




# Climate Hazard Assessment Town of Torbay, NL Proposed Great Pond Water Treatment Plant



FINAL REPORT  
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February 13, 2026

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Dear Mr. Murray and Mr. Wassmansdorf:

*RE: Climate Hazard Assessment: Town of Torbay Proposed Great Pond Water Treatment Plant – Draft Report*

CBCL Limited (CBCL) is pleased to submit the Climate Hazard Assessment report for the Town of Torbay proposed Great Pond water treatment plant project using the Public Infrastructure Engineering Vulnerability Committee (PIEVC) High Level Screening Guide risk assessment methodology.

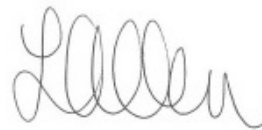
Please do not hesitate to contact the undersigned if you have any questions regarding this report.

Yours very truly,

CBCL Limited



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# 1 Introduction

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Climate change is expected to increase both the frequency and intensity of average and extreme weather events in Newfoundland and Labrador (NL). To ensure the long-term sustainability of infrastructure, water treatment systems must be designed and operated with climate resilience in mind. The *Atlantic Canada Water Supply Guidelines (2022)* recommends conducting climate risk assessments, particularly during major plant upgrades or new construction.

In alignment with these guidelines, the Canadian Urban Institute, in consultation with the Town of Torbay, is supporting the completion of a climate hazard assessment for the planned Water Treatment Plant (WTP) at Great Pond. The assessment will inform future design and management decisions and help build resilience to climate change impacts, promoting reliable service to the community over the long term.

## 1.1 Project Background

The Town of Torbay's existing municipal water supply, North Pond, is currently at maximum capacity and cannot support further population growth or future development. To address this limitation, Great Pond has been identified as a supplementary and future primary water source. Feasibility studies, including water quality assessments and yield analyses, have confirmed that Great Pond has sufficient capacity and acceptable water quality to support a portion of the town's present and anticipated future demand.

The WTP is proposed to be located at the north end of Great Pond off Bauline Line and is currently in the conceptual design phase (Figure 1-1), with the town evaluating two treatment options: Dissolved Air Flotation (DAF) with media filtration or membrane treatment (unspecified pore size). The development of this new water supply will include associated infrastructure such as a water intake, water control structure, storage tank, pump stations, and a fishway to mitigate potential impacts on aquatic habitat.

According to the 2021 water balance and yield assessment (Wood), Great Pond has sufficient capacity to supplement the town's existing water supply and support some near-term development. However, the combined capacity of North and Great Pond will not meet all projected future demand without additional sources or storage.

Water quality in Great Pond is typical of Newfoundland surface waters, with high turbidity and color, low pH, and occasional elevated manganese and aluminum concentrations. The proposed WTP's primary treatment objectives are to remove turbidity, provide effective disinfection, and minimize downstream disinfection by-products (DBPs). In addition, protecting the watershed and preventing source water contamination is a priority, particularly given nearby sources with emerging contaminant concerns such as PFAS. The proposed plant is not currently designed to control cyanotoxins, taste-and-odour compounds, PFAS, or manganese.



**Figure 1-1: Proposed Location of Great Pond WTP and Storage (WSP, 2023)**

## 1.2 Scope of Assessment

The climate hazard assessment examines climate-related risks that could affect the design, operation, and long-term performance of the proposed Great Pond WTP under current and future climate conditions. It draws on preliminary conceptual design, prior studies, stakeholder input, and regional climate data to identify hazards and provide recommendations to enhance climate resilience. While some conceptual design work has been completed, no final decisions on treatment processes, intake design, or infrastructure have been made. The recommendations from the climate hazard assessment are intended to guide future design and operations.

The assessment evaluates potential climate impacts such as from extreme precipitation, drought, winter storms, high temperatures, algal blooms, and wind events, considering source water reliability and treatment capacity for both existing users and near-term development. Priority is given to the WTP's core objectives: water supply, removal of turbidity and DBP control, and effective disinfection. Other factors, including removal of colour, control of TOC/DOC, cyanotoxins, taste-and-odour compounds, and parameters such as manganese or aluminium, were considered but are not included in the intended WTP treatment design; this is reflected in the consequence scoring.

Using the Public Infrastructure Engineering Vulnerability Committee (PIEVC) High Level Screening Guide (HLSG), a structured methodology was applied to assess risks to physical and operational assets, prioritize high-risk climate impacts, and support the development of adaptation and resilience strategies for long-term reliable service.

## 2 Methodology

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The climate hazard assessment for the proposed Great Pond WTP follows the general principles of the PIEVC HLSG, a framework designed to evaluate the potential impacts of climate change and extreme weather on infrastructure systems.

The PIEVC HLSG applies a risk-based approach, combining the likelihood of climate-related events occurring with the consequence of its potential impact. For this assessment:

- ▶ **Likelihood** was determined using available climate data, observed historical trends, and future projections over the expected design life of key infrastructure components (typically 50+ years).
- ▶ **Consequence** was evaluated using professional judgment and stakeholder input (interactive workshop), considering physical impacts, safety, operational and maintenance disruptions, environmental effects, and potential financial losses.

The process involves identifying and evaluating potential impacts arising from various climate-asset interactions, focusing on how specific climate hazards (e.g., extreme rainfall/storms, drought/low flows, extreme heat) could affect the system's operation, performance, and physical infrastructure components. A climate-asset interaction refers to the way a particular climate hazard affects a specific component of an asset or system. These interactions are evaluated by examining the asset's exposure to the hazard, its sensitivity to climate-related stresses, and the likelihood that the hazard will disrupt functionality or cause damage under current and future climate conditions. This analysis was completed through a desktop review, input from subject matter experts in process engineering, and feedback gathered during a workshop with relevant representatives and stakeholders from the Town of Torbay.

Each interaction was assessed and scored using a risk matrix to allow for clear prioritization of risks, from low to high, across each evaluated time horizon, where:

$$\text{Risk (R)} = \text{Likelihood (L)} \times \text{Consequence (C)}$$

The primary objective of this assessment is to support the long-term resilience of the proposed WTP by identifying priority vulnerabilities and risks and informing targeted adaptation strategies.

## 2.1 Likelihood Scoring

The next step in the risk assessment process is to conduct a climate projections analysis to assign likelihood scores representing the projected climate changes. The following likelihood scoring system, based on the principles from the PIEVC HLSG, was designed to emphasize relative risk among various possible climate-asset interactions. Different approaches were used to assign likelihood scores for different types of climate parameters, as outlined in Table 2-1 and Table 2-2.

**Table 2-1: Scoring Scales (#1-#3) for Likelihood Scores**

Score	Scale #1	Scale #2	Scale #3
	Return Period	% of Days in the Year/Season	Qualitative
0	Significant Single Event (100+ years)	N/A	Negligible
1	Likely to occur once in 51 and 100 years	Not expected to occur annually	Highly unlikely
2	Likely to occur once in 31 and 50 years	≤ 5% of the days	Remotely possible
3	Likely to occur once in 11 and 30 years	> 5 and ≤ 35% of the days	Possible occasional
4	Likely to occur once per decade	> 35 and ≤ 75% of the days	Somewhat likely
5	Likely to occur every two years, annually, or more frequently	> 75% of the days	Likely

**Table 2-2: Scoring Scales (#4-#5) for Likelihood Scores.**

Score	Scale #4	Scale #5
	% Change	Relative Temperature Change
0	≤ 10%	≤1.5°C
±1	> 10 and ≤ 30%	> 1.5 and ≤ 3.0°C
±2	> 30 and ≤ 50%	> 3.0 and ≤ 4.5°C
±3	> 50 and ≤ 75%	> 4.5 and ≤ 6.0°C
±4	> 75%	>6.0°C

## 2.2 Consequence Scoring

The next step of the risk assessment process includes assigning consequence scores for each climate-asset interaction. The purpose of consequence scoring is to quantify the impacts or consequences of loss in performance or functionality of an infrastructure component, assuming an event occurs.

The consequence scoring scales applied in this Climate Resilience Assessment were obtained from the PIEVC HLSG. The assigned scores reflect:

- ▶ Type of impacts considered likely to be faced at the facility (e.g., physical),
- ▶ Level to which impacts might affect operations, maintenance, or repair requirements at the site,
- ▶ Potential health and safety risks to operational staff,
- ▶ Possible financial consequences of impacts, and/or
- ▶ Owner/ operator defined risk tolerance.

The consequence scoring scale used to evaluate physical infrastructure, operations, and financial impacts is presented in Table 2-3 below.

**Table 2-3: Criteria Used to Determine Consequence Scores (PIEVC Protocol)**

Severity Score	Description
0	No Effect
1	Insignificant
2	Low
3	Moderate
4	High
5	Very High

Using the above scale, each climate-asset interaction was assigned a consequence score of 1 to 5. Preliminary scores were assigned by the CBCL project team based on background documentation and professional judgement of the risk assessment team. These preliminary scores and risk rankings were then finalized in an interactive workshop with relevant stakeholders from the Town or Torbay.

## 2.3 Risk Calculation and Prioritization

Once the likelihood and consequence scores were determined, the overall risk score for each climate-asset interaction was computed as the product of the likelihood and consequence. A visual representation of this is provided in the matrix shown in Figure 2-1. Risks were then ranked from low to high according to their overall score as described in Figure 2-2.

5	Consequence	5	10	15	20	25
4		4	8	12	16	20
3		3	6	9	12	15
2		2	4	6	8	10
1		1	2	3	4	5
		Likelihood				
		1	2	2	4	5

**Figure 2-1: PIEVC Risk Classification (with CBCL modifications to medium-risk categories for enhanced granularity in prioritization)**

Risk Score (R)	Risk Classification		
17-25		High Risk	Risks that require action.
13-16		Medium-High Risk	Risks that likely require further action.
10-12		Medium-Low Risk	Risks that may require further action.
0 – 9		Low Risk	Risks requiring minimal action.

**Figure 2-2: PIEVC Risk Classification (with CBCL modifications to medium-risk categories for enhanced granularity in prioritization)**

Since likelihood scores were assessed for each respective time horizon considered in the assessment, individual risk scores were obtained for each time horizon to characterize the risk to an asset over its entire lifecycle.

Based on the overall risk score, risks are categorized from low to high with different levels of controls recommended for each risk category (refer to Figure 2-2). The asset components identified as having medium and high-risk profiles are addressed in the findings and recommendation sections in the following chapter. While this assessment aims to emphasize high- and medium-high risk items, general guidance is also provided for items with medium-low risk classifications, primarily in the form of best management practices and strategies.

## 3 Infrastructure Overview

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The following chapter outlines CBCL's understanding of the relevant proposed infrastructure assets included in the climate hazard assessment, including data sources, an overview of the conceptual design, and a description of key infrastructure components to be analyzed.

### 3.1 Data Gathering and Sufficiency

To support the climate change hazard assessment, a review of available background documentation was conducted, along with ongoing discussions with subject matter experts, to gain a comprehensive understanding of the proposed WTP infrastructure and operations at Great Pond.

The relevant information/ documents reviewed include:

- ▶ Feasibility Study and Conceptual Cost for a Water Treatment Facility for the Town of Torbay (CH2MHill, 2011)
- ▶ Great Pond Study (Wood, 2021)
- ▶ Great Pond WTP Conceptual Design – DRAFT (Wood, 2021)
- ▶ Town of Torbay Great Pond Fish and Fish Habitat (Wood, 2021)
- ▶ Great Pond Water Supply Project Description (Registration of Water Body), (WSP, 2022)
- ▶ Water Treatment Options Study Using Great Pond as Source – Final (WSP, 2023)
- ▶ Great Pond WTP and Pine Ridge Servicing – Capital Cost Estimates (WSP, 2024)
- ▶ Source Water Sampling Program (Wood) - Annual reports 2020-2024

### 3.2 Review of Conceptual Design

The proposed Great Pond Water Treatment Plant (WTP) is being developed to provide a reliable municipal water supply for the Town of Torbay, supplementing the existing supply from North Pond and supporting anticipated future development. The plant will be designed to treat raw water from Great Pond to meet regulatory standards, with a focus on removing turbidity, color, and organic matter (TOC/DOC), controlling cyanotoxins and taste-and-odour compounds, and reducing disinfection by-product (DBP) formation.

The Great Pond water balance and yield assessment, based on a 1-in-50-year drought with a 120-day dry period, indicates an average inflow of 4,320 m<sup>3</sup>/day and a required

environmental release of 1,728 m<sup>3</sup>/day, yielding a net reliable withdrawal of approximately 2,600 m<sup>3</sup>/day. The proposed WTP's average demand of 2,000 m<sup>3</sup>/day (2,500 m<sup>3</sup>/day raw water including 20% treatment loss) effectively utilizes reliable yield, leaving little margin for sustained peak withdrawals. Peak-day demand (4,000 m<sup>3</sup>/day, or 5,000 m<sup>3</sup>/day raw water) must be met from finished water storage. While adequate for current and near-term growth, combined supply from Great Pond and North Pond was reported to be insufficient for long-term development (WSP, 2023; Wood, 2021). The watershed is not provincially protected, and with approximately 58% of the pond's volume in the top 2 m (Wood, 2021), source water is sensitive to surface runoff and climate impacts (e.g., increased rainfall intensity, hot temperatures).

Raw water is proposed to be drawn from the deepest portion of the pond (approximately 8 m) near the northwest corner via an intake pipe extending roughly 150 m to a raw water pump station. A water control structure and integrated fishway at the pond outflow will maintain high water levels and allow fish passage.

The WTP building will be located on the northwest side of Great Pond and house filtration, disinfection, chemical systems, pumping, residual management, offices, a laboratory, washrooms, and a maintenance garage. The WTP will accommodate either:

- ▶ Dissolved Air Flotation (DAF) with media filtration, or
- ▶ Membrane treatment with pretreatment filtration.

Both treatment options can remove turbidity, color, and organic matter. Primary disinfection will be provided by ultraviolet (UV) treatment, followed by alkalinity and pH adjustment, with secondary chlorine dosing for residual disinfection and virus control. Finished water will be conveyed via an approximately 700 m transmission main to a proposed storage tank with a booster pump station.

