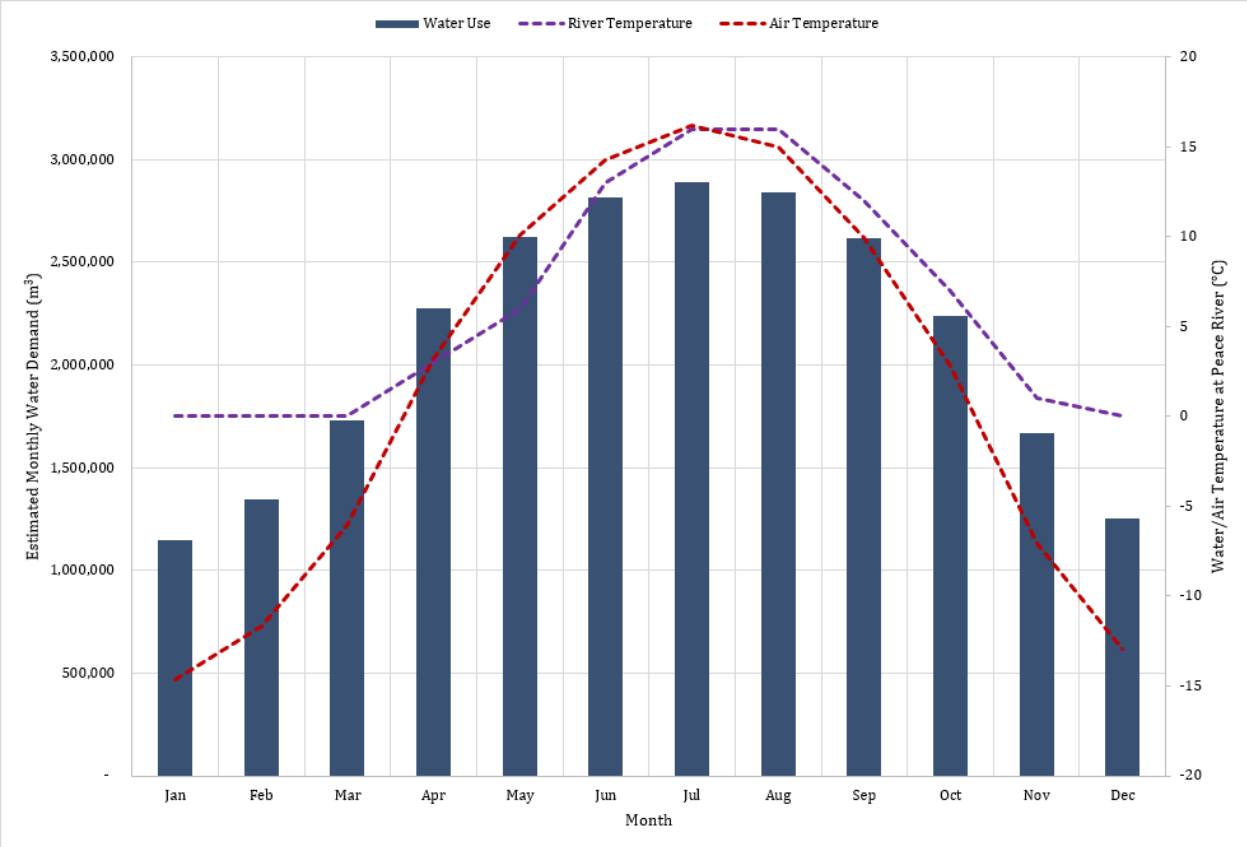



*Figure 16. Estimated monthly water demand for the 1,200 MWe reactor (Case Study 7).*

Cooling water demands are lower during the winter months when colder air and water temperatures improve cooling efficiency and increase the temperature differential available for heat rejection. Conversely, cooling water demands increase during the summer months as warmer ambient conditions reduce cooling efficiency and require greater water use to dissipate the same amount of thermal energy.

Figure 17 compares the modelled monthly water demand with the estimated monthly water availability under the median and dry flow years presented in Figure 15. Monthly water availability was calculated as the integrated area under the availability curves for each month. Although cooling water requirements increase during the warmer summer months, projected demand remains low relative to available water under both streamflow years, accounting for less than 1% of the estimated monthly water availability.

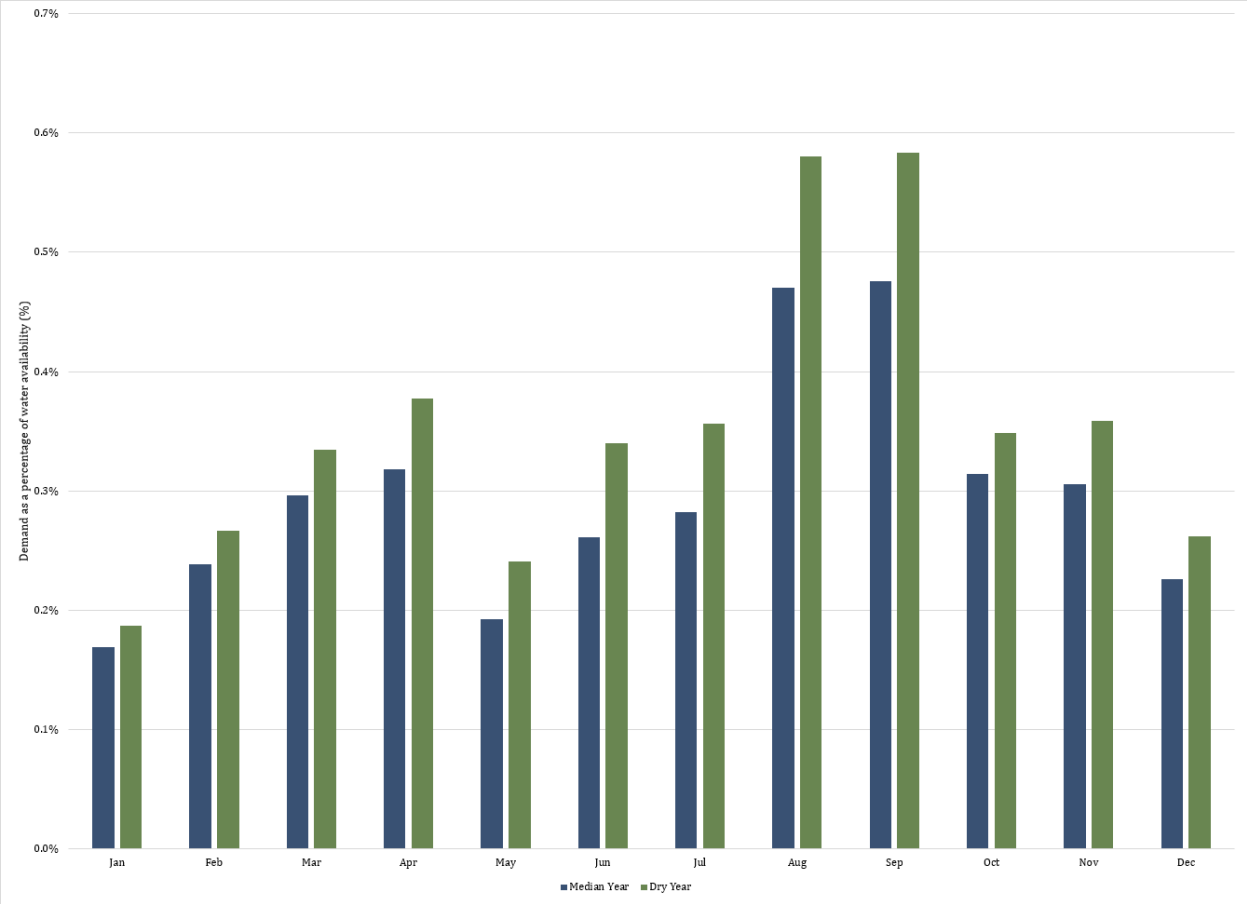



*Figure 17. Estimated water demand (Case Study 7) as a percentage of water availability (in 2026) in the Peace River.*

