Webequie Supply Road Project

Webequie First Nation

January 15, 2026

AtkinsRéalis Ref: 661910-4E-L01-PA or 00

APPENDIX I: WEBEQUIE SUPPLY ROAD CLIMATE CHANGE RESILIENCE

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1. Introduction

As climate changes over time especially in Ontario's Far North, it is critical for infrastructure to be robust and be designed and constructed with potential future climate in mind. An assessment of climate change effects on the proposed Webequie Supply Road Project (WSR, the "Project") is needed to assist in identifying unintended potential risks and impacts on the infrastructure longevity but also on the nearby ecosystems and the human health and safety. Such analysis can be carried out by figuring climate risk levels to or because of the road infrastructure during the construction and operation phases, in the context of increasing average temperatures and trending severe weather events.

Pursuant to requirements of the Ontario Environmental Assessment Act and the federal Impact Assessment Act, the assessment of climate change effects was carried out while considering the general guidelines provided in the draft "Technical guide related to the Strategic Assessment of Climate Change: Assessing climate change resilience" from Environment and Climate Change Canada (ECCC, 2022) and the guidance document entitled "Considering Climate Change in the Environmental Assessment Process" from the Ontario Ministry of Environment, Conservation and Parks (MECP, 2021). The following items were considered during this analysis:

- Project location and immediate environment.
- Current project design considerations.
- Historical and future climate projections at project location during its expected lifetime.
- Geotechnical, hydrogeological and hydro-geomorphological baseline conditions within the project's immediate setting.
- Indigenous knowledge regarding historical climate events and trends.
- Identification of all potential climate change related impacts on various project components.
- Selection of control measures for components for which unacceptable potential risks could occur at one point during the project's lifetime.
- Recommendations on a monitoring program assessing the performance of control measures.

This document provides a Statement on the Project's resilience to climate change covering the aforementioned items in accordance with the following work plan.

1.1 Work Plan

This report covers all essential objectives from a Climate Change Resilience Statement by first compiling the information allowing to provide an informed judgement on the climate for the region where the WSR will be located. This will then lead to the vulnerability assessment followed by the risk assessment of identified project components on a set of impact criteria that include WSR's long-term sustainability; WSR users health and safety; and the natural environment and ecosystems. Overall, this report consists of seven sections including the current introduction:

- **Project description and setting: This** provides an overview of the WSRs structures for waterbody crossings, including the road itself and how climate change is being integrated into the design. A broad description of the nearby environmental context and setting along the WSR is also summarized, with the intent to support on the selection of project components and impact criteria to be analyzed in terms of climate risks.
- **Historical climate conditions:** This section covers the baseline climate conditions based on existing meteorological data sets and studies specific to the region, including any Indigenous Knowledge or observed changing climatic conditions or trends observed by Indigenous communities. It also deals with past extreme

weather conditions. Baseline conditions with regard to hydrology and geotechnical conditions along the WSR are also examined.

- **Future climate projections:** This section presents the expected trends of different climate indicators based on temperature and precipitation that will be considered during the vulnerability assessment phase. This analysis will cover the period up to 2100 covering the operations and maintenance phase of the Project that is considered to be 75-years based on the expected timeframe when major refurbishment of the road components (e.g., bridges, culverts) are anticipated.
- **Climate risk assessment:** This section will first list the weather-related climate hazards (i.e., extreme precipitations) as well the climate hazards affected, at least in part, by climate change (i.e., landslides, droughts, freshets) that could potentially have an impact on at least one project component. In presence of a potential interaction, these sensitive components will be identified through the consideration of climate observations and projections related to the climate hazard, but also of the environmental setting. For each of these potential vulnerabilities, a proper risk assessment will be carried out determining the probability of occurrence and the related consequence for a given criterion. This assessment will result in a risk level (from very low to high) for the given vulnerability.
- **Selection of control measures:** Control measures (during the final design phase or the operation phase) to minimize or eliminate potential climate risk will be identified and applied for risks identified as « moderate » and « high ». The residual risk level when considering the control measure will also be established, with expectations to eliminate all unacceptable climate risks. Otherwise, compensation measures may need to be considered, where feasible.

1.2 Study Area

The following study areas have been defined for the purposes of climate change effects assessment and are based on the geographic extent of available regional climate data and greenhouse gas (GHG) emissions.

- **Local Study Area** (LSA) extends 50 km from each side of the centreline of the preliminary recommended preferred route, and 500 m from the boundaries of temporary and permanent supportive infrastructure.
- **Regional Study Area** (RSA) includes the geographical area of northern Ontario.

2. Project Description and Setting

This section reviews the main project components and describes the environment setting along the WSR. The information provided below are meant as an overview of elements that could potentially be relevant in terms of climate resiliency and were mainly excerpted from the WSR draft Environmental Assessment Report/Impact Statement (EAR/IS) in which more details are provided.

2.1 Project Overview

The proposed WSR is a new two-lane all-season road within a cleared right-of-way (ROW) of approximately 35 metres (m) in width and approximately 107 km in length. The preliminary recommended preferred route for the road consists of a northwest-southeast segment running 51 km from the Webequie First Nation Reserve to a 56 km segment running east-west before terminating near the McFaulds Lake within the mineralized deposit area known as the Ring of Fire. A total of 17 km of the WSR is within the Webequie First Nation Reserve lands, with the remainder of the road located on un-surveyed Ontario Crown lands.

The Project is located in north-western Ontario on un-surveyed Ontario Crown lands and WFN Reserve lands approximately 525 km northeast of the City of Thunder Bay in northwest Ontario as shown in **Figure 2.1**. The WSR is intended to facilitate the movement of materials, supplies and people from Webequie to the mineral exploration areas near McFaulds Lake area. It is expected to accommodate an annual average daily traffic of less than 500 vehicles consisting of light to medium personal vehicles, commercial vehicles and heavier trucks hauling industrial supplies and equipment.

The northwest-southeast segment of the road (51 km) rest mostly over mineral soil will be cleared of all vegetation across the 35 m ROW to accommodate the two-lane all-surface road. Shoulders, ditches, and berms of stripped organic materials on the outside will also be shaped along this segment.

The segment of the WSR running in an east-west direction is located within the Hudson Bay Lowlands Ecozone which includes the James Bay Ecoregion and is composed mostly of peatland (muskeg) having a depth of 2-4 m of waterlogged organic soil, which represents poor to very poor conditions for building a road. A floating road design is therefore considered by adding an underlying layer of aggregates (along with geotextile fabrics or geogrids) that will compress the peat resulting in settlement and consolidation. A surface layer of crushed stone will be added to complete the road that is expected to lay 1.2 m above the surrounding lowland areas.

For the west half of the WSR in stable soil conditions, the surface layer of the road that represents the driving surface for vehicles will be a chip seal treatment, which is similar to asphalt pavement, and consists of a tar slurry and gravel. For the east half of the road in the peatlands with poor soil conditions it is proposed the driving surface be initially gravel. During the operations phase, monitoring of the east half of the WSR in the peatlands will be conducted to assess performance/settlement, serviceability, and safety issues/concerns related to dust along the WSR. Depending on the outcome of this monitoring, the gravel driving surface may be replaced in a timeframe of approximately 3 to 5 years with a surface treatment such as chip seal treatment, or asphalt pavement.

The 35 m ROW where all vegetation will be cleared will accommodate a two-lane road, shoulders, ditches (for the western half only) as well as earth cut and fill sections when needed. It will require watercourse crossings over thirty-one waterbodies (**Figure 2.2**) using:

- Single-to-multi span bridges crossings of six major waterbodies, including the Muketei River, the Winiskisis Channel and the Winisk Lake; and
- A variety of culverts (e.g., corrugated steel pipe, concrete box culvert) to cross the minor watercourses.

The WSR will require regular maintenance and operation activities, so supportive infrastructure is proposed to facilitate that work. A permanent Maintenance and Storage Facility (MSF) will be erected at one location near the WSR with the purpose of storing the equipment and materials used for inspection, maintenance, and repair activities. An aggregate pit (ARA-4) will also be required during the operation and maintenance phase of the Project to provide processed aggregates, crushed stones and rocks needed maintain and repair the road and waterbody crossing structures.

Table 2-1 provides an overview of the components or group of components associated with the WSR and includes general details regarding their design and configuration at the current planning stage as described in Section 4 of the EAR/IS. It excludes what is considered minor components for which climate change is not expected to be a factor including:

- Road signage and fencing, where applicable.
- Road lighting/illumination as it is currently not considered in the design.

Table 2-1 also describes the construction and operation and maintenance activities as they are considered during the vulnerability and risk assessment, especially with regard to health, safety, and the environment (HSE).

Table 2-1: Overview of Components Associated with the WSR Project

Component	Description
WSR layout	The 107 km long preferred route of the WSR will cross 31 waterbodies. The first 3 km of the road will follow an existing gravel roadway exiting Webequie, the remaining road ROW and supportive infrastructure locations for construction camps, aggregate source areas and access roads will require clearing and grubbing of vegetation, with the exception of east half of the road (56 km) in the lowlands/peatlands where no grubbing or vegetation clearing outside the road footprint will be conducted. The 35 m ROW will accommodate two undivided lanes of 3.5 m, two shoulders of 2 m, ditches for a total roadway width of approximately 11 m. Rest areas are recommended to be located along the WSR at alternating directional intervals of every 25 km (total of approximately 4). In addition, maintenance areas are recommended to be located along the WSR at alternating directional intervals of every 50 km (total of approximately 3). To accommodate rest and maintenance areas, the ROW will need to be expanded to a maximum width of 70 m, as opposed to the typical ROW width of 35 m. The maximum ROW width of 70 m will be at the centre of the facilities and then tapered to the standard 35 m ROW width over a distance of approximately 570 m to allow for acceleration and deceleration lanes. The road will be compliant to safety guidelines (MTO Roadside Design Manual) in terms of design elements such as the horizontal alignment at road curves; vertical alignment at road dips; slopes at roadside ditches; barriers systems (e.g., guiderail); and sight distance along the road to provide drivers with sufficient time to identify and appropriately react to all elements of the road environment.
Road structure (western part)	The western segment of the WSR is located in mildly rolling terrain that will need vertical alignment by either lowering or raising the existing grades by around 3 m. The mineral soil exhibits fair to good conditions for building a road, hence requiring a 600 mm underlying layer composed of aggregates and will be surfaced with a pavement composed of an asphalt or chip seal mixture. For the purpose of drainage and safety, the road surface will have a cross-fall of 4%. The WSR will be built according to design codes, standards, and guidelines applicable to provincial highway projects, more specifically for Rural Collector Undivided facilities in the Northeast and Northwest regions. Regular maintenance and repairs of the road will be carried out on a needed basis. An access road of approximately 5 km connecting the ARA-4 aggregate pit to the WSR will be constructed in a similar way but without pavement.
Road structure (eastern part)	The eastern segment of the WSR is generally flat being located within the James Bay Lowlands composed mostly of peatland (muskeg) having a depth of 2-4 m of waterlogged organic soil, which represents poor to very poor conditions for building a road. A floating road design is recommended and will consist of an 800 mm underlying layer of aggregates that will compress the peat resulting in settlement and consolidation. Extra fill will be needed depending on compression level. It is currently recommended to use a geosynthetic layer (geotextile fabric or geogrid) to mitigate compression and reduce differential settlement of aggregates over the peat which should improve road performance and long-term maintenance. A 200 mm surface layer of crushed stone will be added to complete the road that is expected to lie approximately 1.2 m above the surrounding lowland areas. Following several years of compression to achieve stability (estimated to be approximately 3 years), a pavement composed of chip seal will be spread on the surface.