Treatment residuals will be managed on-site in two lined lagoons designed for solids settling, decanting, and environmentally compliant discharge. Site infrastructure will include access roads, fencing, and civil works, with primary power supplied via overhead lines and a backup generator with a 24-hour fuel supply.

Key assumptions applied in the climate risk assessment include:

- ▶ **Power and Control Systems:** All critical equipment will be connected to emergency power via underground lines, with an automatic transfer switch. SCADA system enables fully automatic operation and remote monitoring for operational flexibility.
- ▶ **Electrical Safety:** Generators and exterior equipment (pump stations, tanks, etc.) will be properly grounded.
- ▶ **Subsurface Infrastructure:** All buried utilities and pipelines will be designed and installed to meet applicable frost depth/insulation standards.
- ▶ **Building Design:** Assumed to be designed to the current version of the National Building Code of Canada (NBCC) adopted by the province for post disaster rated

structures. It is noted that the 2025 NBCC was recently issued and includes updates for considerations of climate change.

### 3.3 Asset Characterization

Assets have been grouped by function to reflect their roles within the facility and shared vulnerabilities to climate-related impacts, with subcomponents identified to support targeted risk evaluation (Table 3-1). The characterization aims to describe critical structural and operational infrastructure, systems, and equipment associated with the proposed water treatment plant, highlighting those potentially at risk of damage, failure, or service disruption under future climate and extreme weather conditions.

**Table 3-1: Asset Characterization**

Asset Group	Key Assets and Functions
Water Source and Yield	<ul style="list-style-type: none"> <li>• Great Pond reliable yield: ~2,000 m<sup>3</sup>/day</li> <li>• Yield analysis based on historical 1-in-50-year drought and assuming 120-day dry period.</li> <li>• Max-day demand: 4,000 m<sup>3</sup>/day</li> <li>• Maximum treatment feed flow: 5,000 m<sup>3</sup>/day (includes ~20% treatment waste) is thought to be able to be supported by Great Pond (Wood, 2021)</li> <li>• Water balance inputs: precipitation, runoff, evapotranspiration, controlled outflows (environmental maintenance flows for fish passage) evaluated based on historical recorded climate data (ECCC St. John's A climate Station ID: 8403506).</li> <li>• Groundwater was determined to not be a contributing factor to storage in Great Pond (i.e., <math>GW_{in} = GW_{out}</math>)</li> </ul>
Water Level Control and Environmental Protection Structures	<ul style="list-style-type: none"> <li>• Water control structure: located at pond outflow, concrete and earth-fill structure to be designed to maintain pond water levels at the existing high watermark. Unknown if overtopping/ spillway included.</li> <li>• Integrated fishway: Concrete fish passage structure, constructed in conjunction with the control structure to maintain fish passage.</li> </ul>
Intake and Withdrawal Infrastructure	<ul style="list-style-type: none"> <li>• Intake location: Northwest corner of pond at deepest pond point which is approximately 8 m depth.</li> <li>• Intake pipe: proposed HDPE</li> <li>• Raw water pump station lifts water to treatment plant</li> </ul>
Treatment Processes	<ul style="list-style-type: none"> <li>• Treatment objective: TOC/DOC and DBP precursor removal; designed to manage high turbidity, color, and organic matter</li> <li>• Treatment options: <ul style="list-style-type: none"> <li>• DAF &amp; media filtration</li> <li>• Pretreatment filtration &amp; membrane treatment</li> </ul> </li> </ul>

Asset Group	Key Assets and Functions
Water Quality Control Systems	<ul style="list-style-type: none"> <li>• Primary disinfection: UV system (variable power, flow-paced)</li> <li>• Secondary disinfection: Liquid chlorine (12% NaOCl)</li> <li>• pH/alkalinity adjustment: Soda ash (Na<sub>2</sub>CO<sub>3</sub>) dosing system</li> </ul>
Finished Water Storage and Distribution	<ul style="list-style-type: none"> <li>• Finished water storage tank and booster pump station located northeast of Great Pond</li> <li>• Storage Tank ~2,150 m<sup>3</sup> glass-lined steel bolted tank (15 m diameter × 14 m height)</li> <li>• Transmission main: ~700 m, along existing corridors</li> </ul>
Residuals and Waste Management	<ul style="list-style-type: none"> <li>• Two on-site lined residual lagoons with synthetic liners and protective granular cover, designed for solids settling, decanting, and a combined minimum of 12 months residuals storage, and controlled overflow discharge to the pond outflow channel.</li> </ul>
Power Supply and Backup Systems	<ul style="list-style-type: none"> <li>• Primary power via overhead electrical distribution lines</li> <li>• On-site diesel backup generator with fuel storage for minimum 24 hours full plant operation</li> </ul>
Monitoring, Control, and Operations	<ul style="list-style-type: none"> <li>• SCADA and instrumentation for flows, levels, and water quality</li> </ul>
Building Infrastructure	<ul style="list-style-type: none"> <li>• WTP building located northwest of Great Pond. Construction details: <ul style="list-style-type: none"> <li>• Concrete foundations; wood or steel superstructure.</li> <li>• Assumed sloped roof design.</li> <li>• Assumed designed to post disaster rating standards.</li> <li>• Heating and Ventilation equipment present. It is unknown at this time if active cooling will be included at the process building.</li> </ul> </li> </ul>
Site Infrastructure	<ul style="list-style-type: none"> <li>• Access roads: gravel roads, parking and walkways</li> <li>• Site fencing and civil works for operations and maintenance</li> </ul>

## 4 Climate Analysis

The detailed climate analysis, projection data, and likelihood score justification can be found in Appendix A. The list of climate parameters considered for this study was developed by the risk assessment team in consultation with subject matter experts in each major engineering discipline (e.g., process, civil). The climate change parameters identified that could potentially impact building assets are summarized in Table 4-1 below.

**Table 4-1: Climate Parameters Considered in the Climate Resilience Assessment**

Climate Parameter	Index
Hot Temperatures	Number of Days Max. Temp > 25°C in Warm Months
Freeze-Thaw Cycles	Winter Number of Days with Max. Temp > 0°C and Min. Temp < 0°C
Extreme Rainfall	1 in 10-year Sub-daily Rainfall Intensity 1 in 100-year Sub-daily Rainfall Intensity
Ice Accretion	1 in 20-year Ice Accretion Thickness
Drought	Prolonged Dry Period resulting in Low Water Levels
Wind Load	1 in 50-year Hourly Wind Pressure
Storms and Extreme Winds	Hurricanes and Tropical Storms
Winter Storms	Intensity and Frequency of Winter Storms including blizzards and nor'easters
Thunderstorms and Lightning	Intensity and Frequency of Thunderstorms; Average Number of Days with Lightning (within 25 km)
Wildfire	Frequency and Intensity of Wildfire

### 4.1 Data Sources

The following primary sources of climate information were used for assessment of the atmospheric climate parameters:

1. **Climate Normals.** Collected from Environment and Climate Change Canada (ECCC) Climate Data Normals St. John's A Station (ID 8403506).
2. **IDF Curves.** Obtained from ECCC St. John's A Station (ID 8403506) for characterization of baseline climate conditions.
3. **ClimateData.Ca.** A data portal from ECCC, which provides a variety of climate indices derived from both historical observations and climate model projections. Model

projections are based on an ensemble of 26 statistically downscaled GCMs in the Sixth Coupled Model Intercomparison Project models (CMIP6).

4. **Clausius-Clapeyron Equation.** A “temperature scaling” approach based on the Clausius-Clapeyron (CC) Equation, where each degree of warming results in an approximately 7% increase in precipitation intensity (Westra *et al.*, 2014) for daily precipitation events. An approximately 7% increase in precipitation intensity for temperatures below 12°C and 14% for temperatures above 12°C (Westra *et al.*, 2014) was applied for sub-daily rainfall events. This method is considered scientifically defensible by authoritative sources such as CSA PLUS 4013:19 and Cannon *et al.* (2020).
5. **Literature.** In addition, for the climate parameters that are not readily available in global or regional climate model outputs, information was obtained from the literature (e.g., process-based understanding from measurement or modelling study conducted elsewhere).

## 4.2 Emission Scenarios

For this assessment, the higher emissions scenarios (RCP 8.5 and SSP5-8.5) from the Coupled Model Intercomparison (CMIP) Phases 5 and 6 was applied for projections, where available.

## 4.3 Projection Horizons

Climate parameters were characterized for “baseline”, “near-term” (2030s), “mid-term” (2050s), and “long-term” (2080s). The baseline represents the historical period, when measured data are available (e.g., 1981-2010 if available). Project horizons encompass the following periods:

- ▶ Baseline: 1981-2010
- ▶ Near-term (2030s): 2021-2050
- ▶ Mid-term (2050s): 2041-2070
- ▶ Long-term (2080s): 2071-2100

## 4.4 Climate Projection Summary

Table 4-2 and Table 4-2 present a high-level summary of future projected trends for each climate parameter considered in the project scope and associated likelihood scores, respectively.

**Table 4-2 Future Projected Climate Trends in the Project Region**

Climate Parameter	General Future Projected Climate Trend
Warm Temperatures	The frequency and duration of warm temperatures are projected to increase significantly over the 21 <sup>st</sup> century, with more frequent, longer, and more intense warm spells. This reflects strong warming signals across all global climate models (GCMs). Confidence in projections are

Climate Parameter	General Future Projected Climate Trend
	high, as temperature projections are among the most robust in climate science.
Drought	Drought conditions, particularly in summer, may worsen over time, driven by higher temperatures, increased evaporation, and longer dry periods. Confidence is moderate, with strong agreement on warming but more variability in seasonal precipitation projections and snow melt contributions.
Freeze-Thaw Cycles	Winter freeze-thaw cycles are projected to remain relatively consistent over time with slight increases by mid-century followed by small decreases later as winters continue to warm. Confidence is moderate, since the balance between warming and freezing thresholds is sensitive to local temperature shifts.
Extreme Rainfall	Extreme precipitation events are projected to increase in both frequency and intensity, with larger increases for high-return-period storms (e.g., 1 in 100-year events). This aligns with the physics of a warming atmosphere holding more moisture. Confidence in projections is moderate to high.
Ice Accretion	Ice accretion projections show a small decrease in the near-term, followed by more significant decreases toward mid and late century as warming reduces the frequency of near-freezing conditions optimal for freezing rain events/ ice storms. Confidence is low to moderate, as freezing rain depends on precise temperature layering in the atmosphere.
Wind Load	Wind load projections show insignificant overall change, although a small conservative increase is sometimes assumed due to potential strengthening of storm systems. Confidence is low, since modern GCMs do not capture wind extremes and mesoscale storm dynamics well.
Hurricanes and Tropical Storms	Conditions favouring formation of hurricanes (e.g., rising sea surface temperatures) are projected to increase overtime, leading to a potential increase in storms occurrence. Confidence is low as hurricanes/ storms are not explicitly simulated by GCMs and projections rely on proxies rather than direct simulation.
Winter Storms	Large winter storms are expected to continue to occur, however, changes in their frequency or intensity remain unclear due to competing influences (warmer air vs. greater moisture availability). Confidence is low, reflecting substantial model disagreement.
Thunderstorms and Lightning Strikes	Conditions favoring thunderstorms, such as increased Convective Available Potential Energy (CAPE), are projected to become more common, potentially increasing lightning strikes. Confidence is

Climate Parameter	General Future Projected Climate Trend
	moderate, driven by agreement on rising atmospheric instability but limited by uncertainties in convective storm modeling.
Wildfire	Conditions favouring wildfire are projected to increase under a warmer climate, such as drier fuels, worsened drought conditions and a longer fire season. When a wildfire starts, it is more likely to become extensive and difficult to control. Confidence in warming-driven wildfire factors is high.

Trends of future changes by the end of the century relative to baseline values under the high emission scenario are depicted based on the symbols defined as below.

Symbol	Description
↑	Increase, e.g., positive change in frequency, intensity or severity of a climate event
↓	Decrease, e.g., negative change in frequency, intensity or severity of a climate event
—	Minor Change, e.g., negligible changes or opposite direction of changes in frequency, intensity or severity of a climate event, low confidence

**Table 4-3 Climate Projection Likelihood Scores**

Climate Category	Climate Parameter	Description	Baseline	2030s	2050s	2080s	Overall Trend
Temperature	Warm Temperatures	Days $T_{max} > 25^{\circ}C$	2	3	3	4	↑
	Freeze-Thaw Cycles	Annual	3	3	3	3	—
		Winter	4	4	4	4	—
Precipitation	Extreme Rainfall	1 in 10-year Sub-daily	4	4	5	5	↑
		1 in 100-year Sub-daily	1	2	3	4	↑
	Ice Accretion	1 in 20-year Ice Accretion Thickness	3	3	2	1	↓
	Drought	Prolonged Dry Period and Low Water Levels	2	3	3	4	↑
Wind & Extreme Events	Wind Load	1 in 50-year Wind Load	2	2	2	3	↑
	Extreme Winds	Hurricanes and Tropical Storms	2	2	2	3	↑

Climate Category	Climate Parameter	Description	Baseline	2030s	2050s	2080s	Overall Trend
	Winter Storms	Intensity and Frequency of Winter Storms	3	3	3	3	—
	Thunderstorms and Lightning Strikes	Intensity and Frequency of Thunderstorms including Average Number of Days with Lightning Strikes (within 25 km) and Hail	2	2	2	2	—
Other Hazards	Wildfire	Frequency and Intensity of Wildfire	1	2	2	3	↑

# 5 Risk Assessment

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## 5.1 Consequence Analysis

The climate hazard assessment evaluated the proposed Great Pond WTP and associated infrastructure based on their ability to reliably supply potable water to the Town and support future development. Consequence scoring focused on the WTP's primary design objectives, including DBP precursor control, pathogen reduction, and consistent delivery of treated water under variable source water quality and flow conditions. Secondary water quality considerations (e.g., manganese or aluminium related to intake depth or stratification) were considered but are not primary design drivers; therefore, consequence scoring emphasizes impacts to design treatment and supply objectives, with secondary effects discussed in Appendix B.