These results indicate that the water requirements of the proposed facility in this case study would constitute a minor proportion of the water available for allocation, even under relatively low streamflow conditions. Interestingly, the highest proportional demand for cooling occurs in August and September, though it is still less than one percent of overall availability. From a screening level perspective, the Peace River appears capable of supporting power generation projects of this scale, subject to project-specific regulatory, technical, and environmental considerations.

# 7. Recommendations and Conclusions

Through a comparison of potential nuclear power generation cooling water demands with current water availability across Alberta, this report demonstrates that the water implications of nuclear development depend strongly on the selected cooling technology (i.e., Low, Medium, or High Use) and its location, which determines both the typical ambient temperatures and the regulatory and hydrologic conditions of nearby water bodies. Nuclear facilities using evaporative cooling can require substantial volumes of water relative to air-cooled systems. However, the magnitude and seasonal distribution of cooling water demand also vary throughout the year in response to environmental conditions, including air and water temperatures.

Consistent with the notion of site-specific implications, this assessment further demonstrates that water-related opportunities, risks, and trade-offs are not uniform across the province. River basins such as the Peace and Athabasca generally exhibit relatively high water availability and are capable of supporting the scales of development evaluated in this study, subject to site-specific regulatory and technical assessments, especially for projects located on the tributaries. In contrast, basins characterized by lower water availability, annual allocation limits, seasonal constraints, or restrictions on new water licences may present additional challenges for large projects relying on more water intensive cooling technologies (e.g., closed-loop cooling ponds and evaporative cooling). These challenges are evident in the Red Deer and Battle River basins presented in Case Studies 4 and 5, respectively, where constraints may arise during low streamflow periods even where annual water availability appears sufficient under typical conditions.

These findings indicate that the feasibility of nuclear development, from a water perspective, is closely linked to cooling technology selection and water sourcing strategy. In areas with limited water availability, dry cooling may be the only practical option for minimizing operational water use unless alternative water supplies can be secured through reuse, transfers, or water-sharing agreements. While cooling technology is the primary driver among the evaluated parameters, project-specific assessments remain necessary to confirm that construction water requirements, ancillary water uses, and other site-specific needs can be accommodated. Water availability should therefore be treated as an important project planning and risk management consideration, rather than as a uniform or absolute enabler of, or constraint on, nuclear development in Alberta. Early consideration of basin-specific conditions can help identify potential constraints and inform the evaluation of technically and regulatorily appropriate project configurations.

The assessment also highlights the importance of planning under future uncertainty. Climate projections indicate that increased precipitation in some northern Alberta basins may partially offset higher evaporation, while portions of southern Alberta may experience CMI deficits over time. At the same time, the illustrative assessment of future non-nuclear water demands suggests that incremental demand associated with population and economic growth could place additional pressure on water resources in several river basins. While estimates are not robust forecasts of future development, streamflow, or water allocation, the combined influence of changing hydroclimatic conditions and increasing competition for water suggests that supply pressures could become more pronounced in certain basins, particularly where water resources are already constrained.

Given these findings, proponents, investors, policymakers, regulators, Indigenous communities, and other decision-makers should carefully consider the potential water-related risks and opportunities associated with nuclear development, with particular attention given to location-specific realities. Through early identification and evaluation of these considerations, effective mitigation measures and water management strategies can be incorporated into project design and planning processes to enable nuclear power development in Alberta without placing undue strain on our shared water resources or preventing other forms of growth.

Several specific recommendations are provided. Building on Hazen Canada's previous hydrogen (2023) and CCUS (2025) reports, these recommendations reaffirm key findings that remain applicable across emerging industries while providing additional detail specific to the nuclear power sector:

1. **Integrate water management considerations into early-stage siting and technology screening:**

    a. Potential sites should be screened concurrently for hydrologic conditions, regulatory water availability, existing allocations, seasonal reliability, water quality, intake feasibility, cumulative water demands, and applicable interprovincial or international obligations. Although this study focuses on the quantitative water demands of nuclear power generation and water availability, candidate sites for nuclear development should also be assessed for potential thermal discharge effects and impacts to aquatic ecosystems early in the planning process.

    b. Project assessments should compare air-cooled, wet-cooled, hybrid, cooling-pond, and other applicable cooling configurations using consistent criteria, including consumptive water use, total withdrawal requirements, seasonal reliability, operating performance, land requirements, and cost. Within the context of location-specific constraints and opportunities, this evaluation should recognize that minimizing water will likely involve trade-offs, such as those related to plant efficiency, land and carbon footprint, capital requirements, and operating costs.

2. **Assess water availability at seasonal and operationally relevant timescales:**

    a. Annual water availability estimates may not fully reflect periods during which available river flow is insufficient to meet project demand. Detailed assessments should therefore evaluate monthly, weekly, or shorter-duration conditions, as appropriate, with consideration for winter low flows, drought conditions, ice effects, intake reliability, required environmental flows, licence priority, and potential operational restrictions. As demonstrated by Case Study #4, a basin may appear to have sufficient water on an annual basis while still experiencing seasonal constraints that could affect facility design, operation, and permitting.

3. **Incorporate cumulative water demand and future uncertainty into project assessments:**

    a. Potential nuclear water demands should be assessed alongside existing allocations and possible growth in other areas, including municipal, agricultural, industrial, data centre, hydrogen, and CCUS.

    b. Assessments should also consider the potential effects of changing hydroclimatic conditions on water availability and seasonal reliability over the facility's operating life. The future demand estimates presented in this report should be treated as illustrative rather than predictive because basin-level growth may differ from provincial trends and may be influenced by water reuse, efficiency improvements, water-sharing arrangements, alternative water sources, regulatory changes, and evolving development patterns.

4. **Consider facility redevelopment opportunities and existing water allocations:**

    a. Where non-nuclear thermal power generation or other industrial facilities are approaching retirement, decommissioning, or repurposing, proponents should evaluate whether existing water licences and associated infrastructure could support new nuclear power development.

b. This evaluation should consider intake and discharge infrastructure, water storage and treatment systems, conveyance, and other site-specific assets. However, the transfer, assignment, amendment, or change in use of an existing water licence or allocation would remain subject to the applicable regulatory framework and should not be assumed to be available or approved without investigation.