Table 2-1 (Cont'd): Overview of Components Associated with the WSR Project

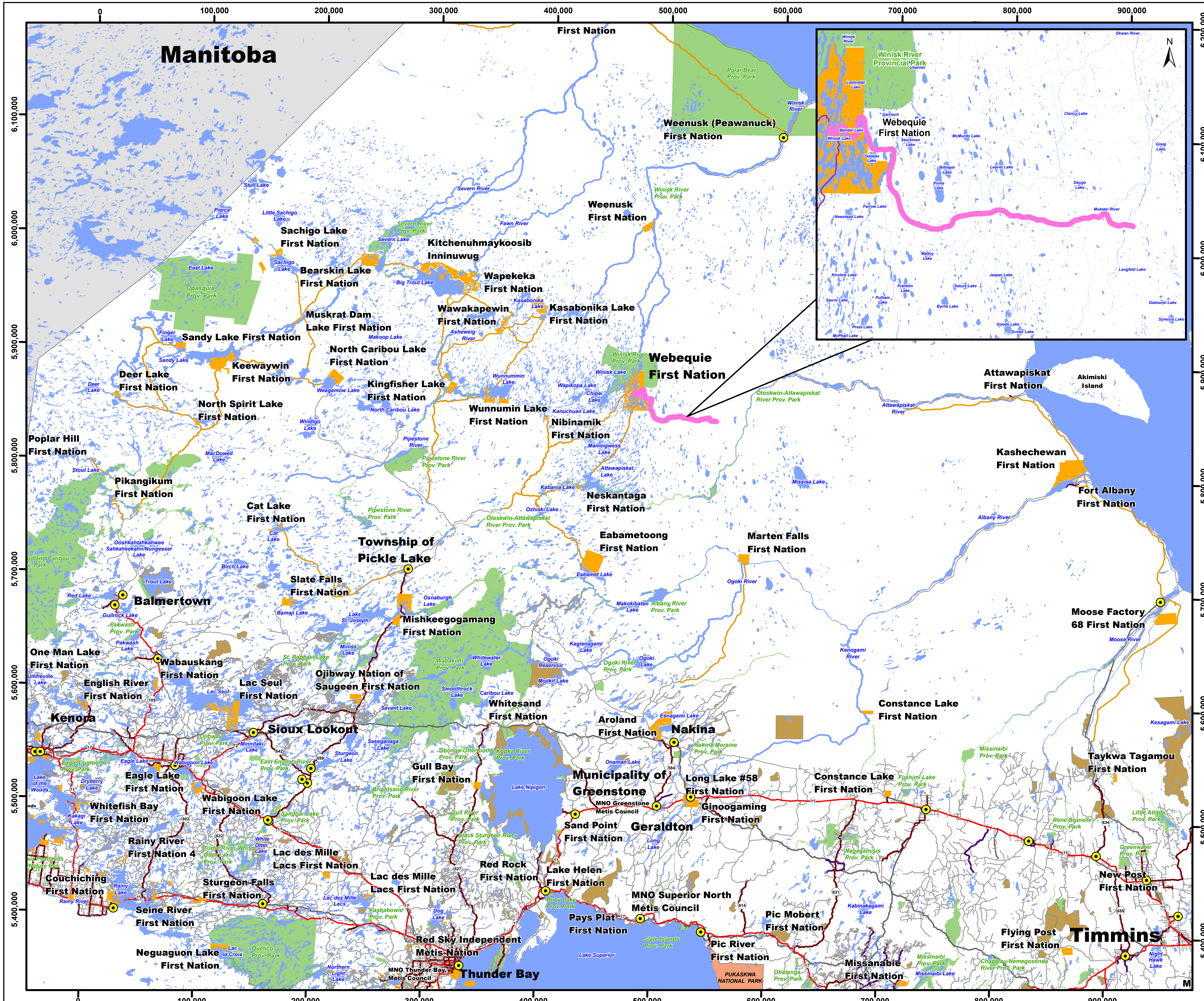
Component	Description
Road structure (eastern part) (Cont'd)	To ensure that the hydraulic conductivity of the peatlands is maintained (movement of groundwater and surface flow), 900 mm in diameter cross-culverts will be installed at intervals of approximately 100 m to 200 m (distance to be confirmed in detail design). Like for the western segment, regular maintenance and repairs of the road will be carried out on a needed basis.
Roadside ditches and earth cut sections	Roadside ditches will be excavated along the western segment of the WSR to convey runoffs from the road and local external catchment areas towards a local waterbody. No ditches are required on the eastern segment of the WSR. They will be sized to convey a minimum 10-year design flow (maximum rainfall event within a 10-year period). Enhanced grass swales incorporating design features such a modified geometry and earthen check dams will most likely be considered during the design phase. Part of the organic materials stripped from the surface during construction will also be placed in berms along the edges of ROW (outside the ditches).
Bridges	The crossing of some waterbodies requires a total of six (6) steel-concrete bridges that will include a substructure composed of a foundation, abutments and piers supporting the superstructure consisting of steel plate girders, the deck and side barriers with railings. In presence of peat or soft soils, driven steel piles, concrete piles or bored piles may be preferred during the detailed design phase instead of abutments. Four (4) bridges will be single span while the other two will be composed of two and six spans, respectively. The bridges will be sized and designed to allow for a minimum of 100-year design flow that will include consideration of climate change with potential 40% increase in rainfall intensities (which is believed to represent the current 1:125-year design flow). Natural revegetation, seeding and/or planting will be done on and around the embankments once the bridge is completed. Some bridges will be also designed as navigable crossings for small vessels (exceeding 3 m horizontal and 1.5 m vertical). A freeboard greater than 1 m will be applied (consisting of the vertical distance between the high-water level and the lowest point of the road profile).
Major culverts	Aside from bridges, several culverts will also be installed to cross minor watercourses. At this time, the types of culverts to be installed are proposed to include 6 corrugated steel pipes, 2 corrugated steel arch culverts and 17 open bottom steel arch culverts. The latter, being the most elaborate, consists of corrugated steel and can be fabricated for a full arch width over a waterbody or can be assembled and bolted together with plate sections at time of construction. The corrugated steel pipes and corrugated steel arch culverts will be embedded or counter sunken below the existing stream bed. Where peat or soft soils is present, these materials will be replaced with suitable engineered fill to place the culverts over the prepared ground. All culverts at waterbody crossings will be sized and designed to allow for a minimum 100-year design flow that will include consideration of climate change with potential 40% increase in rainfall intensities. A freeboard greater than 1 m will also be applied for culverts.
Aggregate pit	Two aggregate source locations are recommended, one of which will be used exclusively during the construction phase (ARA-2) and another (ARA-4) which lifespan will extend during the operation phase to provide aggregates for operations and maintenance of the road. As part of this climate change resilience assessment, only the ARA-4 aggregate source area will be analysed. It is located in an area beyond the southeastern tip of Winisk Lake and is about 5 km from the WSR at its closest point. When fully excavated, it will extend over an area of 85 ha. Based on the available topographic data, the central part of the ridge stands in the order of 25 m high above the surrounding low-relief. Groundwater monitoring wells drilled at site were observed to be dry during the 2020 and 2021 monitoring period, suggesting the management of groundwater is unlikely to be a concern during the mining/extraction of materials at the site. Aggregate production activities will include hole drilling, blasting, and rock conveyance to a nearby crushing plant that should include a primary crusher, a secondary crusher, a screening plant, diesel generators, conveyors, a control tower and supporting mobile loaders. Operations will be carried out periodically on an as-needed basis (outside the winter season) as aggregates will be stockpiled.

Table 2-1 (Cont'd): Overview of Components Associated with the WSR Project

Component	Description
Maintenance and storage facility	The MSF will be configured at the location where construction camp 2A will be erected during the construction phase. The MSF layout will be determined during the detailed design phase but is expected to include an office building, a parking area, garages for vehicles and maintenance equipment, winter material storage facilities, an outside aggregate storage and loading area, and an inside salt storage and loading area. The MSF will be powered with diesel generators so fuel will be conveyed and stored in tanks in compliance with Ontario Regulation Liquid Fuels under the *Technical Standards and Safety Ac*t. Activities occurring at the MSF should mainly include equipment maintenance and repair mostly inside garages and the loading of trucks transporting aggregate.
Rehabilitated sites	Progressive rehabilitation work will be carried out along the WSR as well as at the ARA-2 pit/quarry and the construction camps when construction work is completed or almost completed. Typical rehabilitation measures will be implemented for the WSR including the establishment of suitable vegetation to control soil erosion and grading to ensure there is adequate drainage. The aggregate pit (ARA-2) will first be cleaned up by removing waste and reconfigured using rock tiers into the quarry to reduce the steepness of the wall and depth. The closure of temporary construction camps and laydown areas will involve its cleanup (material, waste, and soil decompaction) followed by the levelling and trimming the areas to encourage natural re-vegetation.
Construction activities	The WSR construction activities will mainly include: ▪ Field surveys, staking and layout. ▪ Vegetation clearing and grubbing. ▪ Construction of supportive temporary infrastructure including storage and laydown yards and construction camps. ▪ Earth excavation, grading, hauling and stockpiling operations. ▪ Drilling and blasting at quarries and specific locations on the WSR where required. ▪ Aggregate processing (crushing and screening) and hauling operations. ▪ Road construction (aggregate placement, bridge construction, culvert placement and/or construction). ▪ Construction of buildings and storage areas at the MSF. ▪ Maintenance of environmental structures/measures (e.g., erosion and sediment control measures), including drainage management features on access roads. ▪ Handling and disposal of waste oil, lubricants and other fluid products used for the maintenance of equipment and vehicles. ▪ Storage, handing and disposal of solid waste generated at temporary construction camps/work sites. ▪ Management and/or disposal of wastewater and sewage, both hazardous and non-hazardous, in the form of liquid effluent generated by the workforce. ▪ Snow removal from access roads. ▪ Clean-up and site restoration, including the dismantling of temporary infrastructures.

Table 2-1 (Cont'd): Overview of Components Associated with the WSR Project

Component	Description
Road maintenance activities	A maintenance team will regularly conduct inspections and maintenance work to ensure the road meets the minimum standards for roadside safety. Such activities will mainly include: ▪ Visual patrols and inspections of the road. ▪ Vegetation management (mowing, brush removal). ▪ Repair and/or rehabilitation of culverts and bridges at water crossings. ▪ Repairs to road surface and shoulders. ▪ Aggregate and rock extraction and processing at ARA-4 site. ▪ Road drainage system maintenance and repairs – drainage cross-culverts, and ditches. ▪ Access road maintenance. ▪ Winter maintenance – snow clearing (no salt or sand will be used for de-icing). ▪ Spills and emergency response; and ▪ Waste and excess materials management.



Legend

- Preliminary Recommended Preferred Route
- First Nation Reserve
- Waterbody
- Provincial Park
- Conservation Reserve
- Federal National Park
- Rail
- Arterial Road
- Collector Road
- Expressway / Highway
- Local, Resource, Recreation, and Service Road
- Winter Road
- Cities/Towns

Webequie Supply Road (WSR)

Project Location

Figure Number:	2.1	REV	PA
Client: Webequie First Nation	Project Number: 661910	Date: 6/5/2024	

DSC	DRN	CHK	APP
	AD	VS	VS

0 20 40 80 Km

WSR WEBEQUIE SUPPLY ROAD

NOTES

1. Coordinate System: NAD 1983 Ontario MNR Lambert.
2. Cadastral boundaries are for informational purposes only and should not be considered suitable for legal, engineering, or surveying purposes.
3. Topographic/landcover features obtained from CanVec v12.0 dataset, Natural Resources Canada Earth and Sciences Sector Centre for Topographic Information; and, Land Information Ontario (LIO) Warehouse Open Data (https://geohub.lio.gov.on.ca/), Ontario Ministry of Natural Resources and Forestry (OMNRF) Download Date : 2021-02-04

DISCLAIMER

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2.2 Geographic and Environmental Setting

The proposed WSR is located in the northwestern region of Ontario. It traverses the Big Trout Lake and James Bay ecoregions as part of the Hudson Plains ecozone located in a cold and dry part of the province. The Big Trout Lake ecoregion (covering the western segment of the WSR) is mostly characterized by sparse, coniferous, and mixed forests covering 50% of the land along with about 20% of non-water wetlands while inversely the James Bay ecoregion (eastern segment of the WSR) consists primarily of wetlands (treed and open fens and bogs covering about 70% of land) along with some coniferous forests (12%). Considering this difference, the WSR will be built differently for both segments.

The western half of the road crossing forest covers will need to be cleared. The majority of the vegetation is coniferous forests with Black Spruce as the dominating species with Jack Pine, White Birch, and Poplar species as associates while the ground cover consists primarily of mosses and lichens, shrubs, and herbs. This segment is mainly composed of glacial mineral terrains composed of till with discontinuous lacustrine clay veneer, glaciofluvial ice-contact, esker ridges, and alluvial floodplains. This segment is also characterized by the presence of large waterbodies. The WSR will avoid these waterbodies, except for the Winisk Lake at one location that will require construction of a long 6-span bridge. Otherwise, around fourteen (14) smaller water crossings (culverts and smaller bridges) will be required along the way.