Following the preliminary consequence analysis, an interactive workshop was held virtually on January 21<sup>st</sup> with stakeholders and Town representatives to finalize climate hazard interactions and assign consequence and risk scores for the WTP and associated infrastructure.

## 5.2 Summary of Findings

The climate hazard assessment identified reduced reliable yield from Great Pond as a high long-term risk. Projected increases in drought, longer dry periods, and higher evaporation could constrain the WTP's ability to meet planned average and max-day demands while maintaining required environmental flows. This risk is currently assessed as medium-low but is expected to increase to medium-high by the near term and a high risk in the long-term.

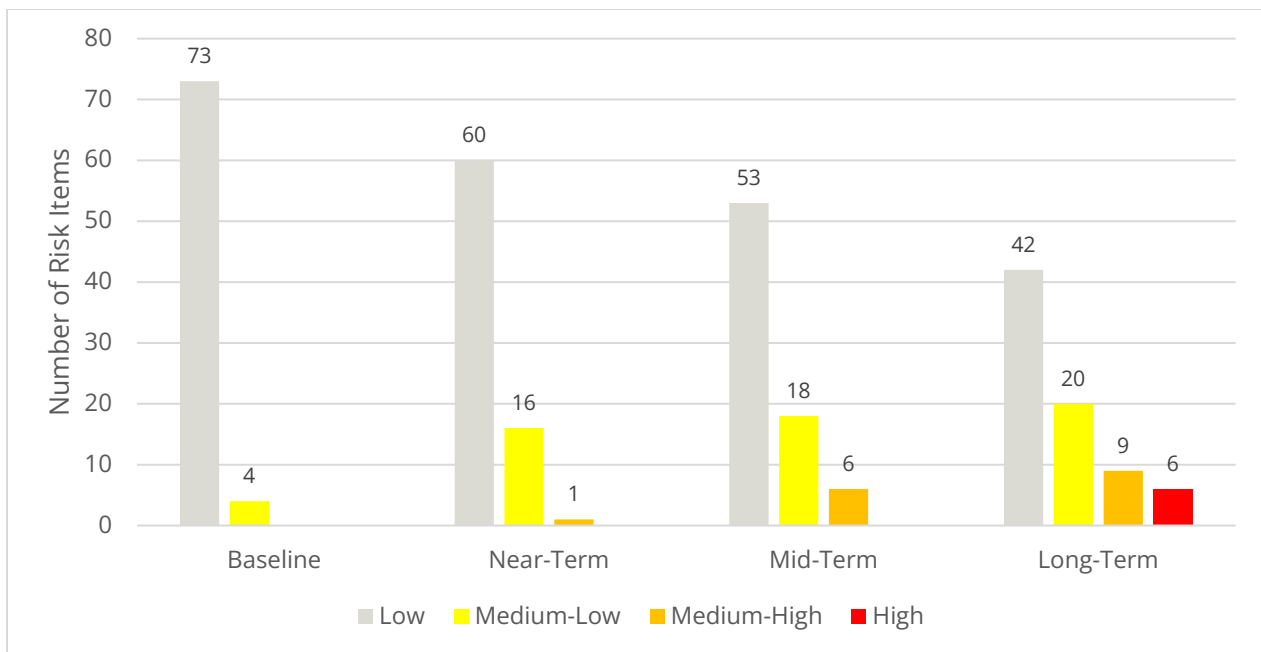
Extreme weather and climate change driven water quality impacts represent a medium-high risk under certain treatment conditions. High temperatures, intense rainfall, or storm-driven runoff may increase turbidity, TOC, cyanobacteria, and algal blooms, temporarily reducing treatment efficiency, increasing chemical demand, or accelerating fouling, particularly in membrane systems. DAF with media filtration is generally more resilient to short-term water quality fluctuations and cyanotoxins, whereas membranes are typically more sensitive to turbidity and organic loading.

Due to the absence of defined flood elevations and significant projected increases in rainfall intensity, flooding was determined to represent a high risk to project infrastructure. Assets located below the 1-in-100-year flood elevation, including climate change considerations, may be at risk of significant structural, operational, environmental, and financial impacts.

Wildfire poses a significant hazard in the region, and the presence of large, forested areas directly bordering/ surrounding the site create conditions where a wildfire could occur near critical infrastructure and interact with the site. Wildfires can cause severe damage, including potential loss of assets and significant health and safety risks for staff. With projected increases in wildfire frequency and intensity, the overall risk to the site is expected to increase over time.

Operational stresses such as high heat, large storms, power fluctuations and lightning strikes, pose medium-low risks to assets such as electrical systems, SCADA controls, pumps, and chemical dosing. These risks are typically mitigated through proper/ resilient design, emergency power provisions, and proactive maintenance practices. Overall, most climate-related risks are classified as low to medium-low.

In total, seventy-seven (77) climate asset interactions were assessed under each of the time horizons, resulting in the risk profile summarized in Figure 5-1 below.



**Figure 5-1 Summary of Risk Profile**

Appendix B presents the complete risk matrix including all climate-asset interactions identified for the proposed Great Pond WTP, with risk classifications ranging from low to medium-high over time and associated impact statements.

## 6 Priority Risks and Resilience Recommendations

This chapter presents resilience recommendations to address climate change hazards related to identified risks with high to medium-high risk profiles as identified through the risk hazard assessment process. High level considerations such as monitoring and best management practices are provided for risk items classified in medium-low risk category.

Risk Classification		
	High Risk	Risks that require action.
	Medium-High Risk	Risks that likely require further action.
	Medium-Low Risk	Risks that may require further action.
	Low Risk	Risks requiring minimal action.

Recommendations for incorporating climate resilience into infrastructure design and/or management typically include one or more of the following actions:

- ▶ **Physical infrastructure design or upgrade considerations** to incorporate resilience, repair or replace asset subcomponents.
- ▶ **Management actions**, such as updates to asset-specific or site-specific operational plans, including emergency response plans.
- ▶ **Monitoring and maintenance** of existing assets to limit vulnerability to risks.
- ▶ **Additional assessments** or studies to fill data gaps.




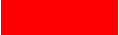
For each priority risk, the associated hazards, potential impacts, and recommended mitigation measures are provided. Where applicable, additional operational considerations and best management practices (BMPs) are included to support proactive maintenance, operational preparedness, and strategic planning to enhance supply and treatment reliability and resilience to future climate variability. As the project is in the conceptual design phase, several assumptions (Section 3.2) are reiterated as design considerations and BMPs for future development. While preliminary design work is complete, no final decisions have been made; these recommendations should be considered in future design and operational planning.

A high-level order of magnitude opinion of probable cost has been provided for the medium-high recommendations outlined in the sections below. Costing for capital and expenditure have been classified as low to high per the structure outlined in Table 6-1 below.

**Table 6-1: Opinion of Probable Capital Cost Categories**

Cost Category	Capital Costs
Low	< \$100,000
Medium	100,000 - \$500,000
Medium/High	\$500,000 - \$2,000,000
High	> \$2,000,000

## 6.1 Source Water Yield and Storage

Risk Summary								
Asset Subcomponent	Source Water Yield							
Climate Parameter	Highest Risk Profile							
<b>Drought</b>	Baseline		2030s		2050s		2080s	

The proposed Great Pond WTP is designed with capacity to withdraw near the full reliable yield of Great Pond under current conditions, with an average-day demand of 2,000 m<sup>3</sup>/day. This leaves minimal margin for sustained peak withdrawals, which must be supplied from finished water storage, highlighting the pond's yield-limited nature during drought conditions. Climate change impacts such as more frequent and intense droughts, longer dry periods, altered seasonal precipitation patterns, and higher evaporation, are expected to reduce the reliable yield of Great Pond over time.

Reduced reliable yield is anticipated to limit the WTP's ability to meet planned average and peak demands, constrain the ponds capacity for future development, and challenge the maintenance of required environmental flows. Groundwater does not significantly contribute to net pond storage (Wood, 2021), making storage and yield in Great Pond more vulnerable to changes in precipitation, runoff, and evaporation. It is noted that the yield assessment did not account for climate change considerations, as recommended in the Atlantic Canada Water Supply Guidelines (2022).

The following are recommended measures to strengthen resilience to increasing drought intensity and frequency in the project region.

Resilience Measure	Description
<p><b>Integrate Climate Change into Yield Assessment and Plant Capacity</b></p>	<ul style="list-style-type: none"> <li>• It is recommended to incorporate climate change considerations (e.g., changes in drought frequency, seasonal precipitation shifts, changes in snowpack and melt regimes, and evaporation) into the Great Pond reliable yield estimate, consistent with the Atlantic Canada Water Supply Guidelines (2022).</li> <li>• Use climate-adjusted yield estimates to define realistic limits on current operations, peak demand, and future development. Limit reliance on Great Pond for planned future growth unless yield is confirmed sufficient under projected climate conditions.</li> <li>• Cost Category: Low</li> </ul>
<p><b>Optimize Withdrawals for Drought and Peak Demand</b></p>	<ul style="list-style-type: none"> <li>• Establish formal drought-response procedures (e.g., conservative withdrawals) during sustained drought periods to protect source reliability (i.e., maintain pond levels) and meet environmental flow and fish passage requirements. Refer to Section 6.4 Emergency Response Plan for further details.</li> <li>• Rely on finished water storage to meet peak-hourly demands, while ensuring that treatment capacity can meet maximum-day demand, since planned average-day withdrawals are close to the pond's maximum reliable yield.</li> <li>• Additional treated water storage to protect against drought conditions is not recommended per the Atlantic Canada Water Supply Guidelines (2022).</li> <li>• Cost Category: Low</li> </ul>
<p><b>Intake Design</b></p>	<ul style="list-style-type: none"> <li>• Conceptual design locates the intake in the deepest part of Great Pond. This reduces risk and maintains operability during drought conditions (i.e., low water levels) and reduces exposure to surface water affected by algal blooms and temperature fluctuations.</li> <li>• Where feasible, adjustable or multi-level intake configurations allow operators to select optimal water layers, avoiding blooms/ cyanotoxins and contaminants (e.g., manganese) and improving raw water quality during stratification and high-temperature periods (refer to Section 6.3 for further information).</li> <li>• Per applicable design guidelines, the intake should be equipped with a screen for debris management and to address sediment and organic loading during storms and extreme rainfall.</li> </ul>

Resilience Measure	Description
	<ul style="list-style-type: none"> <li>• Cost Category: Cost varies significantly with site specific multi-level intake design, in range of medium/high to high.</li> </ul>
<b>Continuous Monitoring and Adaptive Management</b>	<ul style="list-style-type: none"> <li>• Monitor pond levels, inflows, withdrawals, and seasonal trends to support proactive operational decisions and inform future evaluations of yield and drought response procedures.</li> <li>• Refer to Section 6.5.2 for further details on monitoring and sampling recommendations.</li> <li>• Cost Category: Low</li> </ul>

## 6.2 Flood Protection

Risk Summary							
<b>Asset Subcomponent</b>	Electrical, Mechanical/ Process Equipment, Building, Residuals Lagoon, Stormwater Management						
<b>Climate Parameter</b>	<b>Highest Risk Profile</b>						
<b>1 in 100-year Rainfall</b>	Baseline		2030s		2050s		2080s

The project area is not included in the Province’s Flood Risk Mapping, and no flood data was available at the time of this assessment. Wood (2022) states “No floodways and floodway fringes are within the Great Pond watershed”; however, it is unknown if this area was included in the scope of evaluation of the referenced flood lines.

Great Pond levels may be vulnerable to rapid fluctuations during storm events because of the relatively small watershed size and hydraulic interaction with river flows. Therefore, the 1-in-100-year rainfall event is likely a suitable proxy to assess potential flood impacts. Due to the absence of defined flood elevations and significant projected increases in rainfall intensity, flooding was determined to represent a high risk to project infrastructure.

Assets located below the 1-in-100-year flood elevation, including climate change considerations, may be at risk of significant structural, operational, environmental, and financial impacts. Key risks include:

- ▶ **Structural Damage:** Buildings, berms, outlet structures, and foundations may experience overtopping, erosion, scour, and prolonged saturation, leading to loss of integrity.
- ▶ **Loss of Operational Capacity:** Pumps, motors, electrical systems, and treatment equipment are vulnerable to inundation, resulting in reduced or complete loss of function.

- ▶ **Critical System Failure:** Flooding of generators, control panels, and instrumentation can cause extended outages and limit the ability to maintain treatment performance and supply.
- ▶ **Outlet Structure Failure:** Overtopping or submerged controls may impair flow regulation, increasing upstream water levels and downstream risk.
- ▶ **Residuals Lagoon Risks:** Overtopping or berm erosion may lead to impacts to structural integrity and uncontrolled discharge.
- ▶ **Water Quality Impacts:** Floodwater intrusion into treatment units, chemical storage, or residuals areas can compromise treated water quality.
- ▶ **Fuel and Power Risks:** Flooding of the emergency generator or fuel tank may result in loss of backup power or uncontrolled fuel release.
- ▶ **Access Limitations:** Flooded access roads may restrict operator entry, delaying response actions during critical events.

The following resilience recommendations were developed to reduce flood risk and improve long-term system reliability.