**5. Undertake early and sustained engagement with Indigenous communities:**

a. Engagement with Indigenous communities should begin before major siting and design decisions are made and should continue throughout project planning and development. Engagement should extend beyond minimum procedural Consultation requirements and provide opportunities for meaningful dialogue regarding culturally and ecologically important waters, traditional land and water uses, community priorities, cumulative effects, and potential partnership opportunities with rightsholders. Early engagement can help identify considerations that may influence site selection, technology choice, monitoring programs, mitigation measures, and long-term water management.

**6. Coordinate nuclear development planning with basin-level water management initiatives:**

a. Provincial regulators should lead the coordination of information related to potential siting areas, generation loads, water requirements, development timing, and planning horizons. WPACs, utility providers, projects proponents, and other relevant stakeholders should support this process by contributing watershed perspectives on water availability, infrastructure, demand, and project-specific inputs to inform integrated planning and decision-making.

b. Improved planning coordination would support the use of consistent assumptions, reduce duplicated effort, and facilitate the early identification of potential cumulative water management concerns for all water users throughout the basin. It could also help determine where WMPs, IFNs, allocation tools, monitoring programs, or regional assessments may need to be reviewed or updated to support future development planning.

# 8. Closure

This report has been prepared for the specific uses described herein. It evaluates the potential water management considerations associated with nuclear power development in Alberta, including water demand characteristics, watershed-level considerations, regulatory context, and potential interactions with existing water users. The report provides a strategic, province-scale assessment and does not constitute a site-specific feasibility study, environmental assessment, regulatory application, or detailed engineering design. Future water availability, hydrologic conditions, regulatory decisions, facility design parameters, operating practices, and technology selection are subject to uncertainty and may influence project-specific outcomes.

The analysis and recommendations represent the best judgment of Hazen and Sawyer Canada Ltd. (Hazen Canada) based on the information available at the time of this report. The assessment was completed using Hazen Canada's established technical methods and procedures and is consistent with the scope, assumptions, data sources, and analytical framework described throughout this report, as well as with APEGA-recognized professional standards and generally accepted industry practices applicable to the scope of work.

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The Association of Professional Engineers and Geoscientists of Alberta (APEGA)

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# 10. Appendices

## 10.1 Appendix A – Nuclear Power Reactor Classifications

This Appendix provides an overview of the fission process used to generate nuclear power and the classification frameworks commonly used to differentiate reactor technologies.

### 10.1.1 What is nuclear fission and how does it work?

Nuclear energy is produced through reactions that involve the splitting of atoms' nuclei (fission) [19]. The nucleus is the central part of the atom composed of protons and neutrons [51]. According to the International Atomic Energy Agency (IAEA), "nuclear fission is a reaction where the nucleus of an atom splits into two or more smaller nuclei, while releasing energy" [19].

Nuclear fission begins when a neutron collides with a fissile (or dividable) atom. This collision causes the atom's nucleus to split into smaller nuclei, releasing a significant amount of energy along with additional neutrons. These newly released neutrons can then strike neighbouring fissile atoms, causing them to split and release even more energy and neutrons. As this process repeats, a self-sustaining chain reaction is established. The chain reaction continues as long as sufficient fissile material is available and conditions remain suitable for sustaining fission. In a nuclear power plant, this reaction is carefully controlled to ensure that energy is released at a steady and manageable rate rather than all at once.

The energy released during fission is released primarily as heat. The heat is transferred to a coolant, which is then used to produce steam that drives turbines connected to electrical generators. The controlled release of heat from a sustained nuclear fission chain reaction is the fundamental process by which electricity is generated in a fission-based nuclear power [19].

### 10.1.2 Classification of nuclear reactors

Nuclear reactors can be classified based on their design and operating characteristics, including neutron moderator, fuel form, coolant, reactor size, and neutron spectrum, as indicated below. These classifications provide additional context for the reactor technologies presented in Table 1:

- **By neutron moderator:** The material that slows fast-moving neutrons through collisions with non-fissile atoms, increasing the probability of fission while minimizing neutron absorption and supporting a sustained chain reaction [52, 53, 54]. Examples include:
    - **Light water:** Ordinary water (H2O) is the most common moderator. It is highly effective at slowing neutrons but also absorbs a relatively large number of them, requiring enriched uranium.
    - **Heavy water:** Water containing deuterium (D2O). It is less effective at slowing neutrons than light water but absorbs fewer neutrons, allowing the use of natural uranium fuel.
        - The AtkinsRéalis CANDU MONARK reactor is an example of a heavy water moderated reactor.
    - **Graphite:** Carbon-based moderator that absorbs few neutrons, enabling the use of natural or low-enriched uranium fuel. Although less effective at slowing neutrons than water, its low neutron absorption makes it an efficient moderator. It also requires a separate coolant (typically helium) as graphite is less effective at heat transfer.

- **By fuel form:** The type, physical form, and isotopic composition of the nuclear fuel used for fission. Most nuclear power plants use uranium-based fuels, but power plants using thorium are currently under development [55, 56, 57].
    - **Natural uranium:** Composed mostly of Uranium-238 isotope, which makes up to 99% of Earth's naturally occurring uranium. This type of fuel is used by CANDU reactors.
    - **Low-enriched uranium:** Natural uranium that has its concentration of Uranium-235 isotope synthetically increased to above natural levels.
    - **Thorium:** Alternative nuclear fuel source that can be converted into fissile Uranium-233 isotope within a reactor. Although not yet commercialized, thorium offers potential benefits including relative abundance in Earth's crust compared to Uranium.
- **By coolant:** The medium used to transfer heat from the reactor core to external energy conversion loops, making it a critical design consideration for any nuclear power plant. Changes to the coolant impact siting decisions, cost, and environmental trade-offs [22, 58, 59, 60, 61, 11].
    - **Light water:** Most common form of reactor coolant. Light water can be classified into two types; pressurized water reactors (which use separate steam generators to propel electrical turbines in downstream loops) and boiling water reactors (which use the steam inside the reactor core to directly spin the electrical turbines[17]).
        - A recent example of a boiling water reactor design under active consideration in Canada is the GE Hitachi BWRX-300, an SMR selected for deployment at Ontario Power Generation's Darlington New Nuclear Project.
        - The Westinghouse Electric AP1000 pressurized water reactor is being considered for deployment at the proposed Peace River Nuclear Project.
    - **Helium:** Highly pressurized inert gas that works at high temperatures, allowing higher-quality heat (compared to water as a coolant) to be used for other purposes such as industrial processes. It allows for high fuel utilization rates, reducing refueling frequency.
    - **Molten salt:** Used due to its high thermal capacity. Molten salt is adaptable to different fuel sources and can operate in low-pressure environments. Similarly to helium-gas cooling, excess high-quality heat can be used for other purposes.

[17] While boiling water reactors have a different configuration for process loops 1 and 2, water that comes into contact with the reactor core does not mix with the cooling water that is ultimately released to the environment.