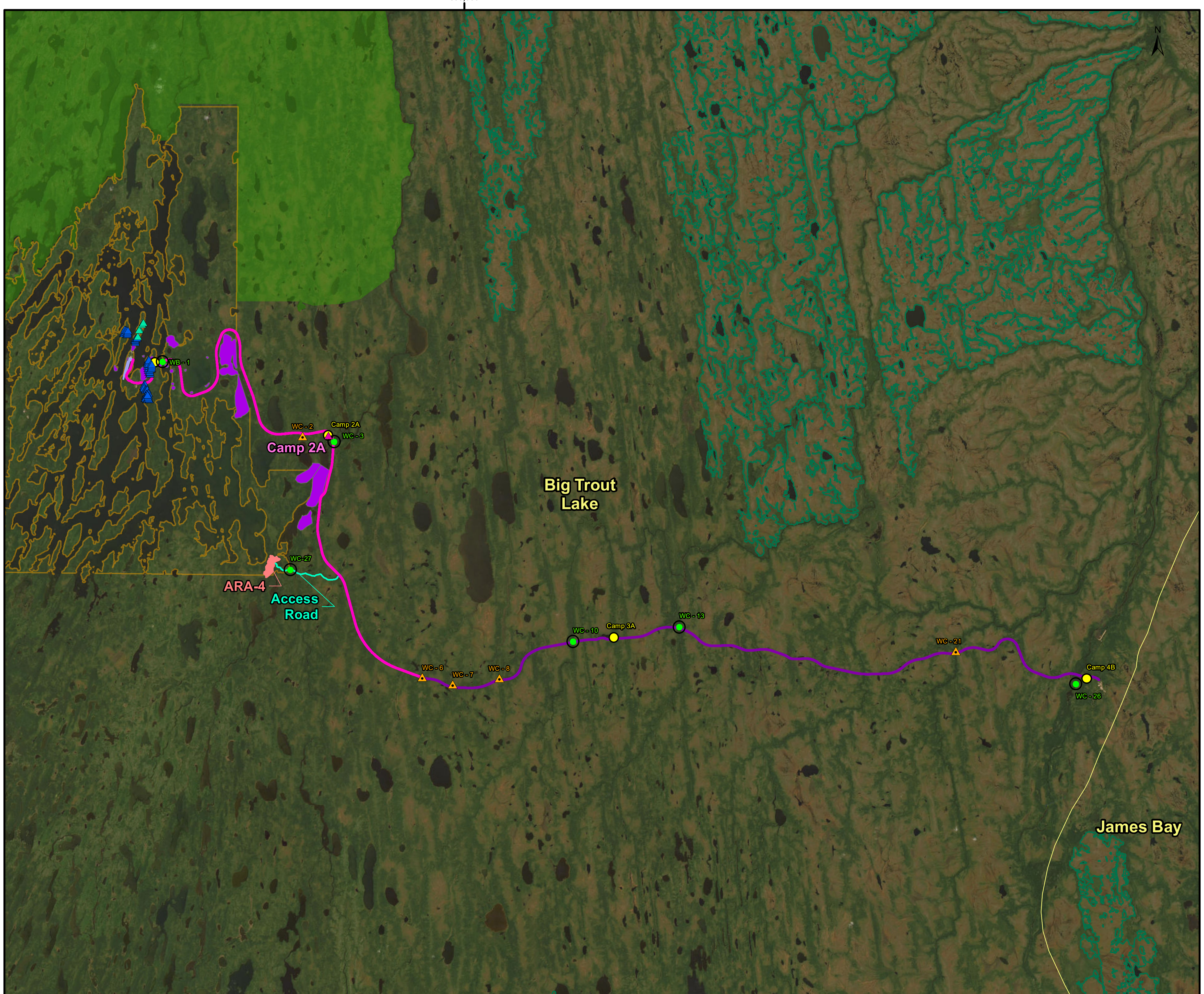
The eastern half of the WSR will pass through large stretches of water-logged areas/marshes with organic surface layer typically from 1 to 2 m in thickness within a vast network of waterbodies, including streams, rivers, lakes, and ponds. In fact, there are several larger river systems in the area, most notably the Attawapiskat, Ekwan and Muketai watersheds. The wetlands are composed of diverse ecosystem types associated with swamps, bogs, fens and scattered marches characterized by organic deposits including peat, muck, and marl. At the Muketei River near the eastern terminal, glaciofluvial in-contact deposits of gravel and sand are present. With the presence of water, the WSR will need to cross over fifteen (15) waterbodies using culverts or small bridges. Small portion of the ROW will also need to be cleared of trees although not to the same extent as the western segment of the road.

The topography along the proposed ROW is generally flat with some localized relief, especially in the western segment of the WSR which is also defined as the upland area since it is elevated at 200 meters or more above sea level while the eastern section, in the lowlands, has elevations of less than 200 meters above sea level.

2.3 Existing Built Environment

The proposed WSR is located mostly in an untouched environment. There are currently few existing structures or infrastructures in the LSA, with the exception of the local airport located south of Webequie and which acts as the starting point for the WSR. Otherwise, the closest dwelling is located over 1 km from the western terminus of the WSR and in the south part of Webequie community, infrastructure includes sanitary sewers and sewage treatment plant, and a diesel fuel power plant. The community is proposing to eventually build new dwellings along the road, mostly on the eastern part of Winisk Lake and near the Webequie airport. This part of the study area is currently composed of forest.

The area east of Webequie is limited to a few sparse informal trails while a formal seasonal winter road is located to the west, connecting Webequie to Pickle Lake. There are tourist lodges, fly-in hunting and fishing camps and other tourist-related activities in the broader study area, but no operators are located in proximity to the proposed ROW. The road will however pass near multiple natural areas known to provide country foods (e.g., wild berries) and used for hunting and fishing. The proposed ROW also intersects traplines legally registered to Webequie First Nation, Neskantaga First Nation and Marten Falls First Nation members.



Legend

WSR Components

Road Footprint
- Upland
- Lowland
- Access Road
- Construction Camps
- Bridges
- Major Culverts
- Maintainace and Storage Facility
- Aggregated Pits

Ecoregion

- Ecoregion

Sensitive Areas

- Institutions
- Future Residential Plots
- Wetland
- Culturally Sensitive Areas
- Air Landing Strip

Limits

- First Nation Reserve
- Waterbody
- Provincial Park

WSR Project Layout

Resilience Report
WSR Project Layout and Environment Setting

Figure Number : 2.2		REV: PA
Client: Webequie First Nation	Project Number: 661910	Date: 7/24/2024

DSC	DRN	CHK	APP
	LZ	SP	

0 1 2 4 6 8 10 KM
SCALE: 1:288,130

WSR
WEBEQUIE
SUPPLY ROAD

NOTES

1. Coordinate System: NAD 1983 UTM Zone 16N.
2. Cadastral boundaries are for informational purposes only and should not be considered suitable for legal, engineering, or surveying purposes.
3. Topographic/landcover features obtained from CanVec v12.0 dataset, Natural Resources Canada Earth and Sciences Sector Centre for Topographic Information; and, Land Information Ontario (LIO) Warehouse Open Data (https://geohub.lio.gov.on.ca/), Ontario Ministry of Natural Resources and Forestry (OMNRF) Download Date : 2021-02-04

DISCLAIMER

3. Historical Climate Conditions

Historical climate conditions and trends are presented in this section based on existing meteorological data and studies in the RSA. Two aspects are addressed: the average trends and extreme weather which are the basis of climate change concerns since they can lead to dangerous situations for people, the environment and/or the sustainability of built systems. It is therefore important to gather all available data on past extreme weather conditions in order to establish a starting point with regard to future events. This section also includes a broad review of local environmental conditions with regard to hydrology, geology and vegetation that could potentially interact with climate hazards presently or in the future.

3.1 Average Climate Trends

The proposed WSR is located within the Hudson Bay Lowlands characterized by a sub arctic climate with cool short summer, with only three months with a mean temperature above 10 °C. It is subjected to cold and extended winters with relatively low precipitations (compared to southern Canada) due to low temperature and related evapotranspiration. The majority will occur during summertime while winter precipitations are generally associated with cyclonic storms. The relatively flat area provides a few barriers to the weather system sweeping down from the north. As a result, the area can experience a variety of weather events.

In absence of specific monitoring station in the LSA, the numbers presented below come from observations at the meteorological stations located in Landsdowne House and Pickle Lake (ECCC, 2024a) which are located respectively 100 km and 250 km from Webequie (**Table 3-1** and **Figure 3.1**). Annual mean temperatures along the WSR are estimated at about -2 °C considering that Pickle Lake and Landsdowne House communities are located to the south. During summer months, mean temperatures reach 13 to 17 °C with a maximum daily average temperature slightly above 20 °C at Landsdowne House (but most likely slightly lower in Webequie). During winter, the average temperature oscillates between -18 and -22 °C, with a minimum daily temperature of -28 °C in January as measured at Landsdowne House station. Temperatures in Webequie have the potential to be much lower as described in **Section 3.2**.

Precipitation levels in the area can range between 550 and 650 mm per year, considering that dryer conditions are typically observed when going northward (compared to Pickle Lake and Landsdowne House stations). In fact, precipitations in the Hudson Bay Lowlands Ecozone are said to range between 500 and 700 mm, with the latter being predominant in the James Bay area. A large portion of precipitations falls as rain during summertime (40% of total annual precipitations) while precipitations during wintertime represent low levels for a typical year (13% of total annual precipitations). Hence, about 30% of total precipitations fall as snow. Most precipitation falls as rain from May to September and as snow from November to March, with April and October as transition months.

Table 3-1: Past Climate Normals for Stations Nearest to Webequie (ECCC, 2024a)

<table>
<tr><th rowspan="2">Station</th><th rowspan="2">Period</th><th rowspan="2">Mean Daily Temperature (°C)</th><th colspan="3">Annual Precipitations (mm)</th><th rowspan="2">Mean Wind Speed (km/h)</th></tr>
<tr><th>Rainfall</th><th>Snowfall</th><th>Total</th></tr>
<tr><td>Pickle Lake
(250-300 km away) (1)</td><td>1991-2010</td><td>0.5</td><td>522</td><td>257</td><td>779</td><td>n/a</td></tr>
<tr><td rowspan="2">Landsdowne House
(100-150 km away) (1)</td><td>1961-1990</td><td>-1.4</td><td>461</td><td>257</td><td>718</td><td rowspan="2">14.2</td></tr>
<tr><td>1971-2000</td><td>-1.3</td><td>489</td><td>242</td><td>730</td></tr>
</table>

(1) Both stations are located to the south-west relative to the WSR.

Figure 3.1: Climate Normals (1971-2000) at Lansdowne House Met Station (Source: ECCC, 2024a)

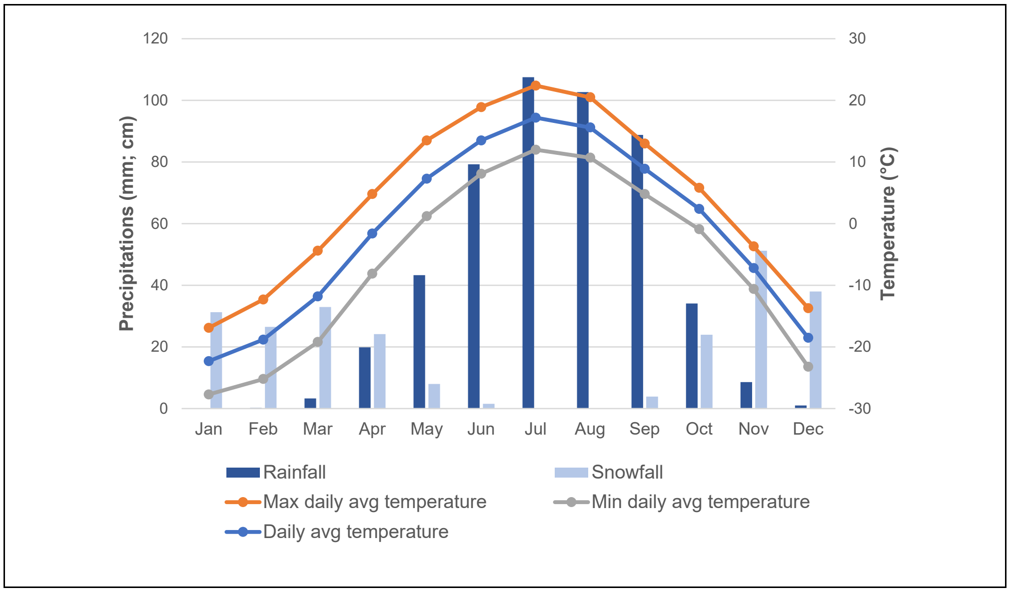
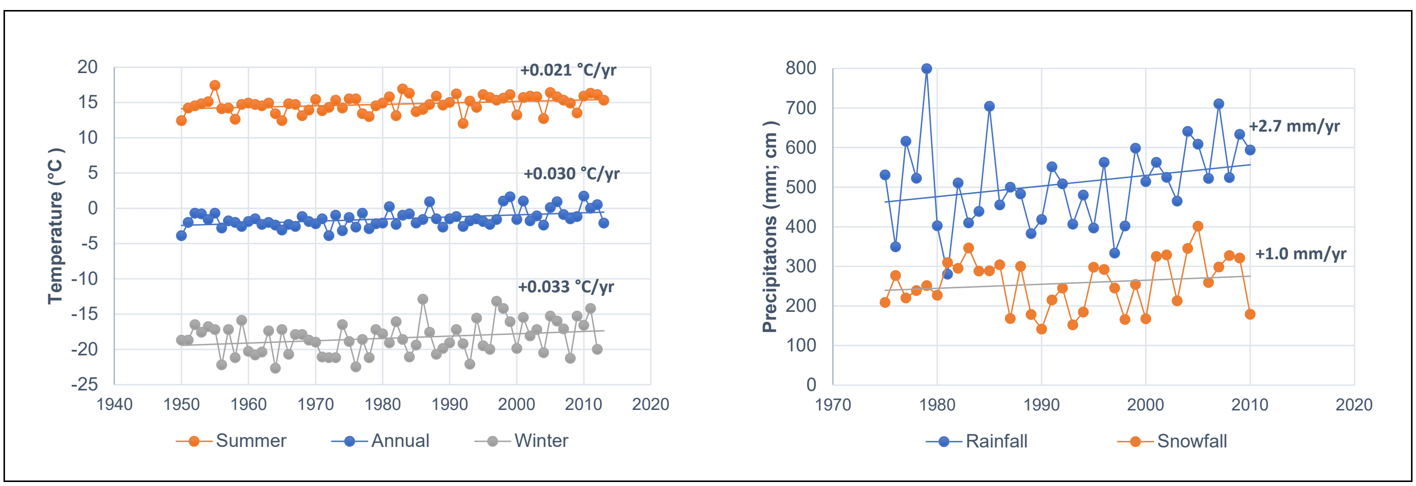


Figure 3.2 illustrates the historical trend for the last decades in terms of mean temperature and total precipitations observed in Pickle Lake. Like many other regions in Canada, the average temperature has been slowly increasing at an apparent rate of +0.030 °C per year, meaning that over the last 50 years the average temperature has increased by 1.5 °C or so. The impact of climate change on temperature is most noticeable during wintertime although the interannual variation is more significant compared to summertime. Although Pickle Lake is located 250 km away from Webequie, similar conclusions are more than likely for the WSR area.