Resilience Measure	Description
<b>Flood Modeling</b>	<ul style="list-style-type: none"> <li>• Update the hydraulic/water balance model to determine the 1 in 100-year flood elevation and extent, incorporating climate-change projections for future rainfall intensity and peak flows.</li> <li>• Include the outlet control structure in the hydraulic model to evaluate performance under current and future flood conditions.</li> <li>• Cost Category: Low</li> </ul>
<b>Critical Elevations</b>	<ul style="list-style-type: none"> <li>• Elevate critical infrastructure (WTP building, electrical systems, generators, control panels, process units) above the 1 in 100-year flood elevation including climate change considerations, considering municipal requirements and meeting applicable regulatory and code-based minimums for freeboard and flood protection.</li> <li>• Cost Category: Significantly depends on flood measures required, informed by the flood modelling.</li> </ul>
<b>Outlet Control Structure and Dam Safety</b>	<ul style="list-style-type: none"> <li>• Design the outlet structure to regulate water levels to an acceptable level for events up to or exceeding the 1 in 100-year flood (based on regulatory requirements and/or Canadian Dam Association Guidelines, as applicable), including consideration for projected climate change driven increases in peak flows and water levels.</li> <li>• It is recommended to review outlet structure and berm safety against Canadian Dam Association (CDA) guidelines to determine whether higher return-period events should be considered.</li> <li>• Cost Category: Low</li> </ul>

Resilience Measure	Description
<b>Stormwater Management</b>	<ul style="list-style-type: none"> <li>Design stormwater systems (e.g., conveyance and post-development retention features) to accommodate projected increased rainfall intensity and runoff due to climate change.</li> <li>Grade the site to direct surface runoff away from buildings, equipment pads, foundations, and access routes.</li> <li>Cost Category: Low</li> </ul>
<b>Access Planning</b>	<ul style="list-style-type: none"> <li>Develop an emergency response plan which considers site access, accounting for road flooding, alternate routes, and restricted site entry during extreme events. Refer to section 6.4 Emergency Response Plan for further details.</li> <li>Cost Category: Low</li> </ul>
<b>Lagoon Resilience</b>	<ul style="list-style-type: none"> <li>Assess residuals lagoon capacity for increased inflows (i.e., rainfall) and evaluate berm freeboard, erosion protection, and overtopping risk. Design should reduce risk of uncontrolled discharge and impacts to settling, including considerations of climate change.</li> <li>Cost Category: Low</li> </ul>

## 6.3 Source Water Quality and Treatment Resilience

Risk Summary							
Asset Subcomponent	Water Quality and Treatment						
Climate Parameter	Highest Risk Profile						
- Max. Temp > 25°C							
- Drought	Baseline		2030s		2050s		2080s
- Extreme Rainfall							

Climate change is expected to increase variability in both water quantity and quality at Great Pond, including more frequent conditions conducive to the occurrence of algal blooms, elevated organic loading, and turbidity spikes, with implications for withdrawal and treatment operations. Key impacts include:

- ▶ **Source Water Level Variability:** Droughts, altered runoff, and higher evaporation may lower and fluctuate pond levels, increasing sediment entrainment, and result in fluctuations in water quality. Extreme rainfall can cause rapid water level changes and debris loading.
- ▶ **Thermal Stratification, Turnover, and Deep Intake Effects:** Elevated temperatures can strengthen thermal stratification, leading to low dissolved oxygen conditions in bottom waters and internal release of metals (e.g., iron and manganese), nutrients, and

reduced compounds. Deep intakes may be exposed to these conditions during stratification, while seasonal or storm-driven turnover events may transport these constituents throughout the water column, causing rapid changes in quality at shallow/ mid-depth intakes.

- ▶ **Algal Blooms, Cyanotoxins and T&O Compounds:** Warmer temperatures, stagnant or low flow conditions, and increased nutrient inputs may increase the likelihood the algal/cyanobacterial blooms may occur that can produce cyanotoxins and taste-and-odour compounds. The impact of a bloom can include increasing chemical demand, filter fouling, and backwash frequency, potentially reducing UV disinfection effectiveness.
- ▶ **Elevated Turbidity, TOC/DOC and DBP Risk:** Runoff and extreme precipitation can mobilize organic material resulting in increased coagulant demand and treatment costs and raise disinfection by-product formation potential. Increased turbidity and solids loading from runoff can stress clarification and filtration processes.
- ▶ **High Water Temperatures:** Elevated temperatures accelerate biological activity, alter reaction kinetics, decrease DO, increase turbidity and organic loading, increase chemical demand, and can challenge treatment consistency.
- ▶ **Coagulant, pH and Alkalinity Adjustment:** Changes in source water quality may result in increased coagulant dosing requirements and pH and alkalinity adjustments.

Relative to membrane treatment, DAF has a lower risk profile under increasingly variable source water quality conditions and is more forgiving of operational fluctuations. Membrane-based treatment systems require more precise operation and control under variable water quality conditions and are at higher risk of fouling during extreme or rapidly changing events, which can result in increased operational complexity, downtime, and lifecycle costs. However, both are industry standard treatment technologies and would be appropriate for treating the source water of Great Pond.

Conventional treatment alone has limited ability to manage cyanotoxins and T&O compounds. Although chlorination can oxidize some cyanotoxins, it is not considered a reliable or appropriate primary control strategy due to its position at the end of the treatment train and the associated risk of elevated disinfection by-product (DBP) formation. During a bloom, additional measures may be required in coordination with regulators. In a worst-case scenario, a Do-Not-Consume advisory may be required.

Overall, DAF is an effective and comparatively robust treatment technology for the removal of algae and cyanobacterial biomass, as well as TOC/DOC. While DAF and membrane filtration (Microfiltration (MF)/ Ultrafiltration (UF)) are effective at removing algal and cyanobacterial biomass, they are not effective barriers for dissolved cyanotoxins or T&O compounds such as geosmin and MIB (2-Methylisoborneol). Nanofiltration (NF) and reverse osmosis (RO) may remove some cyanotoxins but should not be relied upon as the sole treatment barrier.

The Atlantic Canada Water Supply Guidelines (2022) recommends accounting for future changes in water quality, including climate change, during intake and treatment design. The following resilience recommendations highlight key conceptual design features, additional design considerations, and operational practices that enhance WTP resilience, reliability, and flexibility under variable source water conditions.

Resilience Measure	Description
<b>Intake Design</b>	<ul style="list-style-type: none"> <li>Refer to Section 6.1 for recommendations on intake design to enhance resilience to source water quality variability and lake stratification.</li> </ul>
<b>Treatment Process and Chemical Control</b>	<ul style="list-style-type: none"> <li>Select a robust treatment system capable of maintaining performance under source water quality variability resulting from extreme weather and climate change impacts.</li> <li>Conservative process sizing, enhanced coagulation and flocculation, and automated, real-time chemical control improve treatment reliability during high turbidity, elevated organic loading, and algal bloom events, and provide the operational flexibility needed to respond to storm-driven and rapid source water quality changes.</li> <li>It is recommended to consider inclusion of provision for potassium permanganate dosing at the front of the treatment train to support potential future treatment expansion for iron and manganese removal.</li> <li>Cost Category: variable; dependent on the extent of process modifications and integration with overall treatment train; in range of medium/high to high.</li> </ul>
<b>Cyanotoxin Removal</b>	<ul style="list-style-type: none"> <li>Best practice for managing cyanotoxins and emerging contaminants is a multi-barrier treatment approach, incorporating processes specifically designed for dissolved contaminant removal (i.e., advanced treatment).</li> <li>It is recommended to include provisions for potential future expansion of the plant to accommodate advanced treatment. These provisions should be incorporated during the design stage to support long-term treatment reliability and adaptability to future water-quality challenges beyond the current scope. In this context, “provisions” refers to practical design allowances that enable integration of future advanced treatment processes without major reconstruction. This typically includes:               <ul style="list-style-type: none"> <li>Design interconnecting process piping to allow tie-in of a future advanced treatment system.</li> <li>Allocating sufficient building footprint and structural capacity to retrofit the conventional treatment train.</li> </ul> </li> </ul>

Resilience Measure	Description
	<ul style="list-style-type: none"> <li>○ Positioning the connection point and reserving space based on the anticipated configuration of the future treatment technology, recognizing that requirements vary between selected treatment technologies.</li> <li>● Advanced Treatment Options include but are not limited to: <ul style="list-style-type: none"> <li>○ Granular Activated Carbon (GAC): proven and flexible treatment option capable of reducing both cyanotoxins and T&amp;O compounds and may also provide resilience against future contaminants of concern, such as PFAS, should they be present in source water.</li> <li>○ Ozonation: strong advanced oxidation process that oxidizes cyanotoxins, reduces taste-and-odour compounds, improves disinfection, and enhances downstream treatment by breaking down organic matter and increasing resilience to emerging contaminants.</li> </ul> </li> <li>● Cost Category: variable; dependent on selected upgrades; in range of medium/high to high.</li> </ul>
<b>Monitoring and Sampling</b>	<ul style="list-style-type: none"> <li>● Continuous raw and treated water monitoring to detect TOC spikes, DO and pH changes, and algal blooms early.</li> <li>● Routine visual inspections of the pond to detect algal blooms early, support operational awareness, and trigger adjustments to treatment processes or increased water quality monitoring as needed.</li> <li>● Refer to Section 6.5.1 for further details on monitoring and sampling recommendations.</li> <li>● Cost Category: Low</li> </ul>
<b>Operational Response</b>	<ul style="list-style-type: none"> <li>● Operational planning should enable rapid and effective response to changing raw water quality and climate-driven events.</li> <li>● Develop standard operating procedures (SOPs) that allow for process optimization during high-risk periods, rapid adjustment of coagulation, chemical dosing, and UV disinfection in response to raw water quality changes, using monitoring data to support proactive decision-making.</li> <li>● Cost Category: Low</li> </ul>
<b>Maintenance</b>	<ul style="list-style-type: none"> <li>● Routine preventive maintenance of chemical feed, UV, and filtration systems to ensure reliable performance. Increased flushing and backwashing should also be considered.</li> <li>● Cost Category: Low</li> </ul>
<b>Watershed Protection</b>	<ul style="list-style-type: none"> <li>● It is recommended to formally designate the Great Pond watershed as a protected public water supply area to reduce risk of contaminant runoff (e.g., fertilizer, PFAS, other</li> </ul>

Resilience Measure	Description
	<p>contaminants) and associated water quality risks from uncontrolled or unauthorized watershed activities.</p> <ul style="list-style-type: none"> <li>○ It is understood that an application for this designation has been submitted by the Town at this time of this assessment.</li> <li>○ For further information on relevant Provincial and municipal regulations/policies, water supply and watershed classifications, and land-use designations within protected areas, refer to the Great Pond Study; Section 4.3 (Wood, 2021) and Great Pond Water Supply Project Description (Wood, 2022).</li> <li>● It is recommended to develop a Source Water Protection Plan (SWPP) which incorporates climate change impacts informed by the climate hazard assessment, recognizing that shifts in watershed hydrology, increased storm intensity, altered forestry conditions, and soil erosion can significantly affect source water quality over time.</li> <li>○ It is noted that there are owner/ operators of land within the watershed boundary (e.g., farms, residential) which should be considered within the SWPP as they are potential point sources for contamination.</li> <li>● Cost Category: Low</li> </ul>

## 6.4 Emergency Response Plan

Risk Summary								
Asset Subcomponent	Site Infrastructure and Staff							
Climate Parameter	Highest Risk Profile							
Wildfire	Baseline		2030s		2050s		2080s	

Wildfires present an increasing risk to site infrastructure, operational continuity, and the health and safety of staff, making proactive planning essential. To ensure the facility can respond effectively to a potential wildfire hazard in the region, as well as other extreme events (e.g., drought conditions, flooding), it is recommended to develop an Emergency Response Plan which should include the following key components.

- ▶ For wildfire preparedness, maintain defensible space around critical infrastructure by managing vegetation and establishing firebreaks along berms, access roads, and control structures. Ensure emergency access routes are maintained.
- ▶ Regular staff training with clearly defined emergency roles and procedures. Maintain year-round access routes for inspections, maintenance, emergency response, and

evacuation, and conduct post-event inspections to identify and address damage or performance issues.

- ▶ Work collaboratively with local authorities, such as the municipal fire department and regional emergency management agencies, to develop and refine wildfire response procedures, evacuation plans, and communication protocols. Engage these partners in periodic reviews, joint exercises, and site assessments to ensure plans remain current and aligned with regional wildfire risk conditions.
- ▶ Establish site-specific standard operating procedures for drought and low water levels, extreme rainfall, storms, and flooding, power outages, and wildfire or smoke events. Procedures should define trigger thresholds, response actions, operational limits, and roles required to maintain treatment performance and regulatory compliance.

## 6.5 Design Considerations and Best Management Practices

The following recommendations outline key design, operational, and management measures to improve the resilience of the proposed Great Pond WTP to extreme weather and long-term climate change. Resilience recommendations are intended to support reliable operation, regulatory compliance, and adaptability under increasingly variable source water and climate conditions.

### 6.5.1 Design Strategies for Enhanced Resilience

Climate resilience should be integrated into the WTP's design to reduce vulnerability to hazards such as extreme rainfall, flooding, wind/storms, lightning and temperature extremes.

#### Treatment Process Selection and Flexibility

Treatment process selection should prioritize robustness and adaptability to variable and changing source water quality conditions:

- ▶ Recognize that DAF with media filtration is generally more tolerant of short-term water quality variability (e.g., turbidity, TOC, algae, cyanobacteria) than membrane-based systems, which may be more sensitive to fouling and organic loading.
- ▶ Design treatment systems with flexibility for future upgrades, including provision for activated carbon or advanced oxidation, and permanganate, to address cyanotoxins and taste-and-odour risks, manganese removal, or other emerging water quality challenges associated with climate change.
- ▶ Where feasible, design redundancy and operational flexibility should be incorporated as a best practice to improve system resilience under future condition variability due to climate change.

## Site and Infrastructure Design Considerations

The following site and infrastructure measures are recommended to improve resilience to climate-driven hazards:

- ▶ The recently released 2025 NBCC includes updates for climate-change considerations and should be noted during design development, recognizing that formal adoption timelines may vary by jurisdiction.
- ▶ Consider designing the PDR structure (e.g., components such as the lateral load resisting system and the roof system) for wind loads above the minimum NBCC requirements, using the projections outlined in this report (Appendix B). This should be evaluated together by the client and the design team. While the structure is intended to meet post-disaster performance requirements, making major damage unlikely, increasing wind loads over time may mean the building no longer fully meets post-disaster criteria toward the end of its service life.
- ▶ Consider designing the building in accordance with relevant FireSmart principles and construction standards.
- ▶ Consider selection of durable building envelope systems to improve resilience to heavy rainfall and moisture exposure, including continuous air/water barriers, rainscreen wall assemblies, robust roof membranes with positive drainage, and materials resistant to freeze-thaw deterioration.
- ▶ Ensure proper construction and installation of envelope components, particularly flashing, penetrations, joints, and transitions, to reduce vulnerability to water intrusion, as improperly installed systems are a leading cause of moisture-related failures under extreme weather.
- ▶ Consider incorporating active cooling or include HVAC design provisions that allow for future installation of active cooling systems to ensure electrical and process equipment remain within required operating temperature limits (e.g., during extreme heat conditions) and maintain acceptable indoor air temperatures for operators.