- **By reactor size:** The rated electrical generating capacity of the reactor [62, 63].
    - **Small Modular Reactor:** Reactors that can vary in size from around 20 MW to 300 MW and can produce up to 7.2 million kWh per day. They can use a range of possible coolants, including light water, liquid metal, or molten salt.
        - **Micro Modular Reactor:** Reactor designed to generate electricity and/or heat at a scale suitable for remote communities, industrial facilities, and off-grid applications, with a typical output of less than 50 MW.
    - **Conventional (Large):** Reactors that have typical outputs of over 1,000 MW and can produce 24 million kWh per day.
- **By neutron spectrum:** The energy, or speed, of the neutrons that sustain the nuclear fission reaction. Different neutron speeds require different designs to harness them for productive applications [53, 64].
    - **Thermal reactor:** Reactors whose neutrons have been slowed by a moderator to energies comparable to the thermal motion of surrounding atoms. Thermal neutrons are what cause a fission reaction with natural and low-enriched uranium.
    - **Epithermal reactor:** Reactors designed for neutrons with energies between thermal and fast neutrons. They typically represent a transitional stage as neutrons slow down through interactions with a moderator.
    - **Fast reactor:** Reactors designed for neutrons whose energy is higher than 1 MeV (Mega-electronvolt) on average. Fast reactors do not rely on a moderator and generally require higher concentrations of fissile nuclei.

## 10.2 Appendix B – Current and Future Water Availability in Alberta for Nuclear Power

June 22, 2026

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# Current and Future Water Availability in Alberta for Nuclear Power

## Context

WaterSMART Solutions Ltd. (WaterSMART) has been engaged to examine the future potential available water for nuclear power development in Alberta. MacDonald Hydrology Consultants Ltd. (MacHydro) was retained by WaterSMART to provide guidance on how water availability may change in Alberta in the future from anthropogenic climate change. This memo documents the methods used to assess water availability and provides estimates of the projected change under an ensemble of 8 CMIP6 General Circulation Models under three varying emissions pathways (SSP1-2.6, SSP2-4.5, and SSP5-8.5). These climate projections enlist statistically downscaled high-resolution climate data for 20-year periods to assess their impact on water availability in Alberta. This analysis accounts for all upstream basins and water at each outlet, offering the ability to assess water availability in both major river basins and tributaries into the future. Discussion of the context and limitations for these estimates are provided along with an analysis of the potential drivers to future hydrologic change in Alberta and its effects on water availability.

## Methodology

### Study Area

This study evaluates the projected changes in precipitation, evaporation, and water availability across the province of Alberta. The study area encompasses the entire province of Alberta. Drainage basin delineations were provided by the Province of Alberta's Hydrologic Unit Code (HUC) 10-level, a hierarchical basin system used to assess water resource planning and environmental analyses (Figure 1). These basins define the areal extent of surface water drainage at a point at the subbasin scale. HUC10 coverage was expanded to include all upstream HUC10s by mapping the routing/flow paths of river basins such that each HUC10 covers the full upstream area. This delineation does not consider upstream areas outside of the province (e.g., the headwaters of the Peace River are in British Columbia). For clarity, in this memo major main-stem drainage systems (e.g., the North Saskatchewan River) are referred to as basins, while the smaller, nested HUC10 units are referred to as subbasins.

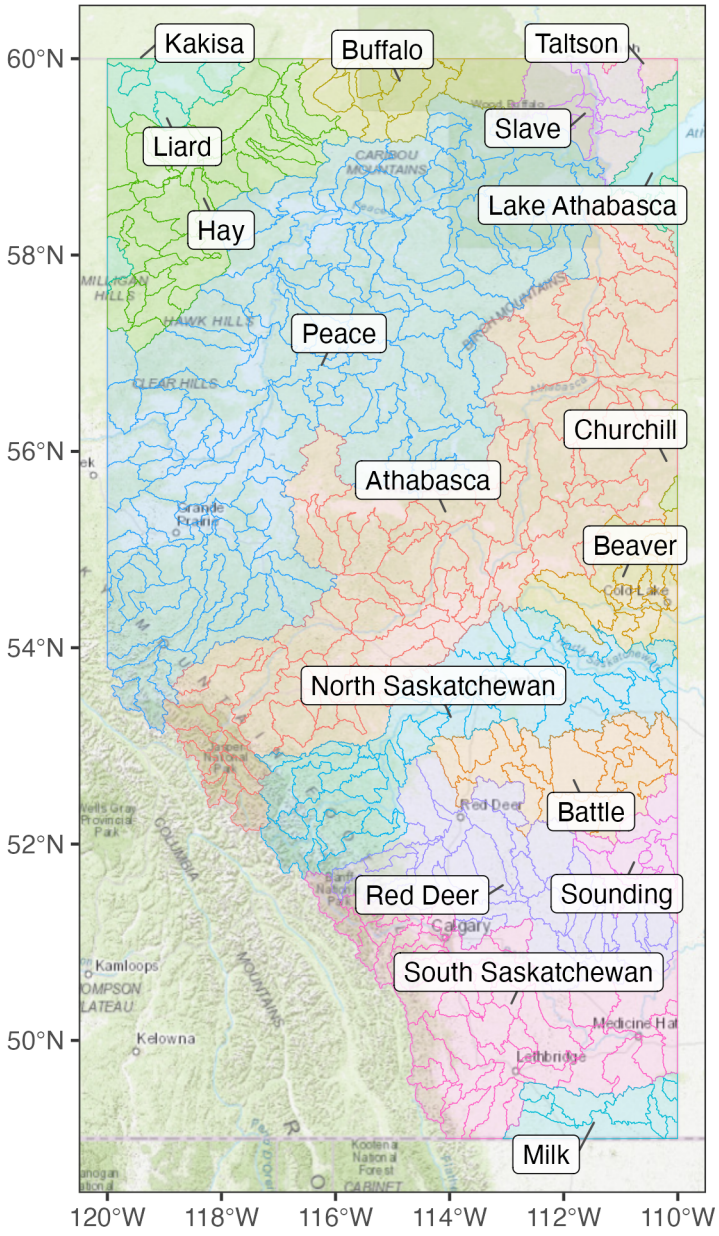



**Figure 1. Spatial extent of the study area showing major basins (labelled) and nested subbasins (delineated within each basin).**

## Climate Data

Climate data for Alberta was extracted using the climR package for both historical and future projections of climate from ClimateNA (Mahony et al., 2022). These observed data are generated by interpolating historical weather data using the Parameter-elevation Regressions on Independent Slopes Model (PRISM) and downscales this product to gridded monthly normal data (Daly et al., 2008). Future projections of climate data were generated based on 8 General Circulation Models (GCMs) from

Coupled Model Intercomparison Project (CMIP6). These GCMs include ACCESS-ESM1.5, CNRM-ESM2-1, EC-Earth3, GFDL-ESM4, GISS-E2-1-G, MIROC6, MPI-ESM1.2-HR, and MRI-ESM2.0. These models were selected for a mean ensemble as per suggestions Mahony et al. (2022) as they are more consistent with the IPCC's assessment of climate sensitivity. Historical (2010-2020) and future (2020 - 2100) climate data for all 8 downscaled GCM's, including Mean Annual Precipitation (P), Hargreaves evaporation (E) (Hargreaves and Samani, 1985), and Climate Moisture Index (CMI) were downloaded for the entirety of Alberta.