Total precipitations monitored over a 35-years period (1975 – 2010) also appear to have slightly increased, but it is less definite due to the large annual variations. The annual increase in precipitations from **Figure 3.2** is equivalent to less than 1 % of total annual precipitations seemingly showing that it does not and is not expected to increase by much in the near future. Extreme precipitations are however expected to increase at a greater rate, as explained in **Section 3.2**.

Figure 3.2: Mean Annual Temperature and Total Annual Precipitations over Several Decades at the Pickle Lake Meteorological Station (ECCC, 2024a)



3.2 Extreme Weather Conditions

Table 3-2 provides a list of extreme conditions that were measured at Lansdowne House and Pickle Lake meteorological stations in the past (ECCC, 2024a). The following observations can be inferred:

- Maximum temperatures historically reached 36.7°C in Lansdowne House while the temperature exceeded 30 °C for a total of 2.1 days per year in average from May to August (**Figure 3.3**). However, when considering data from Pickle Lake, it is likely that past extreme temperatures in the Webequie area are lower by probably 1 to 2 °C since it is located northward of the meteorological stations.
- Minimum temperatures historically reached -47.8°C in Lansdowne House while the temperature went below -30°C for a total of 34 days per year on average. In fact, temperatures have dropped below -40°C during the month of December to March in the past (**Figure 3.3**). Similarly, Webequie has likely seen lower minimum temperatures in the past and a higher frequency of days with temperatures below -30°C and -40°C.
- Extreme rainfall has reached 108 mm per day in Lansdowne House but only 78 mm per day in Pickle Lake even though higher precipitation events are to be expected in more southern localities like Pickle Lake. However, the number of days with substantial (>10 mm/d) and heavy (>25 mmm/d) precipitations is more significant in Pickle Lake meaning that Lansdowne House has probably seen a 1:100-year event or so in 1974 while the frequency of high daily precipitations remain lower. Again, Webequie has likely less frequent extreme rainfall events compared to Lansdowne House and especially Pickle Lake, although such events are also conditional to local topography. High rainfall events occur during summertime including September (**Figure 3.3**).
- The maximum hourly wind speed reached 80 km/h in Landsdowne House but given that wind is highly specific to location, it is likely not entirely relevant to the LSA. In fact, different wind regimes are to be expected along the proposed ROW depending on terrain, the presence of lakes, vegetation and so forth. As it is the case for most of northern Ontario, the maximum hourly wind speed should be expected to range between 50 and 60 km/h (Tang, 2016) and wind gusts can be expected to exceed 100 km/h along the WSR.

Other notes of importance include:

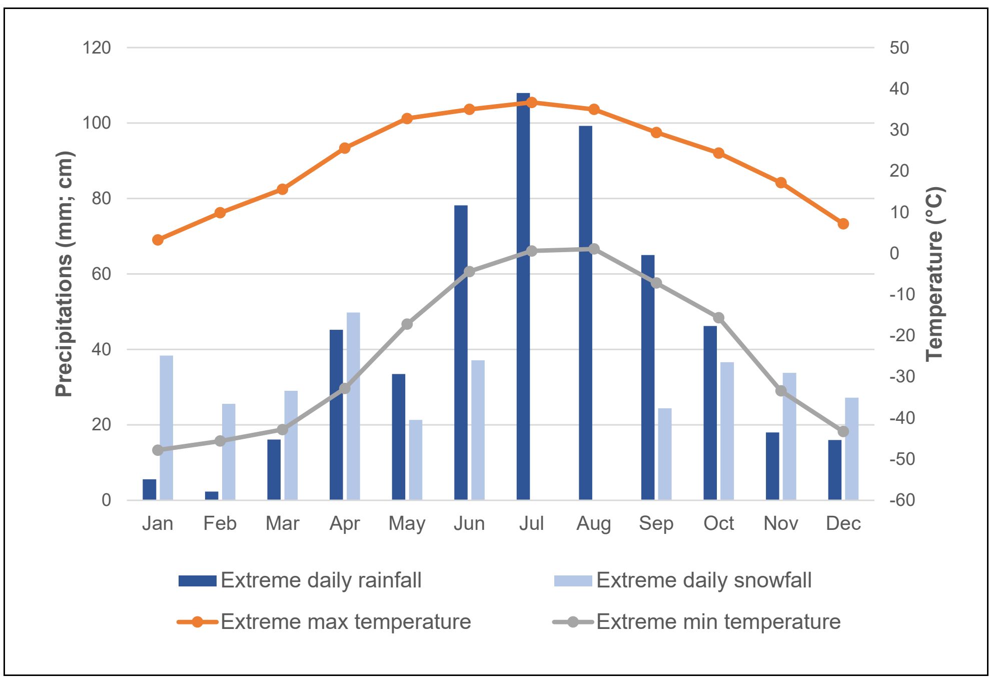
- Winter winds are typically from the west to northwest, with the summer winds usually from the west to southwest. Lakes typically begin to freeze in mid-October, with spring thaws typically initiating in mid-May.
- Fog is common, with extended periods typically expected in the transition months of ice 'freeze-up' in the Fall months and ice 'break-up' or freshet in the Spring. It is also not unusual to have fog occurring during the summer months.
- Annual ice formation in the Hudson Bay Lowlands Ecozone is caused by air temperatures consistently falling below freezing and the subsequent lowering of surface water temperatures starting in September / October. Thawing begins in spring, even before the mean daily air temperatures rise above freezing. Hudson Bay exerts a cooling effect on the Hudson Bay Lowlands Ecozone extending a substantial distance inland well into the summer.
- Snow coverage in the Hudson Bay Lowlands Ecozone often remains until June, reflecting much of the arriving radiant energy back into the atmosphere. In recent years, spring thaw has been observed at early dates.

Table 3-2: Extreme Values at Meteorological Stations Nearest to Webequie (ECCC, 2024a)

Indicator		Lansdowne House (1971-2000) (100-150 km away) [1]	Pickle Lake (1981-2010) (250-300 km away) [1]
Extreme temperature (°C)	Maximum	36.7°C in 1975	38.8°C in 1995
	Minimum	-47.8°C in 1943	-42.8°C in 2004
Number of days in average with temperatures exceeding 30 °C		2.1	4.8
Number of days in average with temperatures below -30 °C		34	17
Extreme precipitations	Rainfall (mm)	108 mm in 1974	78 mm in 2002
	Snowfall (cm)	50 cm in 1971	44 cm in 2008
Number of days in average with precipitations exceeding:	10 mm	15	20
	25 mm	2.6	3.7
Extreme sustained hourly wind speed		80 km/h in 1957	61 km/h in 1999
Number of days in average with winds exceeding 52 km/h		6.8	1.3
Extreme wind gust speed		117 km/h in 1987	111 km/h in 1996

(1) Both stations are located to the south-west relative to the WSR.

Figure 3.3: Temperature and Daily Precipitation Extremes Observed at Landsdowne House Met Station (ECCC, 2024a)



3.3 Local Environmental Conditions

This section provides a broad overview of currently observed conditions with regard to hydrology, geology, and vegetation that could potentially be impacted by climate change in presence of the Project or that could have an impact on the Project itself. The descriptions provided in the following subsections come mostly from the Natural Environment Existing Condition (NEEC) Report (AtkinsRéalis, 2024) for the WSR EA/IA for the respective field. As described in the NEEC report, the study area for characterizing local environment conditions extends approximately 1 km to 6 km from the centreline of the ROW for the proposed WSR, and 500 m to 5 km from the boundaries of temporary and permanent supportive infrastructure. For the purpose of describing local environmental conditions in the following subsections, this study area is referred to as the general project area.

3.3.1 Hydrology and Hydrogeology

Streams in the region have low velocity flow throughout most of the year. Stream flow peaks in the spring and early summer (May to June) as a result of snowmelt runoff and rainfall runoff from saturated soils. Flows recede through the summer and increase in the fall due to an increase in rainfall and a decrease in evaporation. Flows are normally lowest in the winter, and some small streams freeze completely to the stream channel bed. Through much of the area, surface waters move as diffuse flow through broad, densely vegetated fens, with occasional consolidation in defined channels. The stream banks are typical of low gradient and are well defined by earth, boulders, bedrock outcrops and natural levees.

The primary source for groundwater recharge is precipitation including rain and snowfall (melting) which flows in shallow water bearing zones (overburden or shallow bedrock zones) towards nearby water bodies. However, during major storm events, surface water levels within the water bodies may rise quickly and recharge groundwater for a short period of time. The groundwater contribution rates to the stream flows along the proposed WSR are estimated to be ranging typically from 20% to 30% at major streams and tributaries. The groundwater contribution tends to be smaller at small tributaries compared to major streams and tributaries, and greater during dry seasons compared to wet seasons.

Localized eskers are scattered along the north-south section and towards the east end of the WSR. These eskers are comprised predominantly of sand and gravel and so, the charge rates are expected to be higher than the remaining sections of the WSR.

Thirty-one (31) waterbody crossings have been identified for the proposed WSR. Twenty-seven (27) have a defined channel/flow path and do not include wetlands or areas that may experience ephemeral flow. The estimated highwater levels (water depth above the stream bed) at the water crossings based on field observations and measurements range from 0.4 m to 4.1 m.

3.3.2 Terrain and Geotechnical Conditions

The WSR will cross extensive organic terrains along the east-west section and glacial terrains with mineral soils (sand to silty sand till, silt to silty clay till) on the roughly north-south section leading to the community of Webequie. The organic deposits include peat, muck, and marl from a vast network of bogs (open and treed), fens (open, treed and shore) and swamps with glaciofluvial in-contact deposits of gravel and sand as the eastern terminus. The road will pass through layers of peat and organic clays from 0.5 to 2 m in thickness with some locations greater than 3 m. The organic layer is underlain by a clay/silt till layer of up to 2 m thick, and a Quaternary till layer of up to 5 m thick. Depth to bedrock ranges from 5 to 12 m below the surface.

The terrain and topography along the proposed WSR are relatively flat with two distinct sections: the north-south trending section consisting of a high relief plateau; and the east-west trending section which is an area of low relief. The region has a very low level of seismic activity with the LSA being classified generally as having a “very dense soil and soft and soft rock profile”.

3.3.2.1 Permafrost

The proposed WSR is located within a band of sporadic permafrost where areas have permafrost beneath the land surface while other areas are free of permafrost. Based on this classification, it is estimated that 10-50% of the land area is underlain by permafrost of a few meters thickness with the upper 10-20 m of the ground containing less than 10% of ice. That said, no observed areas of permafrost were documented along the WSR during soil and terrain field investigations. In fact, dense/hard till and bedrock have no challenges with thaw consolidation while the overburden thickness along the WSR is generally small; therefore, thaw strain is not expected to be substantial. Taliks, supra-permafrost, sub-permafrost and/or intra-permafrost groundwater are not expected either.

3.3.2.2 Erosion

Erosion is the physical dislodgement of soil particles from the Earth surface by the action of wind, rain, or other weather processes. This occurs naturally over time, but human interference can cause it to accelerate. The degree of erosion risk at a given site is a function of its regional climate, the erodibility of the soil, and the terrain. For example, erosion risk is increased in regions with heavy rainfall and high winds. Based on prevalent soils along the WSR (silty clay, sandy silt, and organic material), their erodibility is classified as medium. That said, the primary connection between terrain and erosion is the way in which terrain affects hydrology. Higher flow velocities cause increased erosion. The flat and heavily vegetated terrain along the WSR slows overland water flow velocities substantially, resulting in low erosion risk in general.

3.3.2.3 Geohazards

There are no major hazardous slopes within 1 km of the proposed ROW. No landslide hazards were identified, nor were sinkholes or major geological depressions or geological anomalies observed along the proposed ROW.