## Power Reliability and Renewables

Reliable power supply is critical to maintaining treatment, pumping, and distribution during extreme weather events and grid disruptions. The following measures are recommended to enhance power resilience:

- ▶ Provide backup power for all critical systems (treatment processes, pumps, SCADA, controls) via automatic transfer switches and underground electrical connections where feasible.
- ▶ Size on-site emergency generation for a minimum of 24 hours of operation; extended fuel storage is recommended for prolonged outages or restricted site access.
- ▶ Install surge protection and lightning protection for exterior electrical and control equipment.
- ▶ Select energy-efficient equipment and automated controls to reduce electrical demand and operational stress during high-load conditions.
- ▶ Consider renewable energy options (e.g., solar PV) to enhance long-term energy resilience and reduce reliance on the grid.

- Solar PV systems should be sited outside flood-prone areas, designed for appropriate wind and snow loads, and coordinated with roof structure, drainage, and waterproofing systems.
- Using energy-efficient equipment and renewable energy sources also helps minimize greenhouse gas (GHG) emissions by lowering overall electricity consumption. Incorporating these measures during design supports long-term operational sustainability and aligns the facility with climate-responsible infrastructure practices.

## 6.5.2 Monitoring and Maintenance

Active monitoring and proactive maintenance are essential to maintaining treatment performance and regulatory compliance as source water conditions become more variable due to climate change.

### Monitoring and Sampling

A comprehensive monitoring and sampling program is recommended to support proactive operational decision-making and long-term source water assessment:

- ▶ Continuous monitoring of pond levels, inflows/outflows, withdrawals, and intake performance to support evaluation of pond performance and reliable yield over time.
- ▶ Routine sampling of raw and treated water for key parameters, including TOC/DOC, turbidity, colour, pH, alkalinity, temperature.
- ▶ Regularly inspect source water for algal blooms during high-risk periods (e.g., high temperatures, low flows). Conduct cyanotoxin and taste-and-odour sampling during these periods, increasing frequency if a bloom is suspected.
- ▶ In general, increase monitoring and sampling frequency during algal blooms, high-flow conditions, and extreme weather events.
- ▶ Monitoring of environmental flow requirements and residuals lagoon discharges to ensure ongoing environmental compliance.

### Inspection and Maintenance Planning

Routine inspection and preventive maintenance reduce the likelihood that climate-driven stressors will result in service disruptions or infrastructure damage. An inspection and maintenance plan should include:

- ▶ Routine and post-event inspections of treatment systems and equipment, building components (e.g., roofs, foundations, windows), and site infrastructure (e.g., residuals lagoons, outfall/fish passage structure), with additional inspections following major storms or extreme weather events.
- ▶ Routine preventive and proactive maintenance programs for all process, mechanical, electrical, and structural components, including upkeep of access roads, drainage, fencing, to ensure reliable operation and all-weather site access under variable climate conditions. Snow clearing and regular debris removal from site as required.
- ▶ Maintain records of extreme weather events, observed impacts, maintenance actions, and operational responses to support adaptive management and long-term resilience planning.

## 7 Closing

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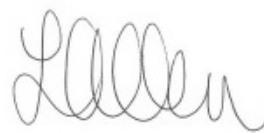
A climate hazard assessment was conducted to evaluate the potential risks that climate change poses to the proposed Great Pond WTP, supporting long-term asset management and planning. The assessment involved a review of site-specific vulnerabilities, an analysis of current climate conditions and future projections, and identification of key climate hazards affecting the infrastructure, with a primary focus on treatment effectiveness.

It is recommended that all future studies, analyses, and design efforts at the plant integrate climate change considerations where cost effective, to ensure resilient, long-term decision-making. Key design elements should address projected climate impacts such as drought, increased source water quality variability, and increased frequency of severe weather events.

This assessment prioritized key risks and developed corresponding resilience recommendations. The report also outlines how these measures have been incorporated into design or where operational and maintenance best management practices or adjustments can be incorporated in the future. Additionally, a high-level opinion of probable cost category is provided to support informed, risk-based decisions for future design and infrastructure investments.



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# APPENDIX A

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## Climate Change Projections

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# 1. Introduction

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The enclosed Climate Change Summary Report presents baseline climate conditions, future climate change projections, and associated likelihood scores used in the Climate Hazard Assessment for proposed Water Treatment Plant (WTP) at Great Pond in the Town of Torbay, NL. The list of climate parameters considered in this assessment was developed with subject matter experts in each relevant engineering discipline. The list of climate parameters considered for this study was developed by the risk assessment team in consultation with subject matter experts in each major engineering discipline (e.g., process, civil). Thresholds were derived from various sources, including climatic values (e.g., design loads) presented in the National Building Code of Canada (NBCC).

The following list are the climate parameters considered for the assessment:

- ▶ **Warm Temperatures:** Number of Days with Max. Temp > 25°C in Warm Months
- ▶ **Freeze-Thaw Cycles:** Winter Number of Days with Max. Temp > 0°C and Min. Temp < 0°C
- ▶ **Extreme Rainfall:** 1 in 10-year Sub-daily Rainfall Intensity; 1 in 100-year Sub-daily Rainfall Intensity
- ▶ **Ice Accretion:** 1 in 20-year Ice Accretion Thickness
- ▶ **Drought:** Prolonged Dry Period and Low Water Levels
- ▶ **Wind Load:** 1 in 50-year Hourly Wind Pressure
- ▶ **Extreme Winds:** Hurricanes and Tropical Storms
- ▶ **Winter Storms:** Intensity and Frequency of Winter Storms
- ▶ **Thunderstorms and Lightning:** Intensity and Frequency of Severe Thunderstorms and Average Number of Days with Lightning Strikes (within 25 km)
- ▶ **Wildfire:** Frequency and Intensity of Wildfire including smoke transport

## 2. Methodology

The methodology for the climate analysis and development of likelihood scores consists of obtaining climate change projections from various data sources (Section 2.1), for a given emission scenario (Section 2.2), over select projection horizons (Section 2.3). The climate change projections were then converted to likelihood scores for each climate parameter (Section 2.4). See Section 2.5 for assumptions and considerations for uncertainties.

### 2.1 Data Sources

The following primary sources of climate information were used for atmospheric parameters.

- 1 Climate Normals.** Collected from Environment and Climate Change Canada (ECCC) Climate Data Normals St. John's A Station (ID 8403506).
- 2 IDF Curves.** Obtained from ECCC St. John's A Station (ID 8403506) for characterization of baseline climate conditions.
- 3 ClimateData.ca.** A data portal from ECCC, which provides a variety of climate indices derived from both historical observations and climate model projections. Model projections are based on an ensemble of 26 statistically downscaled GCMs in the Sixth Coupled Model Intercomparison Project models (CMIP6).
- 4 Cannon *et al.* (2020).** A report to support the future update of the building and bridge design codes, entitled "Climate-Resilient Buildings and Core Public Infrastructure: an assessment of the impact of climate change on climatic design data in Canada". Historical design values are based on the National Building Code of Canada (NBCC, 2020) and Canadian Highway Bridge Design Code CSA S6 (CSA, 2019). Projections are based on the CanRCM4 large ensemble dataset (dynamically downscaled regional simulations from CanESM2, one of the Canadian models used in the Fifth Coupled Model Intercomparison Project models, or CMIP5).
- 5 PCIC Design Value Explorer (DVE).** A web-based technical tool that provides access to historical 19 climate-related design values (such as the 1 in 50-year wind load) and projected future changes in design variables. The historical values are both created from the optimal interpolation of station observations and based on the National Building Code of Canada (NBCC, 2020). Future projections are based on the CanRCM4 large ensemble dataset.
- 6 Clausius-Clapeyron Equation.** A "temperature scaling" approach based on the Clausius-Clapeyron (CC) Equation, where each degree of warming results in an approximately 7% increase in precipitation intensity (Westra *et al.*, 2014) for daily precipitation events. An approximately 7% increase in precipitation intensity for temperatures below 12°C and 14% for temperatures above 12°C (Westra *et al.*, 2014) was applied for sub-daily rainfall events. This method is considered scientifically defensible by authoritative sources such as CSA PLUS 4013:19 and Cannon *et al.* (2020).

**7 Literature.** In addition, for the climate parameters that are not readily available in global or regional climate model outputs, information was obtained from the literature (e.g., process-based understanding from measurement or modelling study conducted elsewhere).

## 2.2 Emission Scenarios

The Coupled Model Intercomparison Project (CMIP) is an international effort to improve climate model projections by coordinating simulations across different climate models. CMIP5 and CMIP6 are successive phases of this project, each using different emissions scenarios to drive climate simulations.

The CMIP5 project uses “Representative Concentration Pathways” (RCPs) to represent different emissions scenarios, whereas the CMIP6 project uses “Shared Socioeconomic Pathways” (SSP). For this study, we used the higher emissions scenario (RCP 8.5 & SSP5-8.5) for projections. The higher emissions scenarios represent when the level of radiative forcing reaches 8.5 W/m<sup>2</sup> by 2100. RCP 8.5 accounts for radiative forcing only through anthropogenic sources, while SSP5-8.5 integrates socioeconomic factors in the emission scenario.

## 2.3 Projection Horizons

Climate parameters were characterized for “baseline”, “near-term” (2030s), “mid-term” (2050s), and “long-term” (2080s). The baseline represents the historical period, when measured data are available (e.g., 1981-2010 if available). Project horizons encompass the following 30-year periods:

- ▶ Baseline: 1981-2010
- ▶ Near-term (2030s): 2021-2050
- ▶ Mid-term (2050s): 2041-2070
- ▶ Long-term (2080s): 2071-2100

It is important to note that CMIP6 projections use a more recent baseline period (1985–2014). However, to ensure greater comparability of delta changes across indices and data sources, a consistent baseline is used throughout this assessment. The exception is literature cited in the assessment, such as Cannon *et al.*, (2020), which uses a baseline period of 1986-2016.

## 2.4 Likelihood Scoring

Within each evaluated time horizon, the relevant climate indices identified to potentially impact the infrastructure considered in the CRAAP have been analyzed and assigned a likelihood score. The purpose of likelihood scoring is to determine the relative probability of different climate trends and events occurring in the future. The probability scoring converts the projections into numerical values that can be compared and used in a risk assessment. The PIEVC scoring system is designed to emphasize relative risk among different possible

climate-infrastructure interactions. Different approaches (or scales) will be used for different types of climate parameters (Table 1, Table 2).

All baseline likelihood scores will be assigned based on Scales 1, 2, and 3 (refer to Table 1). The scale applied to assign each baseline score depends on the type of index. For example, if the index is return period-based such as a 1 in 10-year event, then Scale 1 is applied, if the index is frequency-based such as the number of days per year where a temperature value is exceeded then Scale 2 is applied, or if the index is literature/ process-based such as winter storms then Scale 3 is applied.

Likelihood scores for future time horizons will be assigned based on Scales 1 through 5 (refer to Table 1 and Table 2). The scale applied to assign the score depends on two factors; the type of index (as described above) as well as the projection information available. For example, if an index is frequency-based and projections available (such as through PCIC or ClimateData.ca) provide changes in frequency, then Scale 2 was applied to assign a likelihood score for both the baseline and future time horizons. However, if the projections available are quantified as a relative change from the baseline, then Scales 4 and 5 are applied. For example, projections available through Cannon *et al.* (2020) are predominately quantified as a percent or relative temperature change from a baseline value. In this case, Scales 4 and 5 are applied to the baseline score (assigned based on Scales 1 through 3) and the baseline score is either increased or decreased based on the projected magnitude of change.

**Table 1 Scoring Scales (#1-3) for Likelihood Scores**

Score	Scale #1	Scale #2	Scale #3
	Return Period	% of Days in the Year/Season	Qualitative
0	Significant Single Event (100+ years)	N/A	Negligible
1	Likely to occur once in 51 and 100 years	Not expected to occur annually	Highly unlikely
2	Likely to occur once in 31 and 50 years	≤ 5% of the days	Remotely possible
3	Likely to occur once in 11 and 30 years	> 5 and ≤ 35% of the days	Possible occasional
4	Likely to occur once per decade	> 35 and ≤ 75% of the days	Somewhat likely
5	Likely to occur every two years, annually, or more frequently	> 75% of the days	Likely

**Table 2 Scoring Scales (#4-5) for Likelihood Scores**

Score	Scale #4	Scale #5
	% Change	Relative Temperature Change
0	≤ 10%	≤ 1.5°C
±1	> 10 and ≤ 30%	> 1.5 and ≤ 3.0°C
±2	> 30 and ≤ 50%	> 3.0 and ≤ 4.5°C
±3	> 50 and ≤ 75%	> 4.5 and ≤ 6.0°C
±4	> 75%	> 6.0°C

## 2.5 Key Methodological Considerations

Several factors were considered when choosing sources of climate information:

- 1 Model Resolution** – Climate models vary in spatial and temporal resolution. Global climate models (**GCMs**) have grid cells that are typically one to several hundred km wide. However, some parameters can only be predicted at a higher resolution (for example convective storms which cause high-intensity precipitation). Therefore, these parameters would be better obtained from models with finer resolution that gives more local detail, such as regional climate models (**RCMs**).
- 2 Downscaling** – Downscaling methods (e.g., statistical and dynamical) are used to transform coarse grids of GCMs into finer resolution. Both methods have their own pros and cons. For example, statistical downscaling, including the methodology used by ClimateData.ca, relies on the “stationarity assumption”, implying that past relationships are applied to predict future local climate changes. Dynamical downscaling, on the other hand, requires high-performance computing resources to simulate climate at a higher resolution.
- 3 Uncertainty** – There are several major sources of uncertainty in climate modelling, including natural variability, emission scenarios, and inter-model variability. Therefore, the Intergovernmental Panel on Climate Change (**IPCC**) recommends that an ensemble or range of models is used for climate variables projections. For example, the CMIP6 data used in this assessment from ClimateData.ca is an ensemble of statistically downscaled (i.e., MBCn methodology<sup>1</sup>) 26 climate models. To further characterize model uncertainty, historical measurements were compared with GCM outputs for baseline values.
- 4 Process-based Understanding** – For the parameters that are not readily available in global or regional climate model outputs, information was obtained from literature, e.g., process-based understanding from measurement/modelling study and published literature.