### Scenario Selection

CMIP6 climate projections use scenarios of future greenhouse gas emissions called Shared Socioeconomic Pathways (SSPs). We used SSP1-2.6, SSP2-4.5, and SSP5-8.5 in this analysis. SSP1-2.6 is the sustainable scenario where global commons are preserved, and consumption is oriented towards minimizing material resources and energy usage (Riahi, et al. 2017). SSP2-4.5 assumes moderate mitigation roughly consistent with current emissions policies and economic trends, while SSP5-8.5 is the high end of the baseline scenarios which represents a rapid increase in the rate of greenhouse gas emission over the next several decades which are three times higher than current emissions. This downscaled product recommends 20-year normals for the 21$^{st}$ century as they are deemed more appropriate for detecting changes in a rapidly changing climate (Mahony et al., 2022). The spatially weighted mean value for all three variables was averaged by each subbasin and its upstream drainage area to provide a single statistic for each subbasin for each emission scenarios and period.

### Hydrological Indicators

Projected changes in water availability were assessed using three climate variables: Climate Moisture Index (CMI), Evaporation (E), and Precipitation (P). Together, these variables separate the water balance into its input component (P) and output component (E), while CMI represents the annual sum of net moisture deficit (Eq.1) and serves as a proxy for water availability.

$$CMI = P - E \qquad \text{Eq. 1}$$

A positive CMI value indicates higher water availability while a negative CMI indicates a drier region with lower water availability. The CMI was calculated for five climate normals in 20-year periods (2021-2040, 2041-2060, 2061-2080, 2081-2100) and compared to historical observations for the baseline period (1991-2010).

The P and E in each subbasin were summarised each year (mm year$^{-1}$) and averaged across a historical baseline period (2001-2020) and compared to the four future periods. The relative change was used as a metric to understand how precipitation and evaporation are projected to change across Alberta. For each subbasin, the ensemble median and interquartile range (p10–p90) of percent change from baseline period (2001-2020) were computed across for each future period and emission scenario. The median was used as the central estimate of directional change, while the inter-basin spread (p90–p10) served as a measure of spatial variability. Basins exhibiting both large median increases in CMI and high spatial variability were identified as highest risk, representing basins where drying is both likely and uncertain in magnitude.

## Results

### Climate Moisture Index

Figure 2 shows the spatial distribution of Climate Moisture Index (CMI) across Alberta subbasins for 2021-2040, 2041-2060, 2061-2080, and 2081-2100 under SSP1-2.6, SSP2-4.5, and SSP5-8.5. In the near term (2021-2040), the largest deficits occur in southeastern Alberta, particularly the Milk River Basin, where CMI reaches about -50 mm year$^{-1}$. Deficits become less severe northward, ranging from about -40 to -50 mm year$^{-1}$ in tributaries of the South Saskatchewan and Red Deer basins. In contrast, the headwaters of the North Saskatchewan, South Saskatchewan, Peace, and Athabasca basins show increases of water availability with CMI ranging from 50 to 100 mm year$^{-1}$. Northern Alberta, including the Hay, Buffalo, Kakisa, and Slave basins, is projected to have a CMI of 0 to 20 mm year$^{-1}$. This pattern is generally consistent across scenarios from 2021-2040. In 2041-2060 and 2061-2080, patterns remain similar under SSP1-2.6 and SSP2-4.5, but deficits intensify under SSP5-8.5, as CMI reaches -65 mm year$^{-1}$ in the Milk River Basin and eastern tributaries of the South Saskatchewan Basin. Under SSP5-8.5, headwater basins are projected to range from 75 to 100 mm year$^{-1}$, reflecting increased precipitation. By 2081-2100, CMI under SSP1-2.6 and SSP2-4.5 remains similar to near-term conditions, while southeastern Alberta under SSP5-8.5 is projected to reach about -120 mm year$^{-1}$.

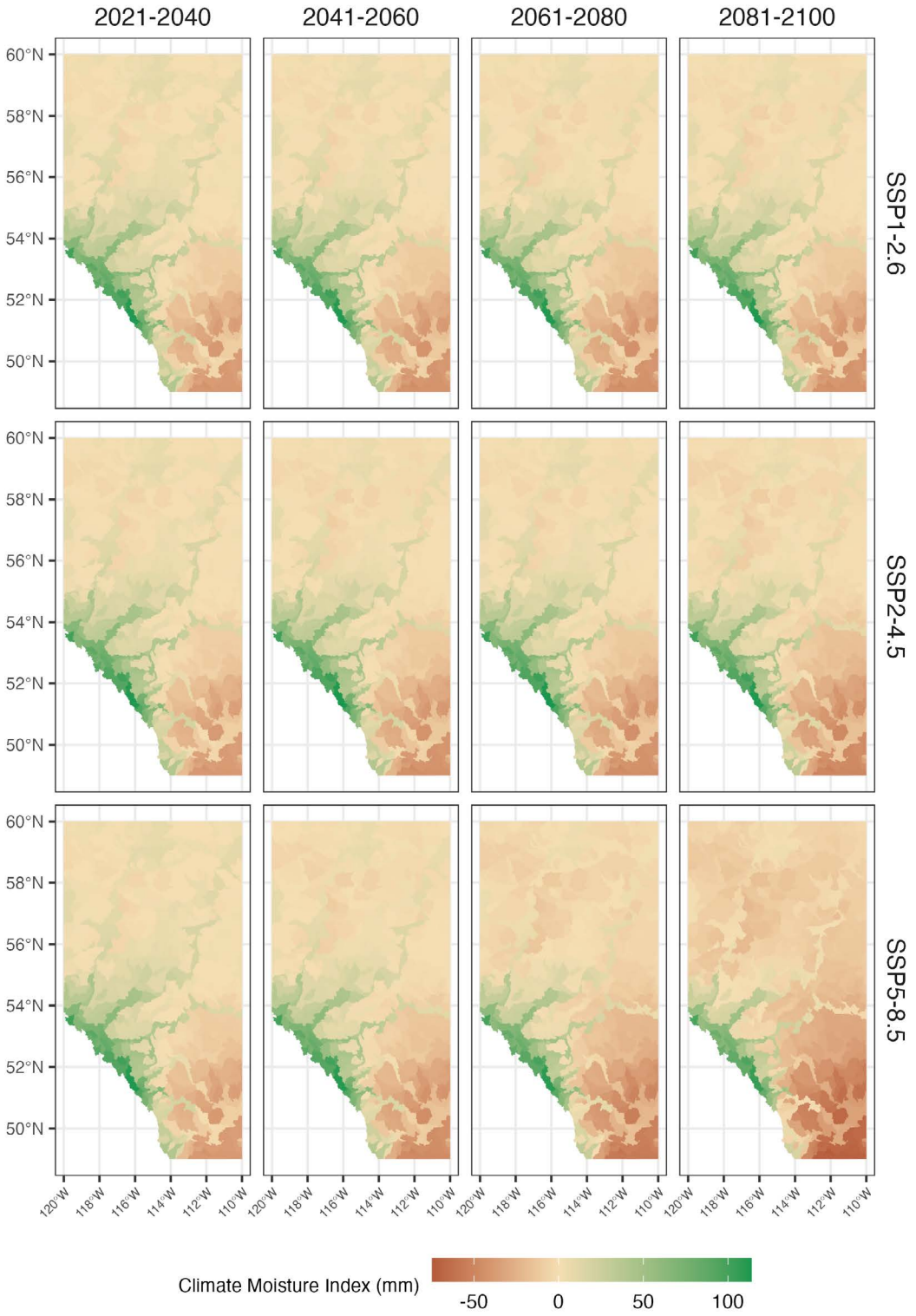



**Figure 2. The spatial distribution of future Climate Moisture Index (CMI) rates in mm year$^{-1}$ for all subbasins in Alberta for future periods 2021-2040, 2041-2060, 2061-2080, and 2081-2100 under three emission pathways SSP1-2.6, SSP2-4.5, and SSP5-8.5.**