Other potential geohazards include isostatic rise or subsidence, or more commonly referred to as isostatic rebound associated ice sheet retreat. In the general project area, uplift rates are in the order of 8 to 10 millimetres (mm) per year. Generally, the potential risks from isostatic rebound to inland (i.e., non-marine) infrastructure and infrastructure projects are perceived to be negligible. However, the potential effects of isostatic rebound in the project area will be evaluated, and its implications to the design and/or operation of the Project will be considered and documented (e.g., effects of rebound on seismic conditions, structure design, etc.).

3.3.3 Vegetation

In the Big Trout Lake Ecoregion, sparse forest covers approximately 21% of the ecosystem in the general project area. Coniferous and mixed forests grow on 19.4% and 8.4% of the area, respectively, and small pockets of deciduous forest grow along river valleys. Burns occupy 8.1% of the ecoregion, the highest percentage in Ontario. This ecoregion is therefore susceptible to fire; however, they are generally smaller than those in more southerly ecosystems in northwestern Ontario. Throughout the western and central portions of the ecoregion, fires are fairly evenly distributed across the landscape, with the exception of the extreme northern fringe. However, in the eastern, wetter part of the ecoregion, burned patches are smaller and further apart (MNR, 2022).

4. Future Climate Projections

This section initiates the vulnerability analysis by consolidating future climate projections for the region until the end of this century since the road's lifespan is indetermined and expected to remain operational for a very long time.

4.1 Future Climate

Projections of the future climate in the WSR region, which is represented by a variety of indicators, are compiled for both annual and seasonal scales. These projections are derived from the results of the WCRP CMIP6 general circulation model (GCM) ensemble, downscaled and bias-corrected using the BCCAQv2 method (a statistical scaling approach for GCM model outputs developed by the *Pacific Climate Impacts Consortium*).

Table 4-1 shows the projected values representative of current conditions (Horizon 2020), medium-term future conditions (Horizon 2050) and future conditions towards the end of the century (Horizon 2080), calculated for the moderate greenhouse gas (GHG) emission scenario (SPP-2; previously RCP4.5, known as stabilization) and the pessimistic scenario (SPP-5; previously RCP8.5, with high and continuous GHG emissions; refer to **Appendix A** for more details). The SPP-2 scenario is the sought target at present, but following the precautionary principle in the resilience approach, the worst-case scenario (SPP-5) must also be considered, since there is no guarantee that GHG emission reduction measures will enable the SSP-2 scenario targets to be achieved on the long run.

The median projections of the 35 models from the CMIP6 ensemble are shown in **Table 4-1** for each emission scenario. These values represent rolling averages over 30 consecutive years to smooth out the modelling results which tend to fluctuate from year to year. **Figure 4.1** illustrates the temporal evolution of selected temperature and precipitation indicators, showing the upward or downward trend, as well as the range of projections when considering all models (excluding outliers). **Appendix A** provides similar figures for other climate indicators for reference. The following findings can be extracted from **Table 4-1** and the various figures:

- The mean annual temperature will rise by 1.4°C (SPP-2) to 2.4°C (SPP-5) in the medium term (Horizon 2050) and by 2.6°C to 5.4°C at the end of the century (Horizon 2080) compared to today (Horizon 2020). This rise would be roughly equivalent for all seasons except for winter under the SPP-2 scenario (+3.9°C during Horizon 2080 instead of +2.2–2.3°C for other seasons), whereas the RCP8.5 scenario shows slightly more variance, with a more significant rise for winter (+7.2°C by 2080).
- Extreme maximum summer temperatures are expected to increase by +3–4°C for Horizon 2050 and +3–6.4°C for Horizon 2080 compared to today. According to projections, the extreme maximum temperature will not exceed 40°C by 2080 (albeit by not much considering the SPP-5 scenario). The number of days with temperatures reaching 30°C or more would rise in parallel, from under 4 days per year in average presently to 12 days per year by the end of the century under the SPP-2 scenario (31 days for the SPP-5 scenario).
- A significant increase in the extreme minimum temperature is also expected for the medium (+2.7 to 3.4°C) and long term (+4.8 to 8.0°C). The coldest temperature should therefore gradually rise from around -39.7°C today to -34.9°C by the end of the century, according to the moderate SPP-2 scenario (-31.7 °C for the SPP-5 scenario).
- Total annual precipitations are expected to rise relatively steadily, reaching a +4–5% increase (+19 to 27 mm) for Horizon 2050 and +6–13% (+32–72 mm) for Horizon 2080 compared to today (549 mm per year). This increase would be evenly distributed across winter and the shoulder seasons (+22 to +25 mm by 2080 for the SPP-5 scenario), while total summer precipitations are projected to decrease by 5% (-11 mm).

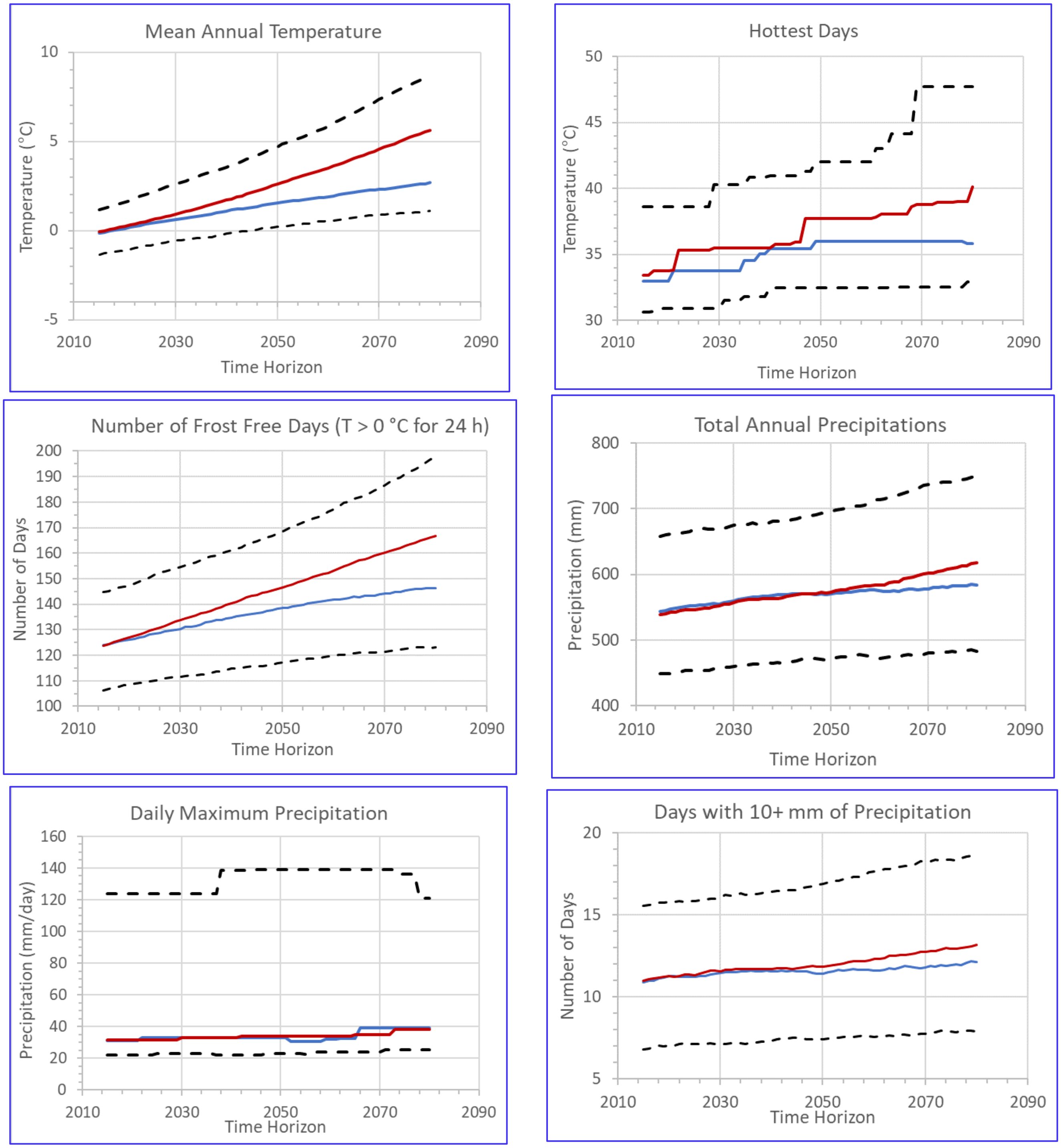
- The models do not project significant increases in maximum daily precipitations (maximum of 38 to 39 mm/d by 2080). That said, model results suggest a slight increase in daily precipitation levels overall. For example, the frequency of daily precipitation greater than 10 mm would rise from the current average of 11 days per year to 13 days per year during Horizon 2080.
- The standardized precipitation evapotranspiration index (**Table 4-1**) currently indicates a slight water deficit (-0.12) on an annual basis due to higher water loss from soils and vegetation by evapotranspiration than water input from precipitations. For the SPP-2 scenario, this trend would reduce to water surpluses according to model results. For the SPP-5 scenario, conditions would however become more drier given the larger increase in temperatures.

Table 4-1: Climate Projections for the WSR Region

Indicator		Season	Horizon 2020	Net variation vs. Horizon 2020 (1)			
				Horizon 2050 (2)		Horizon 2080 (2)	
				SPP-2	SPP-5	SPP-2	SPP-5
Temperature indicators							
Daily temperature (°C)	Mean	Winter	-17.4	+2.3	+3.3	+3.9	+7.2
		Spring	-1.6	+1.3	+2.2	+2.3	+5.1
		Summer	15.3	+1.0	+1.6	+2.4	+4.0
		Fall	3.3	+1.3	+2.1	+2.2	+4.8
		Annual	0.2	+1.4	+2.4	+2.6	+5.4
Extreme temperature (°C)	Minimum	Annual	-39.7	+3.4	+2.7	+4.8	+8.0
	Maximum	Annual	33.5	+3.0	+4.0	+2.9	+6.4
Number of days in average with air temperatures exceeding 30 °C		Annual	3.9	+4.6	+9.3	+8.7	+27
Number of days in average with air temperatures below -25 °C		Annual	45	-15	-20	-23	-39
Precipitation indicators							
Total precipitations (mm)		Winter	87	+6	+12	+15	+24
		Spring	105	+5	+10	+13	+22
		Summer	212	-1	-6	-2	-11
		Fall	178	+11	+9	+13	+25
		Annual	549	+19	+27	+32	+72
Extreme daily precipitations (mm)		Winter	12	+1.6	-2.5	+2.3	-0.4
		Summer	27	+0.3	+0.2	+0.4	-1.3
		Annual	31	+2.2	+2.4	+8.5	+6.6
Number of days in average with precipitations exceeding:	10 mm	Annual	11	+0.2	+0.6	+0.9	+1.9
	20 mm	Annual	1.7	+0.2	+0.5	+0.4	+1.0
Standardized precipitation evapotranspiration index (SPEI) (3)		Annual	-0.12	+0.08	-0.11	+0.08	-0.49

(1) Since this is a comparison with future projections, the values of the modelled historical data from Climate Data Canada were considered (as opposed to measured data at a monitoring station for example).
(2) Horizon 2050: 2041-2070; Horizon 2080: 2071-2100
(3) Standardized precipitation evapotranspiration index (SPEI) is a drought index based on the difference between precipitation and potential evapotranspiration. Negative values indicate water deficit and positive values, water surplus.

Figure 4.1: Future Climate Projections with the Moderate and High GHG emissions scenarios for Select Temperature and Precipitation Indicators for the WSR Region



Legend:
- Projected median from CMIP6 models using moderate emission scenario SPP-2 / RCP4.5
- Projected median from CMIP6 models using high emission scenario SPP-5 / RCP8.5
- Projected range representing the lowest (10th percentile) and highest (90th percentile) values from CMIP6 models using one or both emission scenarios.

Data Source: ClimateData.ca Web Portal

4.2 Extreme Precipitations

Climate models do not project a significant increase in maximum daily precipitations by the end of the century (40 mm/d; **Figure 4.1**). It must be noted that past daily maximums at Lansdowne House and Pickle Lake meteorological stations were much higher (up to 108 mm/d; **Table 3-2**) and that this level of precipitation can certainly occur again. This observation is not inconsistent since it is recognized that statistical scaling of GCMs tends to underestimate precipitation extremes relative to historical data and that further processing is required to obtain more consistent projections (Mailhot et al., 2015). That said, model results still suggest a small increase of daily precipitation levels in general.

To offset this gap, a scale-up approach on Intensity-Duration-Frequency (IDF) curves is often used to establish extreme precipitation values for a given region. These curves, developed according to a dataset from a meteorological station, define the intensity of extreme precipitation events in function of probability (return periods). Some specific IDF values for the Lansdowne House station are presented in **Table 4-2**. For example, a daily maximum of 113 mm is obtained for the 100-year return period based on historical observations. The probability of this occurrence will occur by the end of the century (75 years) is 53%, which assumes that "historical IDF curves remain representative of reality over time".