These considerations result in several trade-offs for sources of climate information. Since no one approach is ideal for all parameters, time horizons, locations, or purpose, best practice is to vary the sources of climate information depending on the quality of available data and characteristics of the climate parameter. It is also best practice to use several sources of climate information (and several models) when possible.

<sup>1</sup> Refer to ClimateData.ca for more details.

### 3. Projections

The following sections provide a summary of each climate parameter including, historical climate information, relevant climate change processes, sources of information used, future projections considering climate change (main findings only) and assigned likelihood scores. Trends of future changes by the end of century relative to baseline values under the high emission scenario are depicted based on the symbols defined in Table 3 below.

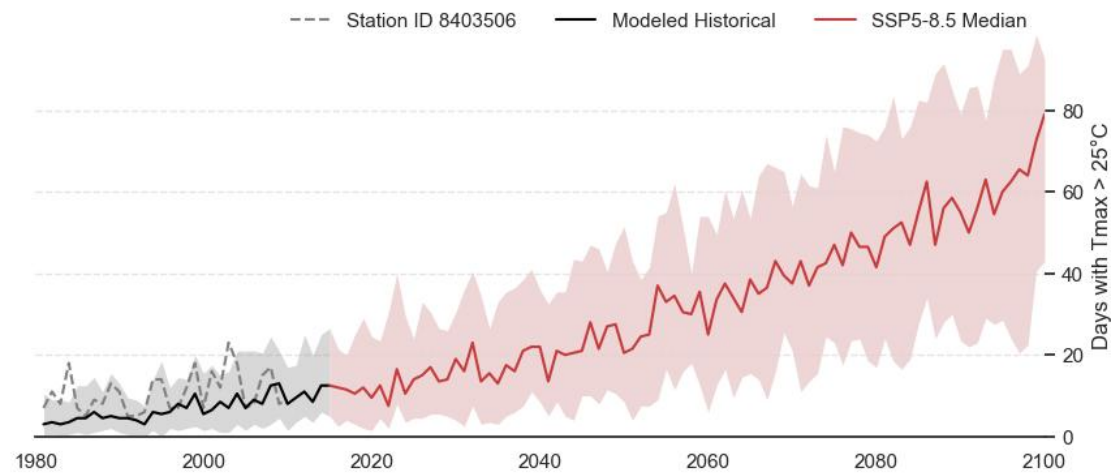
**Table 3 Climate Trends from Baseline Values to the End of Century Under High Emission Scenario**

Symbol	Description
	Significant Increase, e.g., positive and significant change in frequency, intensity or severity of a climate event
	Small/Insignificant Increase, e.g., positive change in frequency, intensity or severity of a climate event, medium or high confidence in changes in one of the aspects
	Decrease, e.g., negative change in frequency, intensity or severity of a climate event
	Minor Change, e.g., negligible changes or opposite direction of changes in frequency, intensity or severity of a climate event, low confidence

### 3.1 Temperature

**Table 4 Climate Change Summary for Temperatures Parameters**

Climate Parameter	Climate Index	Likelihood Scores				Future Trend	Rationale
<b>Hot Temperatures</b>	Number of Days Max. Temp > 25°C in Warm Months	2	3	4	4	↑	<ul style="list-style-type: none"> <li>Historically, warm months in Torbay started in April and ended in October. Temperatures exceeding 25°C, usually occurring from May to September, were relatively more uncommon, with an average of about 10 days per year.</li> <li>An upward shift of average temperature is expected to correlate to an increase in daily maximum temperatures.</li> <li>It is projected that during typical warm months, more days are expected to exceed 25°C, with increasing occurrences in the shoulder seasons. By the end of the century, the number of days above 25°C may increase five-fold (Figure 3-1).</li> </ul>
<b>Freeze-Thaw Cycles</b>	Winter Number of Days with Max. Temp > 0°C and Min. Temp < 0°C	4	4	4	4	—	<ul style="list-style-type: none"> <li>Historically, the area of the site experienced approximately 107 days per year with freeze-thaw cycles, with 40% occurring during an average winter season.</li> <li>As average temperatures shift upwards, either or both daytime and nighttime temperatures may shift from below to above freezing, which impacts daily freeze-thaw cycles.</li> <li>Projections depict minor changes (&lt; 5 days) in days with freeze-thaw cycles during winter. A slight increase by about 5 days is expected in the near- and mid-term, respectively, followed by a small decrease to the baseline value in the long-term.</li> </ul>



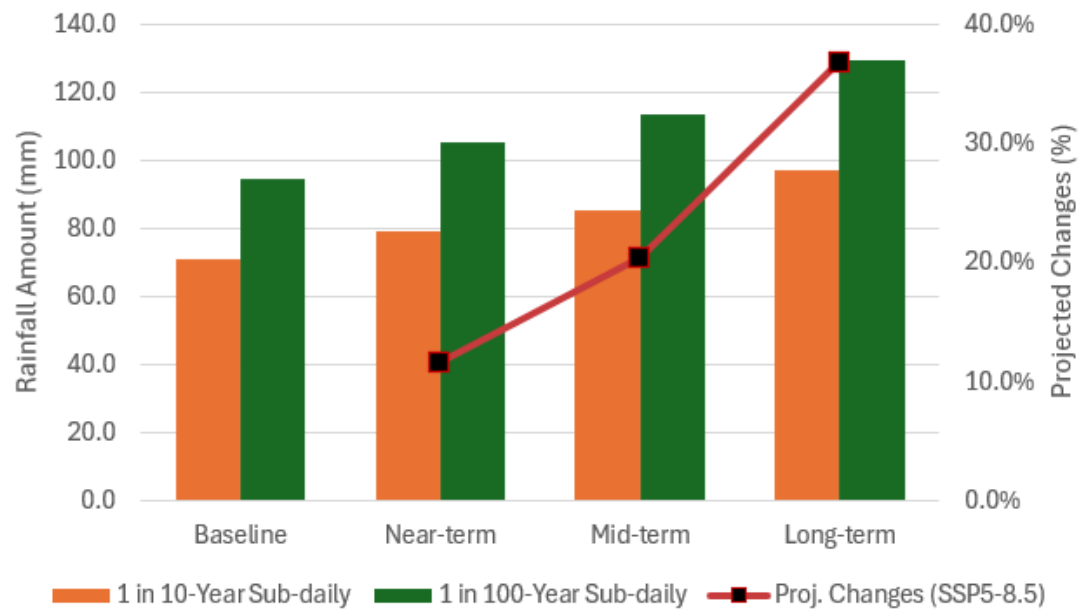
**Figure 3-1: CMIP6 models projected number of days with max. temp greater than 25°C compared with historical climate station data for Torbay under SSP5-8.5 scenario.**

## 3.2 Precipitation

**Table 5 Climate Change Summary for Precipitation Parameters**

Climate Parameter	Climate Index	Likelihood Scores				Future Trend	Rationale
<b>Extreme Rainfall</b>	1 in 10-year Sub-daily Rainfall Intensity	4	4	5	5	↑	<ul style="list-style-type: none"> <li>▶ In the baseline, the 1 in 10-year sub-daily intensity was 71 mm/hr while the 1 in 100-year sub-daily 94.5 mm/hr according to the selected ECCC IDF station.</li> <li>▶ A warmer atmosphere can hold more moisture, which leads to more precipitation (accelerated water cycle). Precipitation intensity is projected to scale at a rate of approximately 7% for temperatures below 12°C and 14% for temperatures above 12°C.</li> <li>▶ Significant increases in rainfall intensity and frequency are projected. Applying the Clausius-Clapeyron scaling factors, projected increases in average temperature result in rainfall intensity increasing by approximately 25% (25%) and 50% (65%) at the 50th percentile (75th percentile) by the mid- and long-term, respectively (Figure 3-2). The current 1 in 5-year rainfall event is expected to occur more frequently over time, potentially becoming an annual event in the long-term. Today's 1 in 100-year extreme rainfall could occur as often as every 5 years in the future.</li> </ul>
	1 in 100-year Sub-daily Rainfall Intensity	1	2	3	4	↑	
<b>Ice Accretion</b>	1 in 20-year Ice Accretion Thickness	3	3	2	1	↓	<ul style="list-style-type: none"> <li>▶ According to the Canadian Highway Bridge Design Code, the area of the site is located in an extreme ice zone, with an average nominal ice thickness of 66 mm.</li> <li>▶ Historically, Torbay saw more than 40 hours of freezing rain annually, with about 4-6 occurrences of extreme ice storms/freezing rain exceeding 18 hours. However, a decreasing trend in the frequency of freezing rain was found in the past decade compared to earlier times in the region.</li> <li>▶ Climate change is projected to cause a poleward shift in the 0°C isotherm due to rising surface temperatures. Rising temperatures are also expected to alter the vertical temperature profile, creating conditions more favorable for freezing rain and ice accretion in the region of the site. However, warm near-surface temperatures are anticipated to lead to instances of rapid melting.</li> <li>▶ Projections depict decreases in the 1 in 20-year ice accretion thickness by approximately 40% in the mid-term and 65% in the long-term (Figure 3-3).</li> </ul>

Climate Parameter	Climate Index	Likelihood Scores				Future Trend	Rationale
							<ul style="list-style-type: none"> <li>▶ However, significant freezing rain events are still anticipated to occur in the project region over time.</li> </ul>
<b>Drought</b>	Prolonged Dry Period and Low Water Levels	2	3	3	4	↑	<ul style="list-style-type: none"> <li>▶ Historically, dry periods in Torbay typically occurred between June and September, but overall, occurrences of significant drought conditions were not frequent in Atlantic Canada. Reported increased occurrence and issues with drought have been experienced in Newfoundland over the last few years, particularly with respect to water supplies.</li> <li>▶ As climate changes, more frequent and intense droughts may occur during warmer months as a result of precipitation deficits paired with warmer temperatures that enhance potential evapotranspiration (Tam <i>et al.</i>, 2019).</li> <li>▶ Using water scarcity approximation as a proxy, there is an increasing trend in the number of days with limited precipitation (&lt; 1 mm) and a warm temperature (&gt; 20°C), indicating potentially increased evaporation in the future (Figure 3-4).</li> <li>▶ However, there is little scientific consensus on seasonal precipitation changes, especially in summer, for the region (Bush and Lemmen, 2019; Tam <i>et al.</i>, 2019; Gu <i>et al.</i>, 2022). By contrast, lakes that depend on snowpack as a source are expected to experience greater impacts, as rising temperatures will likely reduce snowpack availability in the long-term. It is understood that groundwater has limited contribution to annual storage. Therefore, changes in seasonal precipitation, snowpack and melt regimes (refer to Winter Storms section) and increased evaporation are anticipated to impact the water levels in Great Pond.</li> </ul>



**Figure 3-2: Projected changes in extreme rainfall intensities in Torbay using the Clausius-Clapeyron Equation under SSP5-8.5 scenario.**

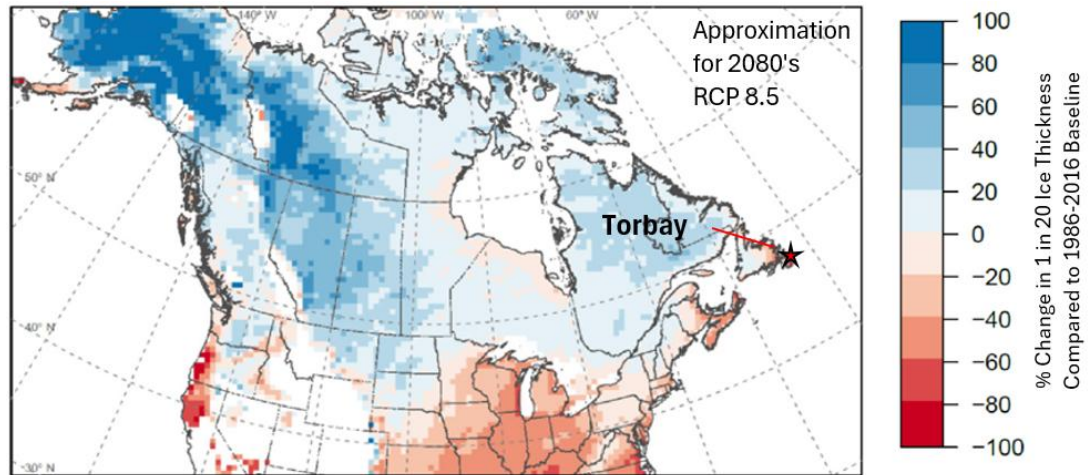


Figure 3-3: Projected changes (in percent) to ice accretion thickness (20-year return period) for +3°C global warming level with respect to the 1986-2016 baseline period (Cannon *et al.*, 2020).

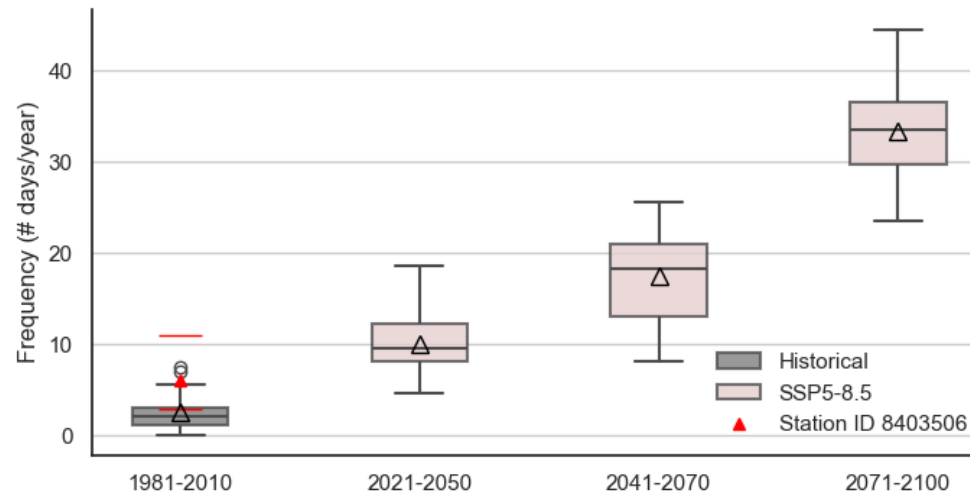


Figure 3-4: Projected water scarcity approximation during the typical dry period in Torbay (June-September), based on the number of days with precipitation < 1 mm and daily temperature > 20°C under SSP5-8.5 scenario.