### Precipitation

Figure 3 shows the change in annual precipitation for all future periods relative to the historical baseline period (2001-2020). Precipitation in northern Alberta is projected to increase from 5% to 20% under SSP1-2.6, SSP2-4.5, and SSP5-8.5 in the future. These trends are amplified near the end of the century under the more extreme emissions scenarios (SSP2-4.5 and SSP5-8.5) where precipitation is expected to increase over 20-30%, particularly the Hay, Slave, Taltson and Peace basins. The basins in central and southern Alberta, such as the North Saskatchewan River, Red Deer, and Battle, are projected to increase by 0-5% in all scenarios and future periods. The more extreme emission scenarios and long-term future (2061-2080 and 2081-2100) show increases of 10 to 20%. The subbasins of the South Saskatchewan River Basin (Red Deer, Bow, and Oldman) and the Milk River watershed are projected to have little to no increase in precipitation in all scenarios and future periods.

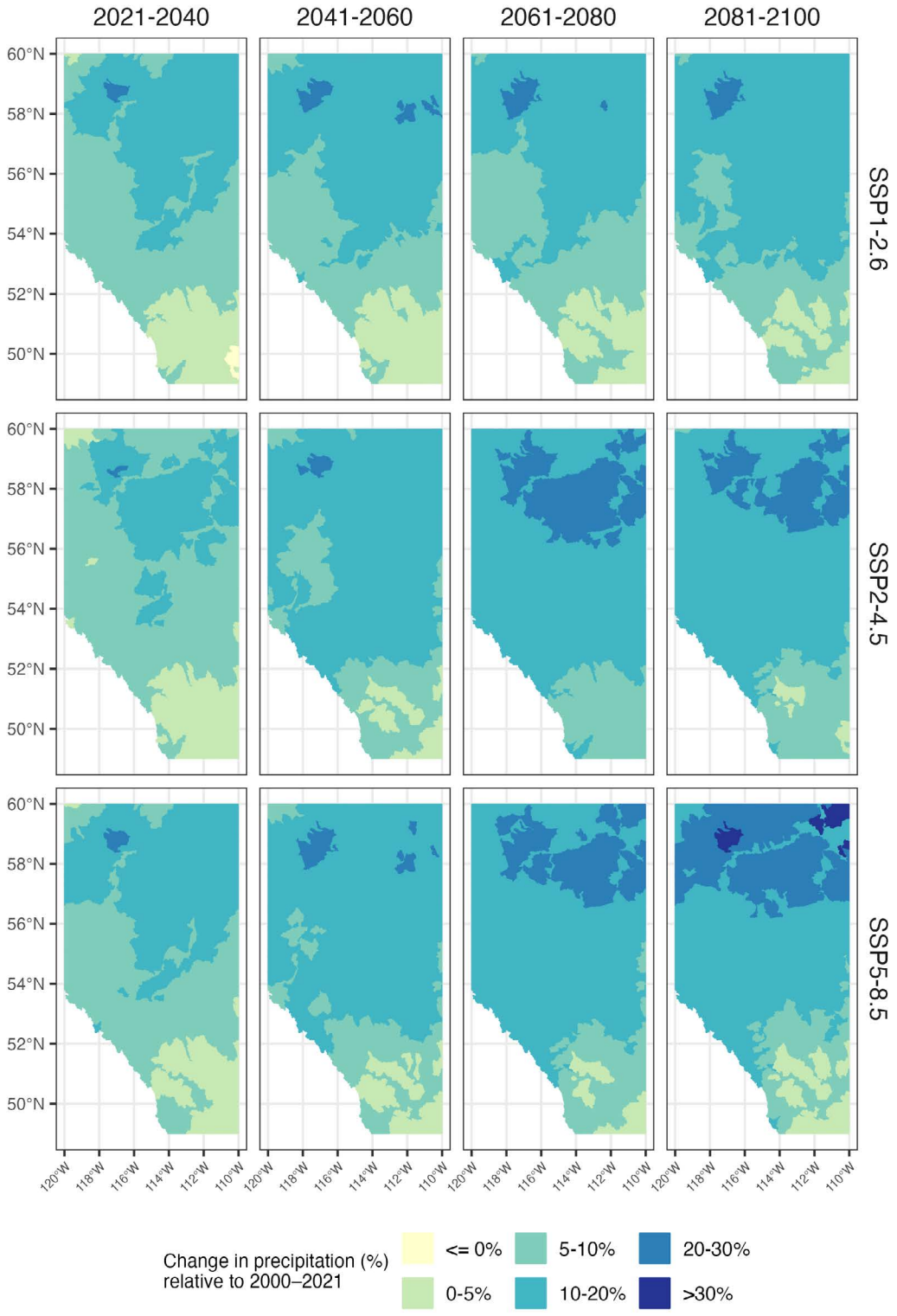



**Figure 3. Relative change in annual precipitation (%) under future periods (2021-2040, 2041-2061, 2061-2080, and 2081-2100) under climate change scenarios (SSP1-2.6, SSP2-4.5 and SSP5-8.5) relative to the baseline period (2001-2020).**

Figure 4 displays the relative change in evaporation (E) under climate change scenarios relative to the baseline period (2001-2020). These results show that E rates are projected to increase across Alberta in the future. Rates of E are projected to rise from 0 to 5% in northern basins including the Peace, Slave, Hay, and Athabasca for all emission scenarios. From 2021-2040, these basins will increase 5 to 10% while some smaller tributaries will experience a 10 to 20% increase for SSP1-2.6 and SSP2-4.5 scenarios. The largest projected increase in evaporation in this region is from SSP5-8.5, which projects a 10 to 30% increase. The headwaters of the North Saskatchewan and South Saskatchewan experience the same effects, with a 10 to 20% increase, rising to over 30% under SSP5-8.5 by the end of the century. The more arid basins in the southern portion of Alberta, including the Milk River Basin and the South Saskatchewan River Basin's subbasins of the Red Deer Basin, Bow Basin, and the Oldman Basin, experience greater evaporation in every scenario, which is projected to increase to over 30% by the end of the century.