Environment and Climate Change Canada (ECCC) recommends using the approach developed by the CSA group (2019) for scaling the IDF values applicable for the future. In short, this method assumes that the increase in extreme precipitation is correlated with the rise in global atmospheric humidity, which in turn increases with global warming.

$$R_{P,Y} = R_C \times 1{,}07^{(T_Y - T_X)} \qquad (1)$$

$R_{P,Y}$: IDF value for horizon *Y* (mm)
R_C: historical IDF value based on data from period *X* (mm)
T_Y: mean annual temperature (excluding winter period) projected for horizon *Y* (°C)
T_X: mean annual temperature (excluding winter period) calculated for the historical period *X* (°C)

The historical IDF values in **Table 4-2** are based on precipitation data from 1971 to 2021, so the difference in projected mean annual temperature for the horizon 2080 (2071-2100) is 4.3°C for the SPP-2 scenario and 7.2°C for the SPP-5 scenario. This results in a 34% to 66% scaling of the historical IDF curves to represent expected conditions at the end of the century. However, the historical data and model projections for the IDF curves are based on results from the Lansdowne House station, which is the closest station to WSR region with available data and located approximately 100-150 km southwest of the WSR region. Since Lansdowne House is projected with an annual temperature of 0.8°C comparing to 0.2°C for the WSR region for Horizon 2020, actual precipitation in the WSR region is expected to be less and the results from the IDF curves used in this analysis are likely overestimated.

The projections in **Table 4-2** should be treated with caution since they remain estimates based on the simple assumption that the rise in extreme precipitation levels is correlated with the average rise in temperature. For example, despite its own uncertainties, another calculation tool (IDF_CC Tool 5.0) developed by a team of Canadian researchers (University of Western Ontario, 2023) projects a lower and more narrow scaling ranging (+28-32%) for the year 2100 at the Lansdowne House station. In reality, scaling factors can vary according to location, type of precipitation event, topography, and natural variability.

Table 4-2: Historical and Future IDF Values for the Lansdowne House Station

Precipitation Period	Frequency of Events		IDF value (mm)		
	Return Period (T)	Probability (P) by the End of the Century (1)	Historical (1971-2021) (2)	Future (Horizon 2080) (3)	
				SPP-2	SPP-5
Hourly	25-years	95 %	44	58	58
	50-years	78 %	50	66	66
	100-years	53 %	56	74	74
Daily	25-years	95 %	91	120	146
	50-years	78 %	102	132	161
	100-years	53 %	113	149	180

(1) Represents the probability (P = 1 – exp(-75/T)) according to the return period (T) that the extreme precipitation event (IDF value) will occur at least once in the next 75 years.
(2) Historical values were calculated according to a precipitation's dataset from 1971 to 2021 at Lansdowne House station. The values were rounded to the closest mm.
(3) Calculated according to equation (1) knowing that the temperature differential between horizon 2080 and the 1971-2021 period is 4.3 and 7.2 °C for SPP-2 and SPP-5 scenarios, respectively. The values were rounded to the closest mm.

4.3 Freezing Rain

Freezing rain occurs over several hours and even several days when the ground-level temperature is below the freezing point when cold droplets solidify in contact of surfaces forming ice. Being a meteorological event of specific nature (often mixed with other types of precipitations like rain, snow, and sleet), the frequency and intensity of freezing rain events are not only linked to the climate but also on the meteorological conditions of the moment.

According to ECCC (2020), the annual frequency of freezing rain is increasing in Canada since last century and this trend will most likely continue for a major part of Canada. However, climate models cannot precisely forecast the extent of this increase at the local scale. Some models seem to indicate a gradual shift of freezing rain events towards higher latitudes because of global warming and the movement of the 0°C isotherm to the north. According to the Ontario Provincial Climate Change Impact Assessment Technical Report (CRI, 2023), the northern regions are expected to see an increase in snowfalls initially but will be followed by declines and more precipitation falling as rain. With the increase of precipitations projected during fall and winter, the rise of maximum daily temperatures in winter, and an increase of frost-free days annually, it suffices to say that freezing rain events will be more frequent in the future which includes the Far North.

The Far North of Ontario currently sees few rains during winter with a rain-to-snow ratio of 1.3% but according to Cheng et al. (2011), Northern Canada (over the 50th parallel) still receives very short-duration freezing rain (< 4 h) about 2.8 days per year. Longer freezing rain events (>4 h) occur an average of 0.8 days per year. For comparison, it represents about 50% of very-short duration freezing rain days observed in the Ontario-Montreal region annually but only, 25% for longer duration events. Cheng et al. (2011) estimates that these "long duration freezing rain events" will double by the end of century for northern Canada regions. However, based on already low occurrences, major freezing rain events are not to be expected to increase a lot in number, at least in the short to medium term.

4.4 Wind

Current modelling of storm intensity, frequency and wind pressure does not allow establishing a reliable trend for the WSR region. Wind is greatly influenced by very local processes, and measurements from a weather station are not necessarily representative of the immediate surroundings, making interpolation for mapping and analysis complex (Charron, 2015).

In a warmer future, earlier ice melt and higher summer temperatures should generate more heat in water bodies, which may lead to more atmospheric instability, theoretically favoring the formation of storms and gusty winds. ECCC (2020) suggests, albeit with considerable uncertainty, that wind speeds and wind-driven rain could increase in Canada with an even higher level of global warming, but at a rate of less than 10% compared with today. For example, ECCC projects an increase in hourly wind pressures for 25-, 50- and 100-year return periods of approximately +5% for the Lansdowne House station for a 2°C rise in mean temperature, and approximately +6% for a 3°C rise. Another study (Cheng et al., 2015) also reports a possible increase in the frequency of wind gusts above 70 km/h towards the end of the century for most Canadian regions, and specifically in summer (+10 to >50%) and winter (+30 to >50%) for regions comprising Northern Ontario. The extent of regional variations is subject to considerable uncertainty, due in part to the lack of consensus between the various models.

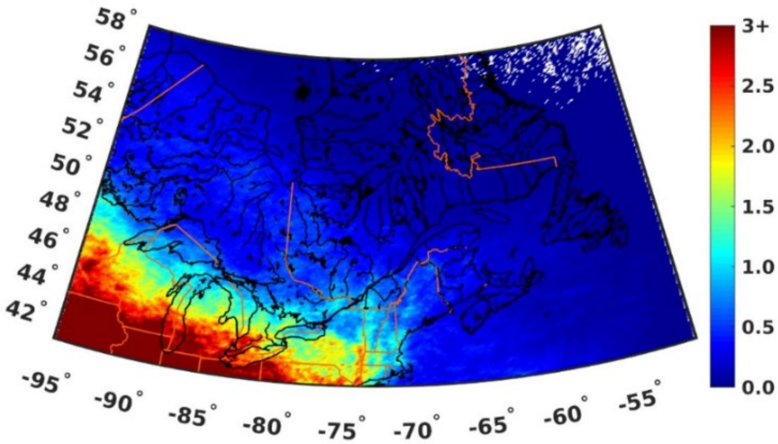
Apart from gusty winds, the formation of tornadoes, downbursts, or derechos (violent rectilinear winds) is another issue for elevated structures. Although no tornadoes were recorded within 100 km of Webequie from 1980 to 2009, one was recorded at Landsdowne House at F0 level in 1980. Also, nine tornadoes ranging between F0-F2 levels were recorded in Ontario at latitudes of 50° or higher between 1980 and 2009 (Webequie latitude is 52.9°).

4.5 Lightning

Lightning strikes have been monitored by the Canadian Lightning Detection Network since 1998, specifically total cloud-to-ground lightning flashes calculated within a 25 km radius of the center of cities or towns (ECCC, 2023c). The closest station with these measurements is in Big Trout Lake, which is approximately 200 km northwest of Webequie. The cloud-to-ground lightning flashes from 1999-2018 amounted to 11,369, representing approximately 0.5 flash per square kilometer per year which is a low frequency value. In fact, Northern Canada usually see few lightning strikes due to the colder climate, as demonstrated in **Figure 4-2**. For comparison, the lightning density in Toronto according to the network is 2.9 flashes/km^2/yr.

Knowledge of the relationship between climate and atmospheric electricity has improved in the past decade. In a recent study (Pérez-Invernón et al., 2023), climate models simulated an increase of global total lightning of 6.4 x 10^8 flashes per year by the 2090s under RCP6.0 scenario with an average global surface temperature increase of 4°C. Polar region total lightning is projected to increase by 56% comparing to 2009-2011 (at 14% per °C of temperature increase), while polar region cloud-to-ground lightning is projected to increase by 28% (at 7% per °C of temperature increase). Given that temperatures are projected to increase by 2.6 to 5.4 °C in the region by 2100, cloud-to-ground lightning may increase accordingly by 18–38% leading to a total of 13,400 to 15,700 flashes per year (or 0.6 to 0.7 flashes/km^2/yr) which all things considered will remain low.

Figure 4-2: Average Lightning Density (per km2 per year) in Eastern Canada (1999 to 2018)



Source: Canadian Lightning Detection Network (www.canada.ca/en/environment-climate-change/services/lightning/statistics.html)

5. Climate Risk Analysis

Climate risk analysis on the project components listed in **Table 2-1** was carried out following a systematic approach to:

- Ensure a complete and exhaustive analysis of factors to consider when proposing a resilience strategy.
- Reduce the subjectivity of analysts using a differentiated analysis based on impact likelihood and their consequence.
- Offer a quantitative basis on which to identify the most significative climate risks for the Project.

The analysis is loosely based on the Public Infrastructure Engineering Vulnerability Committee (PIEVC) Protocol from Engineers Canada and Natural Resources Canada, version 2009, now the ownership of a new partnership. It respects the requirements from the Strategic Assessment for Climate Change (SACC) and Ontario's guidelines within the framework of environmental impact assessments. The risk assessment is carried out in five (5) steps resulting in the calculation of risk levels that act as a climate risk rating. Details on the approach are provided in **Appendix B** and the steps are as follows.

1. Selection of climate hazards and their probability of occurrence ratings (**Table 5-1** in **Section 5.1**).
2. Determining the "potential" vulnerabilities of the components towards each climatic hazard **(Table 5-2** in Section 5.1).
3. Determining the net probability of an impact over the component's lifetime (**Table 5-3** in **Section 5.2**).
4. Determining the consequence of the impact on the component (**Table 5-3** in **Section 5.2**).
5. Calculating risk levels and prioritizing control measures (**Table 5-3** in **Section 5.2**).

The vulnerability and risk assessment on the project components were carried out considering the climate hazards listed in **Table 5-1** that were selected based on the potential to impact on one or more of the components. The hazards can be discerned between meteorological events, whether intermittent (i.e., tornado, freezing rain) or progressive (i.e., increase in average temperatures) and socio-natural features that can be a result of climate change (e.g. landslides, droughts, wildfires, freshets, permafrost degradation). Selection of the climate hazards therefore depends on the site and/or type of structures and infrastructure.

The following hazards were excluded from analysis mainly due to an absence of an interactions or potentially significant interactions with any project components.

- **Heatwaves and extreme temperatures:** Although temperatures should significantly increase in northern Ontario, hotter temperatures in the future, while remaining infrequent and below 40 °C, do not have any particular impact on the road infrastructure like the road base, culverts, and bridges.
- **Hail of large dimensions:** The impact of hail on the road and bridges do not cause damages (other than cosmetic). No impact is also expected from the interaction of hail with a project component on health and safety, natural and built environments covered in this study.
- **Lightning storms:** The infrastructures are not impacted by lightning and are not expected to add to the danger for road users. Note that wind gusts, heavy precipitations, and wildfires that can be associated with lightning are already covered as individual climate hazards.
- **Extreme cold spell:** While extreme cold temperatures can impact some materials and cause cracking for example, such conditions are already well taken into consideration in Canada and are expected to significantly decrease in frequency and intensity.

- **Topsoil droughts, hydrological droughts, and sinkhole formation from droughts:** With cooler conditions in the Far North, severe droughts that would remove groundwater at places enough to cause the land surface to collapse is deemed impossible. Topsoil and hydrological droughts are also not considered to be an issue with regard to the road integrity.
- **Freezing depth:** This hazard is relevant to buried infrastructures like water or gas lines. Hazard not to be confounded with freeze-thaw cycles or permafrost degradation in this case.
- **Tornado / downburst / derecho:** The region is not known for such events and should still be the case in the future. No control measures other than the ones already covered in the “wind gusts” hazard would be available, so a risk analysis specific to tornados is excluded.
- **Ice breakup season:** This hazard applies to the change on the time and extent of ice breakup on large waterbodies. Although the road traverses some large watercourses, this potential change will not have any direct impact on culverts and bridges. Hazard not to be confounded with spring freshets.
- **Landslide / rockslide:** The topography along the road is relatively flat and there are no hazardous slopes or geological anomalies nearby.

5.1 Potential Vulnerabilities

This step consists of establishing whether a component can potentially be affected by a climate hazard for any of the following criteria. If so, an actual risk analysis is performed on the "component / hazard / criterion" combination. Otherwise, the analysis stops at this stage.