### 3.3 Extreme Winds and Storms

**Table 6 Climate Change Summary for Extreme Winds and Storms Parameters**

Climate Parameter	Climate Index	Likelihood Scores				Future Trend	Rationale
<b>Wind Load</b>	1 in 50-year Hourly Wind Pressure	2	2	2	3	↑	<ul style="list-style-type: none"> <li>▶ Extreme winds in the Maritime Provinces (including the Torbay area) are generally associated with storms, such as hurricanes and winter storms. More frequent high wind events occur during the winter months as compared to the summer.</li> <li>▶ Projections depict small (&lt;10%) changes in the 1 in 50-year wind load over time at the site (Figure 3-5) (Cannon <i>et al.</i>, 2020). Conservatively, including considerations of occurrences of storms, including hurricanes, extreme winds may increase by the long-term (see below). It is noted that winds are modelled with low confidence.</li> </ul>
<b>Extreme Winds</b>	Hurricane and Tropical Storms	2	2	2	3	↑	<ul style="list-style-type: none"> <li>▶ Within the monitored historical period (1981-2025) available from NOAA, the area within a radius of 60 nautical miles of Torbay has historically been impacted by tropical storms and hurricanes, for example, Hurricane Igor in 2010 (making land fall as a Category 1).</li> <li>▶ Rising sea surface temperatures hold more available energy which is anticipated to result in increases in intensity of tropical storms/hurricanes. A warmer atmosphere may also enhance the ability of large storms to hold moisture, leading to heavier rainfall during the events (Knutson <i>et al.</i>, 2020).</li> <li>▶ Hurricanes and tropical storms that bring high winds and heavy rains are expected to increase in intensity with climate change. In particular, there is a projected increase in the frequency of Category 4 and 5 Hurricanes in the Atlantic, and the latitude of maximum intensity may move northward (Knutson <i>et al.</i>, 2020; ClimateData.ca, 2024).</li> </ul>
<b>Winter Storms</b>	Intensity and Frequency of Winter Storms	3	3	3	3	—	<ul style="list-style-type: none"> <li>▶ Historically, the region experienced an average of approximately 335 cm of snowfall annually, and winter storms characterized by heavy snowfall, strong winds, and blizzard conditions were not uncommon. In the baseline period, the site experienced an average of 1.1 days per winter with snowfall exceeding 25 cm, with high year-to-year variability.</li> </ul>

Climate Parameter	Climate Index	Likelihood Scores				Future Trend	Rationale
							<ul style="list-style-type: none"> <li>▶ Historical trends show increases in days with heavy snowfall and highest 1-day snowfall in the region (Vincent <i>et al.</i>, 2018), with a poleward shift of storm tracks and a decrease in travel speed (therefore, more impacts) (Karwat <i>et al.</i>, 2022).</li> <li>▶ An upwards shift of average temperature and a resulting shift in winter precipitation from snow to rain may lead to less snowfall. However, extreme winter storm is still expected to occur in the Atlantic Canada, due to the potential further northern shifting of storm tracks.</li> <li>▶ Projections indicate that intense, high-impact snowfall events are expected to continue under warming surface temperatures, potentially occurring less frequently while extreme events become more severe. However, uncertainty remains high due to strong internal atmospheric variability.</li> </ul>
<b>Thunderstorms and Lightning</b>	Intensity and Frequency of Thunderstorms; Average Number of Days with Lightning (within 25 km)	2	2	2	2	—	<ul style="list-style-type: none"> <li>▶ Torbay (similar to other areas on Canada's east coast) does not experience frequent thunderstorms and lightning strikes as compared to cities in central Canada (e.g., Ontario). From 1999 to 2018, the area averaged approximately 4 days per year with lightning activity (Figure 3-6).</li> <li>▶ Across Canada, lightning activity is mainly driven by the daily heating-cooling cycle and the seasonal cycle. These effects are less pronounced over large water bodies, such as coastal regions, compared with inland areas.</li> <li>▶ Warmer air and higher sea-surface temperatures enhance heat and moisture transfer, creating more unstable atmospheric conditions and thus higher convective available potential energy (CAPE). This provides more energy for developing severe weather, including thunderstorms and lightning.</li> <li>▶ It is noted that there is currently no scientific consensus as to whether these processes will translate to a change in the frequency and intensity of lightning occurrence. As a result, the likelihood scores remain consistent.</li> </ul>

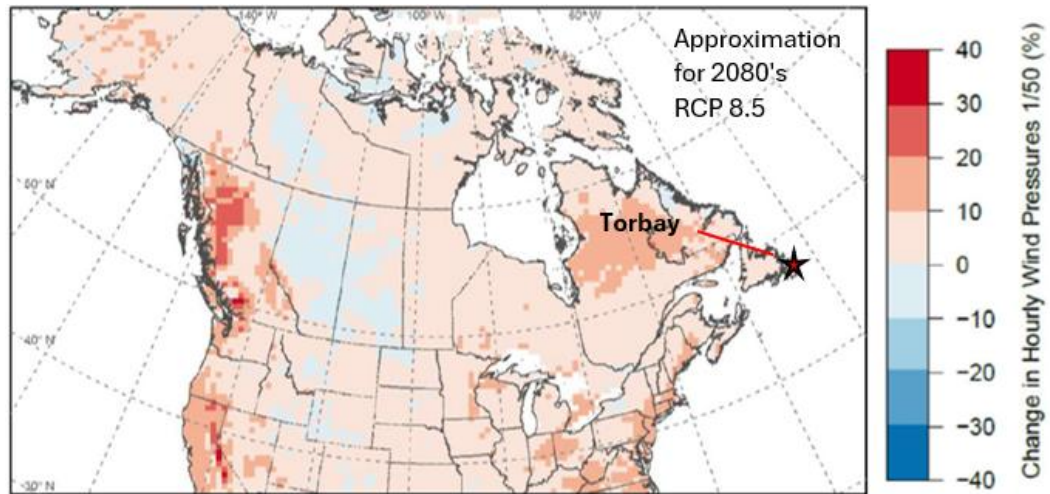


Figure 3-5: Projected changes (in percent) to design wind pressure (50-year return period) for +3°C global warming level with respect to the 1986-2016 baseline period (Cannon *et al.*, 2020).

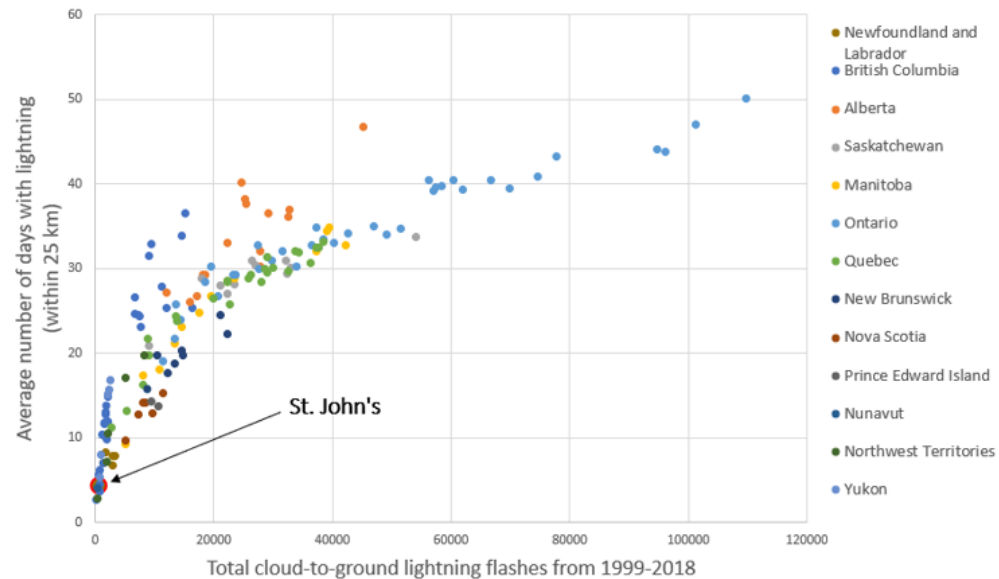



Figure 3-6: Baseline reference for Lightning (ECCC: Lightning activity in Canadian Cities). In comparison to other major Canadian cities.

## 3.4 Wildfire

**Table 7 Climate Change Summary for Wildfire Parameter**

Climate Parameter	Climate Index	Likelihood Scores				Future Trend	Rationale
		1	2	2	3		
<b>Wildfire</b>	Intensity and Frequency of Wildfires	1	2	2	3		<ul style="list-style-type: none"> <li>Historically, the Maritime Provinces (including the Torbay area) have generally experienced very low wildfire occurrences, particularly compared to other parts of Canada (e.g., western regions).</li> <li>As the climate changes, warmer temperatures will enhance potential evapotranspiration. It is predicted that the fire season will lengthen and that the number and extent of wildfires will increase (Flannigan <i>et al.</i>, 2013; Wotton <i>et al.</i>, 2017).</li> <li>It is projected that the intensity of frequency wildfire will increase in the region, due to greater fuel availability and an increase in the proportion of days in fire season with the potential for unmanageable fires (Flannigan <i>et al.</i>, 2013; Gaur <i>et al.</i>, 2021). The number of 'spread days' are expected to increase due to more frequent fire weather conditions that are favorable for significant fire growth (Wang <i>et al.</i>, 2015). Due to the presence of at least 5 km<sup>2</sup> densely vegetated area in the 2.5 km radius of the site, there is potential for wildfire occurrence in the area including the site (Radeloff <i>et al.</i>, 2018).</li> </ul>