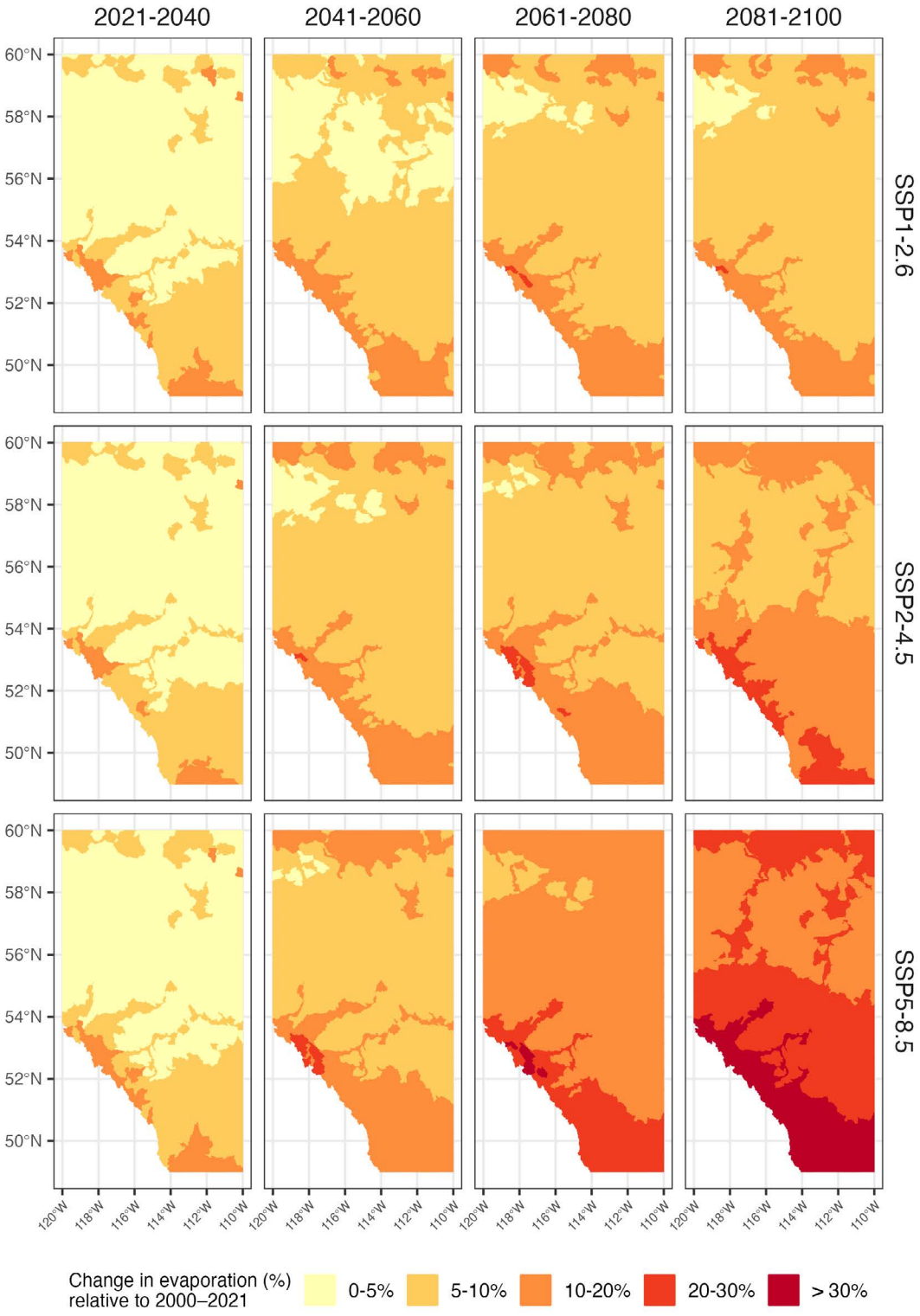



**Figure 4. Relative change in annual evaporation (%) under future periods (2021-2040, 2041-2061, 2061-2080, and 2081-2100) under climate change scenarios (SSP1-2.6, SSP2-4.5, and SSP5-8.5) relative to the baseline period (2001-2020).**

Figure 5 summarizes the median projected changes in Climate Moisture Index (CMI), evaporation (E), and precipitation (P) relative to the 2001–2020 baseline period for each subbasin, grouped by Alberta's major basins under three emissions scenarios. It also shows the spatial variability of projected changes among subbasins in each major basin for each variable. In the near-term period (2021–2040), precipitation is projected to increase across many basins, with the largest gains, around 100 mm year$^{-1}$, occurring in northern Alberta. Evaporation is also projected to increase across all basins, with the largest increases in the drier southern basins, including the Milk, South Saskatchewan, and Red Deer basins. In these southern basins, increases in evaporation generally exceed gains in precipitation, leading to larger water deficits of -10 mm year$^{-1}$ in the future. In contrast, central Alberta basins are projected to remain relatively stable, with CMI median change staying relatively close to 0 mm year$^{-1}$, where the change in P and E change is equal. Northern basins, including the Hay River basin, show increased precipitation that is sufficient to produce a positive shift in CMI. The greatest spread in projections occurs for precipitation, indicating greater variability in larger basins that span diverse hydroclimatic regions, such as the South Saskatchewan. This spatial pattern becomes more pronounced in later periods where higher evaporation drives greater CMI increases in southern and southeastern Alberta, while both precipitation and evaporation continue to rise province wide. Under SSP5-8.5, the variability of CMI change across major basins is greatest. By 2081–2100, E increases in the southern, more arid basins by approximately 200 to 250 mm year$^{-1}$, while northern basins continue to show increases in precipitation of 150 to 200 mm year$^{-1}$ relative to the baseline period.