- **Sustainability and operation (P):** Can the climate hazard cause damages requiring repairs (**P1**); affect the integrity or performance of the component (**P2**); and/or add significant operating costs (**P3**)?
- **Health and safety (S):** Can the interaction between the climate hazard and the component cause dangerous conditions for the drivers (**S1**); and/or employees related to the WSR (**S2**)?
- **Natural environment (E):** Can the interaction between the climate hazard and the component cause adverse impacts to the soil (**E1**); air (**E2**); surface water (**E3**); and/or vegetation/country food (**E4**).
- **Built environment (B):** Can the interaction between the climate hazard and the component cause damage to the Webequie air strip (**B1**); and/or future dwellings that will be built near the road (**B2**). Current residences are not included as a criterion considering that the main features of the WSR are out of the range of influence.

Table 5-2 provides the list of components identified as potentially vulnerable based on available data and observations from previous sections. Explanations on reasons why a component is not deemed vulnerable towards a climate hazard are provided in **Appendix C**.

Given that there is no road infrastructure, beyond the community of Webequie, it is important to note that this assessment was carried out based on the expected impact of climate change over time and not according to the climate strictly speaking. It is therefore acknowledged that the road designers already consider current climate conditions in their decisions.

5.2 Risk Level Assessment

For each identified vulnerability, the risk level is quantified according to the approach described in **Appendix B**, by selecting a correction factor (C_I) for the impact probability allowing to integrate the adaptation capacity ($C_I < 0$) or amplified sensitivity of the component ($C_I > 0$) towards the climate hazard. No correction ($C_I = 0$) implies an absence of mitigating factors.

The consequence rating (G_B = 1 to 5) is attributed based on the expected sensitivity of the component related to the assessed criteria. Like for the probability rating, the selection of the consequence rating has its own uncertainties since the level of damage or tolerance can vary depending on the event. Those uncertainties are integrated into the analysis by multiplying G_B with a correction factor (G_C).

From these ratings, “very low”, “low”, “moderate” or “high” risk levels can be obtained. Risk levels and their associated color coding are presented below.

Risk threshold (R) = Net probability (P_N) x Net consequence (G_N)	
≤ 10	Very low risk
10 - 20	Low risk
20 - 40	Moderate risk
40 - 100	High risk

Table 5-3 presents the results on risks for which a low level is achieved minimally. The risks established as very low are available in **Appendix C**.

Table 5-1: Climate Hazards Selected for the Vulnerability Assessment

Hazard	Description	Main Potential Interaction	Probability of Occurrence (P_A) and Confidence (P_C) Ratings		
			P_A (1)	P_C (2)	Justification
Thick fog conditions	Meteorological phenomena in which fine droplets of water come together to form a thick cloud near the ground, reducing greatly the visibility.	A road geometry (curves and grades) inclinations coupled with bad visibility due to fog can increase the potential of incidents.	3	5	Some areas of the WSR already undergo thick fog during early summer at least, supposedly during snow melting. As a minimum, it is possible that these events will increase in frequency due to rising temperatures, but it also depends on multiple conditions which increase uncertainty.
High-intensity short-duration rainfalls	Heavy rainfalls of short duration that can approach or exceed historical events for the region on an hourly and/or daily basis. Excludes tropical-like events with heavy rainfalls in successive days.	Road damage from water runoffs and infiltration can potentially increase during heavy rain. Also, there will be several water crossings that could be flooded during such events.	4	3	The increase in average temperatures during summer brings an increase in moisture in air and so the potential of extreme precipitations becomes more probable although not absolutely certain given total precipitations during summer are expected to remain constant. Uncertainties remain because of difficulties to properly model climate extremes.
Blizzards	Important snowfall of short duration (i.e., 25+ cm within 24 hours is the warning criteria for winter storms) accompanied by sustained winds.	A road layout with lots of curves and inclinations coupled with bad visibility can increase the potential of accidents (i.e., cross winds and snow accumulation).	3	4	An increase in winter precipitations is expected in the future, although it could eventually fall in liquid form, at least in higher probability than today. While stopping short of being probable, an increase of snowstorm events remains a possibility, but given the presence of open spaces along the road, blizzard conditions could more easily be achieved, increasing the uncertainty level.
Long-duration freezing rain (ice accumulation)	Rainfall events over several hours to days when the temperature at ground level oscillates near the freezing point forming droplets that solidity upon contact on surfaces.	Ice accumulation does not cause issues for ground-level structures but may cause dangerous conditions for drivers.	2	4	An increase in winter precipitation coupled with the increase in temperatures can create conditions favoring freezing rain. Currently, long-duration freezing rains are not frequent in northern Ontario and although it is expected to increase in the future, it is not probable it will substantially cause more issues. That said, this forecast remains uncertain due to limited evidence.
Freeze-thaw cycles	Temperature fluctuations with minimum and maximum daily temperatures oscillating around the freezing point (0 °C).	Freeze-thaw cycles are known to cause damage to roads and ground-level structures.	2	3	Although temperature is set to increase, the number of freeze-thaw cycles annually is not projected to decrease that much in the near to long future. It is not probable that freeze-thaw cycles will increase in occurrences but could eventually become "possible" depending on climate evolution along with meteorological conjectures. Being a northern area increases uncertainty on that respect.

(1) Probability rating going from 1 « extremely improbable » to 5 « highly probable » that the climate hazard increase in frequency and/or intensity in the future according to models and studies on climate for the region.
(2) Confidence rating on the selected P_A rating going from 1 « highly confident » to 5 « low confidence » selected mainly based on the number of proofs and concurring studies about the future evolution of the climate hazard for the region.

Table 5-1 (Cont'd): Climate Hazards Selected for the Vulnerability Assessment

Hazard	Description	Main Potential Interaction	Probability of Occurrence (P_A) and Confidence (P_C) Ratings		
			P_A [(1)]	P_C [(2)]	Justification
Rain on snow events	Significant liquid precipitations on existing snowpack that could freeze and form an ice crust.	Formation of ice can t cause road safety issues but also extra weight that may cause damages on some structures (i.e., bridges and culverts).	4	2	An increase in winter precipitations coupled with the increase in temperatures can create conditions favoring rain events when the region will still have snow on the ground.
Wind gust events	Strong instantaneous winds (compared to normal speeds) over a substantial period which can result in material damage.	Although the road would not be directly impacted, winds may cause problems for the MSF (i.e., roofs, exterior components).	3	5	Studies on that matter do not demonstrate a clear increase in intensity, but rather a low-to-medium likelihood of increasing in frequency. An increase in wind gusts is therefore considered possible for the region, but with very high level of uncertainty when dealing with winds.
Permafrost degradation	Collapse (or at least movement) of soil by settlement due to the degradation (melting) of permafrost (or freezing of infiltrated water in the permafrost).	Land collapse can cause local damage to the road or possibly the MSF.	2	4	The project area is located within a band of sporadic permafrost. However, no observed areas of permafrost were documented along the road ROW during field investigations. It is therefore not probable that permafrost degradation will occur (especially since road construction should help mitigate that potential problem). There remain however uncertainties given that field investigations did not cover all of the 100+ km road.
Spring and torrential freshets	Significant increase of in flow and water level of a watercourse due to extreme precipitation events or snow melting that can cause riverbank flooding. It also applies to the flash melting of snow on land creating local flooding.	The road will cross several watercourses of different type and extent that could be impacted by flash floods.	4	3	A probable increase in intensity and frequency of torrential freshets is considered (similar to high-intensity short-duration rainfalls). With the potential increase in liquid precipitations and increase of temperatures in general, this likelihood rating is also applicable to spring freshets. It is not deemed highly probable due to the rather large catchments in the region that normally help mitigate the impact but that said, there still remain significant uncertainties given the remoteness of the area.

(1) Probability rating going from 1 « extremely improbable » to 5 « highly probable » that the climate hazard increase in frequency and/or intensity in the future according to models and studies on climate for the region.
(2) Confidence rating on the selected P_A rating going from 1 « highly confident » to 5 « low confidence » selected mainly based on the number of proofs and concurring studies about the future evolution of the climate hazard for the region.

Table 5-1 (Cont'd): Climate Hazards Selected for the Vulnerability Assessment

Hazard	Description	Main Potential Interaction	Probability of Occurrence (P_A) and Confidence (P_C) Ratings		
			P_A (1)	P_C (2)	Justification
Riverbank erosion	Natural or anthropogenic process where the soil along the riverbanks is eroded, transported by flow, and deposited at a specific location downstream.	Depending on the watercourse, a change in riverbanks structural stability may potentially have an impact on culverts or bridges in the longer term.	3	5	With the expected increase in runoffs from heavy rainfalls and freshets, it is possible that the erodibility of riverbanks near water crossings would increase. Higher probability is dismissed given that it depends on the uncertain nature of soil at each bridge and culvert locations.
Wildfires	Singular events generally occurring during dry seasons that can be caused by lightning.	The passage of wildfires will damage any structure and possibly road components.	4	3	The western section of the road will traverse wooded areas where wildfires have occurred in the past and could still again occur. Given the summer temperatures are projected to increase and total summer precipitations to stagnate, the increase of wildfire frequency is set to probable with medium uncertainty given the randomness of these events.

(1) Probability rating going from 1 « extremely improbable » to 5 « highly probable » that the climate hazard increase in frequency and/or intensity in the future according to models and studies on climate for the region.
(2) Confidence rating on the selected P_A rating going from 1 « highly confident » to 5 « low confidence » selected mainly based on the number of proofs and concurring studies about the future evolution of the climate hazard for the region.

Table 5-2: Potential Climate Vulnerabilities Identified for the Project

Project Component	Climate Hazard	Criteria				Justifications
		P	S	E	B	
WSR layout	Thick fog conditions		S1			**S1:** Thick fog can affect visibility leading to road accidents. Thick fog can also be a hazard on bridges, especially for traffic in narrow lanes.
	High-intensity short duration rainfalls		S1			**S1:** Heavy rainfall events can lead visibility issues and slippery conditions.
	Blizzards		S1			**S1:** Blizzards can affect visibility and traction of the road increasing the potential for accidents.
	Long-duration freezing rain (ice accumulation)		S1			**S1:** Freezing rain can lead to icy conditions.
	Rain on snow events		S1			**S1:** Rain on snow can lead to icy roads which can be dangerous.
	Wind gust events		S1			**S1:** Wind gusts can deteriorate driving conditions, especially on sections open areas.
Road structure (western part)	High-intensity short duration rainfalls	P1	S1			**P1:** Heavy rainfall can weaken structural integrity of the embankment if water does not drain properly, increasing the potential for road damage such as potholes. **S1:** Heavy rainfall can lead to slippery conditions and hydroplaning if the road is not designed and constructed according to codes (requirements about road surface drainage).
	Long-duration freezing rain (ice accumulation)		S1			**S1:** Freezing rain can lead to icy conditions increasing the potential for accidents.
	Freeze-thaw cycles	P1				**P1:** Freeze-thaw cycles can accelerate heaving, the deterioration of the road and the formation of potholes, as well as weakening of the substructure.
	Permafrost degradation	P1	S1			**P1:** changes in the road geometry as a result of permafrost degradation may require repairs or maintenance. **S1:** Permafrost degradation can destabilize the ground, deteriorate the road and cause major sinkholes or potholes that may create accidents if not corrected rapidly.
	Spring and torrential freshets	P1	S1			**P1:** overtopping on the road might require maintenance to clear debris and may damage the road embankment. **S1:** Overtopping can be a safety hazard. Water crossings of the road can be impacted by overtopping. Low-lying areas are also susceptible to flooding.

Table 5-2 (Cont'd): Potential Climate Vulnerabilities Identified for the Project

Project Component	Climate Hazard	Criteria				Justifications
		P	S	E	B	
Road structure (eastern part)	High-intensity short duration rainfalls	P1	S1			**P1:** Heavy rainfall can weaken structural integrity of the embankment if water does not drain properly, increasing the potential for potholes and sinkholes. **S1:** Heavy rainfall can lead to slippery conditions and hydroplaning if the road is not designed and constructed according to highway design requirements / codes (requirements about road surface drainage).
	Long-duration freezing rain (ice accumulation)		S1			**S1:** Freezing rain can lead to icy conditions increasing the potential for accidents.
	Freeze-thaw cycles	P1				**P1:** Freeze-thaw cycles can accelerate heaving, the deterioration of the road and the formation of potholes, as well as weakening of the substructure.
	Permafrost degradation	P1	S1	E3		**P1:** Distorted road as a result of permafrost degradation may require repairs or maintenance. **S1:** Permafrost degradation can destabilize the ground, deteriorate the road and cause sinkholes or potholes. **E3:** The formation of sinkholes at a road location along the wetland may have some impact on the surrounding waterbodies. .
	Spring and torrential freshets	P1	S1			**P1:** Overtopping require maintenance to clear debris and may damage the embankment **S1:** Overtopping can a safety hazard. Water crossings of the road can be impacted by overtopping. Low-lying areas beside the road are also susceptible to flooding.
Roadside ditches and earth cut sections	High-intensity short duration rainfalls	P2		E3 E4		**P2:** Heavy rain and runoff can wash sediments and large objects into ditches affecting its efficiency over time. No damaging impact though. **E3/E4:** Runoffs and flooding can result from high intensity rainfall events if roadside ditches are at capacity.
	Rain on snow events	P2				**P2:** Snow in ditches can slow down drainage during these events.
	Permafrost degradation	P1				**P1:** Like for roads, permafrost degradation can impact (cracks and holes) ditches and surrounding areas affecting their performance for example.
	Spring and torrential freshets	P2				**P2:** Significant freshet events can wash sediments and large objects into ditches affecting its efficiency. Flooding is not expected to damage the ditches and berms.