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# APPENDIX B

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## Risk Matrix

Asset Group	Asset Subcomponent	Hot Temperatures: Days > 28C	Drought: Low Water Levels	Extreme Rainfall: 1 in 10 year subdaily	Extreme Rainfall: 1 in 100 year	Extreme Winds: 1 in 50 year pressure	Extreme Storms: Hurricanes & Tropical Storms	Ice Loads: 1 in 20 year thickness	Winter Storms	Winter Freeze-thaw Cycles	Thunderstorms and Lightning Strikes	Wildfire and Smoke	
Source Water	Water Quality	Higher water temperatures can contribute to more persistent thermal stratification of the water body which may result in reduced DO concentrations, increased biological activity and/or higher organic concentrations. Higher water temperatures can contribute to conditions favourable for algal and cyanobacteria blooms, increasing the risk/potential of cyanotoxins and taste-and-odour compounds. Low DO concentrations in the hypolimnion may increase potential Fe/Mn release from sediment.	Reduced water levels can contribute to higher water temperatures. Higher water temperatures can contribute to more persistent thermal stratification of the water body which may result in reduced DO concentrations and/or increased biological activity. Higher water temperatures can contribute to conditions favourable for algal and cyanobacteria blooms, increasing the risk/potential of cyanotoxins and taste-and-odour compounds. Low DO concentrations in the hypolimnion may increase potential Fe/Mn release from sediment.	Extreme rainfall can contribute to increased runoff into the source water supply that may result in increased turbidity, TOC/DOC, nutrients, pathogens, and/or metals concentrations.	Extreme rainfall can contribute to increased runoff into the source water supply that may result in increased turbidity, TOC/DOC, nutrients, pathogens, and/or metals concentrations.	Wind-driven mixing and partial disruption of stratification, sediment resuspension in shallow/near-shore areas, increased turbidity. Reduced impact on water quality if system has a deep intake.	Wind-driven mixing and partial stratification (dispersion), sediment resuspension in shallow and near-shore areas, increased turbidity, TOC/DOC, nutrients, pathogens, colour, and episodic metals loading from storm runoff. Reduced impact on water quality if system has a deeper intake.						Asb and particulate deposition can contribute to increased turbidity, TOC/DOC, nutrients in the source water, and taste-and-odour compounds. Impact to water quality can persist for years post wildfire.
		Consequence	2	5	5	5	0	2	0	0	1	0	0
Water Availability and Withdrawal and Hydraulic Structures	Yield, Intake, Outlet control structure incl. fish passage	Increased demand and potential reductions in yield during hot periods; deep intakes may be exposure to low DO, Fe/Mn under strong stratification	Reduced inflows lower available yield, potential limiting ability to meet water demands. Low flows may impact fish passage requirements. Deep intake reduces risk of drawing surface-exposed water with algal toxins, however silt a risk if toxins persist or settle in deeper layers	Elevated turbidity and debris loads cause clogging and abrasion at intake. Reduced impact if intake is deep and is equipped with screen.	Elevated turbidity and debris may cause intake clogging and abrasion; deep, screened intakes reduce risk. Maintenance may be required to restore capacity. High flows could exceed outlet capacity, causing localized erosion. Outlet structure assumed to not be designed to handle overtopping, should overtopping occur, structural integrity may be compromised resulting in significant damage. Unknown impacts to downstream areas.		Wind-driven mixing causes rapid raw-water quality changes, potentially impacting withdrawal. Reduced impact with deep intake. High flows could exceed outlet capacity, causing localized erosion. Structural integrity not expected to be affected. Minor maintenance may be required to clear debris/sediment and restore capacity.			Freeze-thaw cycles may stress pipes, joints, and concrete, but with proper design to frost depth and insulation standards, impacts are anticipated to be limited to normal wear and tear.			
		Risk	4 6 6 8	10 15 15 20	4 4 5 5	5 10 15 20	0 0 0 0	4 4 6	0 0 0 0	0 0 0 0	4 4 4	0 0 0 0	0 0 0 0
Treatment Performance	DAF + Media Filtration	Extreme heat may result in changes in the source water quality entering the WTP and may result in an increase in chemical demand. Significant increase in organic matter or solids may result in shorter filter run times (increase in filter backwashes) and impact the volume of treated water available to enter the distribution system. If an algal or cyanobacteria bloom occurs, DAF is effective at removing algal or cyanobacteria biomass but is not effective treatment for cyanotoxins and/or TAO compounds.	Extreme heat may result in changes in the source water quality entering the WTP and may result in an increase in chemical demand. Significant increase in organic matter or solids may result in shorter filter run times (increase in filter backwashes) and impact the volume of treated water available to enter the distribution system. If an algal or cyanobacteria bloom occurs, DAF is effective at removing algal or cyanobacteria biomass but is not effective treatment for cyanotoxins and/or TAO compounds.	Extreme rainfall events may result in a significant change in source water quality over a short period of time. There may be increased coagulant demand resulting in operators having to make on going dosing adjustments over a short period of time. If there is an increase in filter loading, filter runs may be shortened and require more frequent backwashing. During extreme rainfall, additional water quality and operational monitoring may be required.	Extreme rainfall events may result in a significant change in source water quality over a short period of time. There may be increased coagulant demand resulting in operators having to make on going dosing adjustments over a short period of time. If there is an increase in filter loading, filter runs may be shortened and require more frequent backwashing. During extreme rainfall, additional water quality and operational monitoring may be required.	Increases in source water turbidity or organics may increase the coagulant demand and increase loadings on the filters.	Extreme storms may result in a significant change in source water quality over a short period of time. There may be increased coagulant demand resulting in operators having to make on going dosing adjustments over a short period of time. If there is an increase in filter loading, filter runs may be shortened and require more frequent backwashing. During extreme rainfall, additional water quality and operational monitoring may be required. Depending on season, storms may coincide with lake turnover, increasing Fe/Mn concentrations.						Wildfire within watershed can cause significant and prolonged degradation of source water quality, leading to sustained treatment challenges and increased operational complexity. Potential inability to meet treated water demand if significant impact to filters.
		Consequence	4	4	2	3	1	4	0	0	0	0	5
		Risk	8 12 12 16	8 12 12 16	8 8 10 10	3 6 9 12	2 2 2 2	8 8 8 12	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	5 10 10 15
Treatment Performance	Membrane Treatment	Extreme heat may result in changes in the source water quality entering the WTP and may result in an increase in chemical demand for membrane pre-treatment. Increase biofouling and scaling rates may reduce membrane flux and volume of water treated, requiring more frequent backwashes. If an algal or cyanobacteria bloom occurs, NF/RO membranes can be effective at removing algal or cyanobacteria biomass. NF/RO membranes may be able to remove some cyanotoxins.	Extreme heat may result in changes in the source water quality entering the WTP and may result in an increase in chemical demand for membrane pre-treatment. Increase biofouling and scaling rates may reduce membrane flux and volume of water treated, requiring more frequent backwashes. If an algal or cyanobacteria bloom occurs, NF/RO membranes can be effective at removing algal or cyanobacteria biomass. NF/RO membranes may be able to remove some cyanotoxins.	Extreme rainfall events may result in a significant change in source water quality over a short period of time. There may be increased coagulant demand resulting in operators having to make on going dosing adjustments over a short period of time. Due to increase in loadings, membrane flux may be impacted and membranes may require more frequent backwashes. During extreme rainfall, additional water quality and operational monitoring may be required.	Extreme rainfall events may result in a significant change in source water quality over a short period of time. There may be increased coagulant demand resulting in operators having to make on going dosing adjustments over a short period of time. Due to increase in loadings, membrane flux may be impacted and membranes may require more frequent backwashes. During extreme rainfall, additional water quality and operational monitoring may be required.	Increases in source water turbidity or organics may increase chemical demands and membrane loadings. May result in more frequent membrane backwashes.	Extreme storms may result in a significant change in source water quality over a short period of time. There may be increased coagulant demand resulting in operators having to make on going dosing adjustments over a short period of time. Due to increase in loadings, membrane flux may be impacted and membranes may require more frequent backwashes. During extreme rainfall, additional water quality and operational monitoring may be required. Depending on season, storms may coincide with lake turnover, increasing Fe/Mn concentrations.						Wildfire within watershed can cause significant and prolonged degradation of source water quality, leading to sustained treatment challenges and increased operational complexity. Potential inability to meet treated water demand if significant impact to membrane performance.
		Consequence	4	4	2	3	2	4	0	0	0	0	5
		Risk	8 12 12 16	8 12 12 16	8 8 10 10	3 6 9 12	4 4 4 4	8 8 8 12	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	5 10 10 15
Residuals Management	pH/Alkalinity Adjustment & Disinfection	Extreme heat may result in an increase in organics or biological activity, increasing the chemical demand and potential for DBP formation. Increased temperatures will increase disinfectant decay within the distribution system, adaptive dosing and monitoring required to maintain residuals and DBP control.	Extreme heat may result in an increase in organics or biological activity, increasing the chemical demand and potential for DBP formation. Increased temperatures will increase disinfectant decay within the distribution system, adaptive dosing and monitoring required to maintain residuals and DBP control.	Extreme rainfall events may result in a significant change in source water quality over a short period of time. Increased dosing for pH/alkalinity may be required as coagulant doses are increased. Monitoring of disinfectant doses and residuals as water quality changes should be completed.	Extreme rainfall events may result in a significant change in source water quality over a short period of time. Increased dosing for pH/alkalinity may be required as coagulant doses are increased. Monitoring of disinfectant doses and residuals as water quality changes should be completed.	Minor impact; primarily operational attention for dosing of TOC/Organics increase due to sediment resuspension.	Extreme rainfall events may result in a significant change in source water quality over a short period of time. Increased dosing for pH/alkalinity may be required as coagulant doses are increased. Monitoring of disinfectant doses and residuals as water quality changes should be completed.		Access restrictions during winter storms may temporarily challenge chemical delivery; dual access reduces risk.		Potential increased chemical demand; monitoring and dosing adjustments required to maintain residuals and DBP control.		
		Consequence	3	2	2	3	1	3	0	0	3	0	4
		Risk	6 9 9 12	4 6 6 8	8 8 10 10	3 6 9 12	2 2 2 2	6 6 6 9	0 0 0 0	9 9 9 9	0 0 0 0	0 0 0 0	4 8 8 12
Pumping, Conveyance, and Storage	Pump Stations, Potable Water Tanks, Conveyance Infrastructure	Minor reduction in pump efficiency and equipment life. Warm storage water may increase biological growth, causing taste/odour issues.		Flooding and sump overload may cause pump failure/overload. Assumed pump stations will be designed with flood protection and drainage.		Minor exterior equipment damage from windborne debris	Minor damage to exterior equipment from wind borne debris. Temporary interruption of access or grid power; assumed pump stations or grid power equipped with emergency power.	Temporary interruption of grid power; assumed pump stations equipped with emergency power.	Access delays prolong maintenance and outages. Assumed pump stations equipped with emergency power.	Negligible; if installed to frost depth; normal wear on concrete, pipes/joints	Assumed exterior equipment is grounded. Lightning surges can damage motor and control.		
		Consequence	2	0	5	1	2	1	2	1	1	5	0
Residuals Management	Residuals Lagoon			Shorter retention times during events could temporarily reduce solids settling and increase the risk of short-term non-compliant discharge	Potential exceedance of lagoon detention capacity, triggering controlled overflow or decanting. Shorter retention times during events could temporarily reduce solids settling and increase the risk of short-term non-compliant discharge	Minor wear and tear to liners. Some resuspension of settled materials may occur.	Potential exceedance of lagoon detention capacity, triggering controlled overflow or decanting. Shorter retention times during events could temporarily reduce solids settling and increase the risk of short-term non-compliant discharge. Wear and tear to liners. Some resuspension of settled materials may occur.	Minor wear and tear to liners.	Minor wear and tear to liners.	Minor wear and tear to liners.			
		Consequence	0	0	2	5	1	3	1	1	1	0	0
		Risk	0 0 0 0	0 0 0 0	8 8 10 10	5 10 15 20	2 2 2 2	6 6 6 9	3 3 3 3	4 4 4 4	0 0 0 0	0 0 0 0	

Asset Group	Asset Subcomponent	Hot Temperatures: Days > 28C	Drought: Low Water Levels	Extreme Rainfall: 1 in 10 year subdaily	Extreme Rainfall: 1 in 100 year	Extreme Winds: 1 in 50 year pressure	Extreme Storms: Hurricanes & Tropical Storms	Ice Loads: 1 in 20 year thickness	Winter Storms	Winter Freeze-thaw Cycles	Thunderstorms and Lightning Strikes	Wildfire and Smoke
Site Power and Mechanical and Electrical Systems and Infrastructure	Electrical Service & Distribution, Emergency Power, SCADA, Controls, Security	High heat may reduce efficiency of transformers, generators, and batteries; control panels may overheat if insufficient ventilation			Localized flooding of vaults/conduits may temporarily interrupt power or SCADA; equipment elevation/design assumed to mitigate risk	High winds may damage overhead utility lines or communication antennas, resulting in grid power loss or temporary SCADA communication disruptions. Automatic transfer to backup power mitigates treatment impacts, but monitoring and telemetry interruptions may occur until repairs completed.	High rainfall and flooding combined with wind-related grid outages may cause extended reliance on backup power. Road washouts could delay fuel delivery or site access; however, dual site access reduces risk. Generator failure risk remains low with proper elevation, enclosure sealing, and maintenance.	Ice accumulation on overhead lines and antennas may cause power outages or degrade communication signals, increasing dependence on emergency power systems and extending outage duration.	Regional grid instability during winter storms may cause prolonged outages, increasing reliance on backup generation. Severe storms may delay fuel resupply or operator access; isolated outages beyond generator fuel capacity could affect drasing control and automation if not addressed.	Freeze-thaw conditions may stress conduits, cable penetrations, and exterior enclosures; however, impacts are expected to be negligible assuming underground utilities are installed below frost depth and equipment is designed to applicable insulation and sealing standards.	Lightning strikes may cause power surges that damage motors, breakers, generators, or control systems, resulting in temporary loss of automation or equipment shutdown. It is assumed that all exterior electrical equipment is grounded.	Smoke and poor air quality may clog air intakes and foul sensors, causing ventilation inefficiency or false alarms; impacts are short-term and operational with no expected loss of power if systems are properly maintained.
	Consequence Risk	3 6 9 9 12	0 0 0 0 0	0 0 0 0 0	5 10 15 20	4 8 8 8 8 8	4 8 8 8 8 12	3 9 9 9 6 3	4 12 12 12 12	1 4 4 4 4 4	5 10 10 10 10	2 4 4 6
Building Structure and Envelope	Superstructure, Roof, Cladding, Windows, Doors	Minor wear/tear to seals and exposed components		Roof drainage exceedance may cause localized flooding, mold, or corrosion, design of roof drainage/ leaders anticipated to reduce risk. Water ingress at joints and flashing failures causes interior damage and corrosion	Roof drainage exceedance may cause localized flooding, mold, or corrosion, design of roof drainage/ leaders anticipated to reduce risk. Water ingress at joints and flashing failures causes interior damage and corrosion	Wind uplift pressures and cladding deformation can breach envelope and disrupt services Panel uplift and glazing stresses cause breakage and unsafe conditions	Wind uplift pressures and cladding deformation can breach envelope and disrupt services Panel uplift and glazing stresses cause breakage and unsafe conditions	Excess ice load overstresses roof structures, causing cracking and failure risk Seal failures and glazing cracking cause air leakage and heat loss	Snow buildup restricts access, delays maintenance, and increases roof loading Snowpack against walls retains moisture and stresses structure	Freeze-thaw accelerates concrete cracking, reducing service life and causing spalling Freeze-thaw cycles fatigue materials and increase failure probability	If building not equipped with lightning protection then potential fire risk with timber structures.	potential significant damage up to complete loss of assets.
	Consequence Risk	1 2 3 3 4	0 0 0 0 0	2 8 8 10 10	5 5 10 15 20	2 4 4 4 4 4	4 8 8 8 8 12	1 3 3 3 2 1	1 3 3 3 3 3	1 4 4 4 4 4	4 8 8 8 8 8	5 10 10 15
Building Temperature Control	HVAC Systems	Cooling capacity may be exceeded; reduced performance. Issues maintaining comfortable indoor temperatures.				Windborne debris damages equipment		Intake icing blocks airflow	Snow blockage reduces ventilation and causes overheating and reduced indoor air quality		Lightning surges disrupt control systems and automation	Smoke overloads filters, reducing airflow and fouling systems
	Consequence Risk	3 6 9 9 12	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	1 2 2 2 2 2	0 0 0 0 0	1 3 3 3 2 1	1 3 3 3 3 3	0 0 0 0 0	1 2 2 2 2 2	1 2 2 3
Site Infrastructure	Site Infrastructure & Civil Works	Gravel surfaces; heat impact negligible		Washouts, erosion, potential minor localised site flooding.	Washouts, culvert overtopping, and stormwater exceedance cause erosion and restricted access. Disruption of supply chains and associated impact to treatment if prolonged. Dual access to site reduces risk.	Fence damage and debris impacts compromise security	Washouts, culvert overtopping, and stormwater exceedance cause erosion and access failure. Disruption of supply chains and associated impact to treatment if prolonged. Dual access to site reduces risk.	Icy surfaces create slip hazards	Snow accumulation may restrict access. Disruption of supply chains and associated impact to treatment if prolonged. Dual access to site reduces risk.	Freeze-thaw cycles crack pavements and create uneven surfaces		Site evacuation may be required
	Consequence Risk	1 2 3 3 4	0 0 0 0 0	2 8 8 10 10	4 4 8 12 16	1 2 2 2 2 2	3 6 6 6 6 9	1 3 3 3 2 1	3 9 9 9 9 9	1 4 4 4 4 4	0 0 0 0 0	5 10 10 15



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