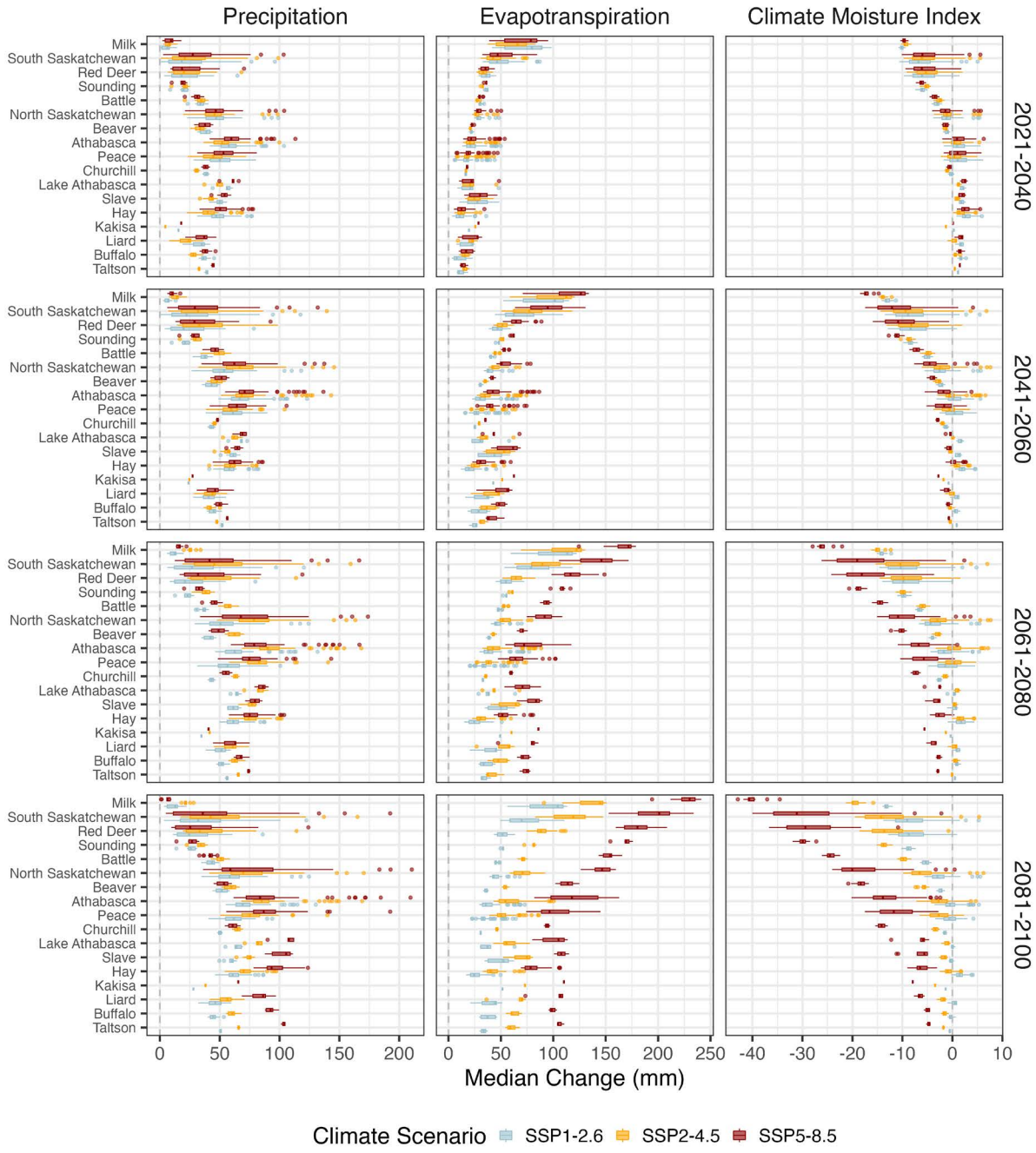



**Figure 5. Median change (mm/year) in Climate Moisture Index (CMI), Evaporation (E), and Precipitation (P) relative to the 2001–2020 baseline for each subbasin, grouped by Alberta's major basins under three emissions pathways.**

## Discussion and Limitations

This work provides a first order estimate of how water availability is projected to change across Alberta into the future under three future climate change scenarios. Broadly, annual precipitation (P) is projected to increase across northern Alberta, while the southern portion of the province is projected

to experience a comparatively minimal increase. Evaporation (E) is projected to increase across the entire province, resulting in an overall reduction in water availability in all regions. However, the more arid basins in southern Alberta are projected to experience more extreme reductions in water availability, where limited precipitation gains are insufficient to offset rising evaporative demand, leading to substantially larger projected increases in Climate Moisture Index (CMI). In contrast, northern basins benefit from greater precipitation increases that largely compensate for higher E, resulting in modest or negligible changes (0 to 10 mm $year^{-1}$) in CMI. A similar pattern is observed in headwater basins along the eastern slopes, where upstream gains in precipitation buffer downstream mainstem deficits. Smaller tributaries situated in more arid regions with little to no upstream headwater contributions are consequently more vulnerable to future water stress.

Based on the change in median and inter-basin spread of projected CMI, P, and E, the Milk, South Saskatchewan, Red Deer and Battle basins are projected to be the most susceptible to greater water deficits under future climatic conditions. However, under all three emission scenarios every subbasin in Alberta is expected to experience increased moisture deficits by the end of the century.

While this work provides insights into the water availability of Alberta by quantifying subbasin water balances, certain limitations must be considered to contextualize these results. First, this work does not consider areas outside Alberta's borders. As a result, upstream sources of water that originate outside the province are not included in this analysis. This is most prevalent in the Peace River Basin (which originates in British Columbia) and the St. Mary and Milk basins (which originate in Montana, USA). Consequently, water availability may be underestimated in these basins.

Secondly, this approach uses annual P and E to determine CMI. As a result, this approach does not account for the seasonal availability of water. Most rivers in Alberta exhibit a nival flow pattern, where the snowmelt provides increased flows in the spring and early summer months and subsequently comparatively low flows during the summer and late fall. As a result, water availability is likely to vary seasonally, which is particularly important for stakeholders and proponents who do not benefit from water storage infrastructure.

The water balance approach applied in this work uses the Hargreaves (1985) method to approximate evaporation which is an empirical relationship that is based on temperature. While it is a sufficient method to approximate evaporation in this context, it does not account for key atmospheric drivers of evaporative demand, including windspeed or net radiation. As a result, evaporation may be overestimated in regions where these variables are expected to change in the future climate conditions (i.e. an increase in cloud cover). This is an especially important in subbasins such as the headwaters where E is particularly sensitive to windspeed and net radiation influences.

Thirdly, this work did not consider land surface effects on the water balance. The land cover affects how P is stored and partitioned on the land's surface, which influences both the seasonality and the timing of water availability. Canopy, forest cover, and vegetation dynamics heavily influence evaporation, which may also influence timing and availability of water. Moreover, hydraulic connectivity and surface water connectivity influence the availability of water in certain regions in Alberta. The prairie pothole regions located in the southeastern prairie basins have contributing areas which have intermittent connectivity between potholes and basins known as non-contributing areas. As a result, this analysis is likely overestimating the amount of available water on the mainstem of many southern basins.

Water use, flow regulation, water management, and water diversions were not accounted for in this water availability assessment. Streamflow is regulated by major dams in most major basins in Alberta, including most notably the Milk, South Saskatchewan, North Saskatchewan, and Peace river basins.

Flow regulation can alter the seasonal timing and availability of water and could include inter-basin transfers (such as in the Milk River system), additional evaporative losses from reservoirs, and a more seasonally consistent flow pattern. Likewise, water licensing and consumptive use is considerable in many basins, especially in southern Alberta, and water demands are expected to increase in the future. While water management is an important component of water availability and is expected to change in the future, especially in response to changing climatic conditions, it is beyond the scope of this work.

## Conclusion

This work developed a first-order estimate of future water availability in Alberta across four time periods and three future ensemble climate scenarios. Results indicate that although precipitation is projected to increase across much of the province, rising evaporation is expected to offset those gains and increase water deficits. Larger rivers supported by upstream mountainous headwaters are more resilient to changes in water availability than smaller tributaries with limited upstream contributions. These reductions in water availability are projected to be most pronounced in southern, more arid basins. Later time periods and higher emissions scenarios, particularly SSP5-8.5, show greater water deficits, along with increased variability in precipitation and evaporation across Alberta by 2081–2100. This analysis provides a broad regional estimate of future water deficits, but it does not account for out-of-province contributions, seasonality, land surface processes, or water management. These factors could materially influence local water availability and should be considered in any more detailed assessment.

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## Closing

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Sincerely,






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