Table 5-2 (Cont'd): Potential Climate Vulnerabilities Identified for the Project

Project Component	Climate Hazard	Criteria				Justifications
		P	S	E	B	
Bridges (including riverbanks)	High-intensity short duration rainfalls			E3		**E3:** Heavy rainfalls may cause large runoffs and localized flooding at water crossings.
	Blizzards		S1			**S1:** Blizzard can affect visibility and cause slippery conditions on bridges increasing the potential for accidents.
	Long-duration freezing rain (ice accumulation)		S1			**S1:** Freezing rain can lead to icy conditions increasing the potential for accidents on bridges.
	Freeze-thaw cycles	P1				**P1:** Freeze-thaw cycles can accelerate the deterioration of bridge components made of concrete.
	Rain on snow events		S1			**S1:** Rain on snow events can lead to slippery conditions especially if drainage areas are blocked by ice.
	Spring and torrential freshets	P1	S1			**P1:** Inspections or maintenance of bridges might be required following significant freshet events reaching and impacting bridge substructures such as piers and/or abutments. **S1:** Water crossings of the road can be impacted by overtopping.
	Riverbank erosion	P1		E3		**P1:** Bridges built in areas with defined riverbank channels and/or that have existing bank erosion may require inspection, maintenance or repairs. **E3:** Erosion caused in part from the bridge piers may locally modify the stream's flow and/or channel characteristics (i.e., width, depth of channel) over time.
Major culverts (including streambanks)	High-intensity short duration rainfalls	P1 P2		E3		**P1/P2:** Heavy rains and runoff can wash sediment and large objects into ditches then affecting the efficiencies of culverts. If the road is not designed appropriately, water can accumulate and cause local flooding which can result in water infiltration into the road base. **E3:** Runoffs and localized floods can result from high intensity rainfalls if culverts are at capacity which can lead to erosion of soil in nearby waterbodies. Excess water not drained properly may damage receiving streams.
	Freeze-thaw cycles	P1				**P1:** Freeze-thaw of soil may result in some movement of the culvert that would lead to repairs.
	Rain on snow events	P2				**P2:** Snow in ditches near culverts can slow down drainage.
	Spring and torrential freshets	P1 P2				**P1/P2:** Significant freshet events can wash sediment and large objects into ditches near culverts affecting its efficiency. Inspections, maintenance or repairs might be required.
	Riverbank erosion	P2				**P2:** Riverbank erosion can increase the sediment load in the water and affect the drainage system. Inspection, maintenance or repairs might be required in some cases.

Table 5-2 (Cont'd): Potential Climate Vulnerabilities Identified for the Project

Project Component	Climate Hazard	Criteria				Justifications
		P	S	E	B	
Aggregate pit	Wind gust events	P1	S2			**P1:** Wind gusts have the potential to damage any temporary structures or loose components not well secured at the site (trailers, lights and etc.) and impact the operation of certain equipment. **S2:** Wind gusts can generate dusty conditions or flying debris at the aggregate pit.
Maintenance and storage facility	Long-duration freezing rain (ice accumulation)		S2			**S2:** Freezing rain can lead to icy and slippery conditions for the workers, also ice can build up on roofs and fall to the ground.
	Freeze-thaw cycles	P1				**P1:** Freeze-thaw cycle can destabilize the soil resulting in cracks in the foundation.
	Wind gust events	P1	S2			**P1:** Wind gusts have the potential to damage roofs and any temporary structures or loose components not well secured. **S2:** Wind gusts can generate flying debris at facility.
	Permafrost degradation	P1				**P1:** Permafrost degradation can impact the stability of buildings and might require maintenance or repairs.
Rehabilitated sites	High-intensity short duration rainfalls			E1		**E1:** Heavy rains and runoffs may lead to the erosion of the surface soil placed during rehabilitation and can be an issue during the first couple of years after rehabilitation activities are completed when the soil has not yet been stabilized.
Construction activities	Thick fog conditions		S2			**S2:** Thick fog can affect visibility leading to road accidents during construction activities on or beside the road.
	High-intensity short duration rainfalls		S2			**S2:** Heavy rain can reduce visibility for operators. Unstable slopes or loose material from excavation can be a hazard to workers.
	Blizzards		S2			**S2:** Blizzards can affect visibility and traction of the road increasing the potential of accidents during construction activities.
	Long-duration freezing rain (ice accumulation)		S2			**S2:** Freezing rain can lead to slippery and hazardous conditions and if construction activities are carried out.
	Rain on snow events		S2			**S2:** Rain on snow events can lead to slippery conditions for workers on-foot.
	Wind gust events		S2			**S2:** Wind gusts can generate dusty conditions or flying debris at the construction site.

Table 5-2 (Cont'd): Potential Climate Vulnerabilities Identified for the Project

Project Component	Climate Hazard	Criteria				Justifications
		P	S	E	B	
Road maintenance activities	Thick fog conditions		S2			**S2:** Thick fog can affect visibility leading to road accidents when maintenance vehicles or crew are on the road.
	High-intensity short duration rainfalls		S2			**S2:** Heavy rain can reduce visibility for the maintenance crew. Unstable slopes or loose material from excavation can be a hazard to workers.
	Blizzards		S2			**S2:** Blizzards can affect visibility and traction of the road increasing the potential of accidents during road maintenance activities.
	Long-duration freezing rain (ice accumulation)		S2			**S2:** Freezing rain can lead to slippery conditions during road maintenance activities.
	Rain on snow events		S2			**S2:** Rain on snow events can lead to slippery conditions for workers on-foot.
	Wind gust events		S2			**S2:** Wind gusts can generate dusty conditions or flying debris at the construction site.

Criteria

P: Sustainability of the component (damages requiring repairs or maintenance « P1 »; integrity or performance « P2 »; operation cost « P3 »)

S: Health and safety (dangerous conditions for the drivers « S1 »; employees related to the WSR « S2 »)

E: Natural environment (environmental damage to the vicinity including soils « E1 »; air « E2 »; waterbodies « E3 »; vegetation/country food « E4 »)

B: Build environment (damage to existing structure and infrastructures including the air strip « B1 »; future buildings along the road « B2 »)

Table 5-3: Climate Risks Classified as Low, Moderate or High

Project Component	Climate Hazard	Criteria	Rating (1)			Justifications	Risk (R) (2)
			C_I	G_B	G_C		
WSR layout	Thick fog conditions	Health and Safety (S1)	-2	3	4	**C_I:** Thick fog reduces visibility on the road and can be hazardous for the traffic. The WSR layout will be designed with standard lane widths and geometry and the topography has few grades. Fog is not known to be particularly severe in this area and is expected to occur on a seasonal basis. Road closures will be done under severe cases. **G:** Low visibility from fog can be hazardous on high-speed roads with low traffic. Accidents may involve collisions or vehicle to veer off-road resulting in first aid treatment or hospital visits under the most serious circumstances.	**10.8**
	High-intensity short duration rainfalls	Health and Safety (S1)	-2	3	4	**C_I:** The WSR layout is expected to be designed with standard lane width, curves and low grades. The presence of rest areas along the road allows the drivers to stop if needed. The 35 m ROW also allows for maximized visibility given the conditions. **G:** Heavy rainfall can decrease visibility and lead to slippery conditions with high likelihood of accidents in curves and on grades. Given the expected low traffic, the most likely outcome is the loss of control of the vehicle and result in first-aid treatment. Serious accidents may involve collisions or vehicle veering off-road resulting in hospital visits.	**17.3**
	Blizzards	Health and Safety (S1)	-1	3	4	**C_I:** The WSR layout will be designed with standard lane width, curves and low grades. Winter snow fencing may be installed in areas more prone to snow drifts. **G:** The most likely outcome in low traffic conditions is the loss of control of the vehicle and result in first-aid treatment. Serious accidents may involve collisions or vehicle veering off-road resulting in hospital visits.	**19.4**
	Long-duration freezing rain (ice accumulation)	Health and Safety (S1)	-1	3	4	**C_I:** The WSR layout will be designed with standard lane width, curves and low grades. **G:** The most likely outcome of slippery conditions in low traffic conditions is the loss of control off-road resulting in first-aid treatment, although serious accidents may also occur involving head-on collisions	**9.7**
	Rain on snow events	Health and Safety (S1)	-3	3	4	**C_I:** The WSR layout will be designed with standard lane width, curves and low grades. The maintenance staff will clear snow according to provincial requirements. **G:** The most likely outcome of slippery conditions in low traffic conditions is the loss of control off-road resulting in first-aid treatment, although serious accidents may sometimes occur involving head-on collisions.	**7.6**

Table 5-3 (Cont'd): Climate Risks Classified as Low, Moderate or High

Project Component	Climate Hazard	Criteria	Rating [(1)]			Justifications	Risk (R) [(2)]
			C_I	G_B	G_C		
WSR layout	Wind gust events	Health and Safety (S1)	-2	3	3	**C_I:** Although cross winds can be a safety hazard to drivers, the road will not be designed with narrow lanes or have physical hazards (e.g., trees in close proximity to road), and where applicable safety guiderail will be placed along the road where standards dictate their use. **G:** The most likely outcome is the loss of control of the vehicle and result in first-aid treatment.	**9.6**
Road structure (western part)	High-intensity short duration rainfalls	Sustainability (P1)	-2	2	4	**C_I:** The embankment will be constructed according to provincial standards with efficient water drainage (with ditches and swales draining to local streams). The presence of asphalt or chip seal also helps on preventing surface damage with water. **G:** Weakened embankment due to heavy rainfall and poor drainage can result in potholes in localized areas that would require normally minor repairs with time.	**11.5**
		Health and Safety (S1)	-2	3	4	**C_I:** The road will be constructed according to provincial standards with regard to water drainage from road surface. The surface treatment will reduce slippery conditions during heavy rain. **G:** Slippery conditions may result most likely to vehicles veering off-road resulting in first aid and less about hospital visits due to low expected traffic.	**17.3**
	Long-duration freezing rain (ice accumulation)	Health and Safety (S1)	-1	3	4	**C_I:** The road maintenance crew will spread sand to increase traction on the road surface. Pavements are also easier to maintain than aggregate roads. **G:** The most likely outcome of slippery conditions in low traffic conditions is the loss of control off-road resulting in first-aid treatment, although serious accidents may also occur involving head-on collisions.	**9.7**
	Freeze-thaw cycles	Sustainability (P1)	0	3	3	**C_I:** The embankment is designed according to provincial standards and there are no extra measures considered warranted against freeze-thaw. **G:** Freeze-thaw can weaken the embankment and road surface causing heaving resulting in potholes that could potentially require localized repairs depending on extent of damages.	**15.4**
	Permafrost degradation	Sustainability (P1)	-1	4	4	**C_I:** Since geotechnical investigations have not yet identified the presence of permafrost, the presence of isolated pockets under the road footprint is expected to be low. Any permafrost encountered during construction will melt. **G:** Formation of sinkholes, although highly unlikely and localized, would require complex work with localized impact on traffic, but it could be worse with the interruption of traffic if it impacts both lanes.	**13.0**

Table 5-3 (Cont'd): Climate Risks Classified as Low, Moderate or High

Project Component	Climate Hazard	Criteria	Rating [(1)]			Justifications	Risk (R) [(2)]
			C_I	G_B	G_C		
Road structure (western part)	Permafrost degradation	Health and Safety (S1)	-1	4	4	**C_I:** Accidents due to the presence of major potholes or sinkholes are considered unlikely events. **G:** Major accidents normally involving one vehicle (due to low traffic) that could lead to hospitalization, but it could be worse (with multiple cars).	**13.0**
	Spring and torrential freshets	Sustainability (P1)	-2	3	4	**C_I:** Overtopping from rainfall events is not likely to cause damage but water infiltration may cause damage in the long term. **G:** Depending on location, the road is subject to the potential damage due to overtopping which may require extensive work with potential impacts on traffic. The absence of flashy streams along the alignment reduces the probability of occurrence as well as potential damages.	**17.3**
		Health and Safety (S1)	-2	2	5	**C_I:** The drivers can avoid driving into a flooded road. It is not probable at worst that an incident due to floods would occur. **G:** Given the low speeds, the impact on the health of the driver should be limited, although it could be worse depending on extent of flooding.	**12.8**
Road structure (eastern part)	High-intensity short duration rainfalls	Sustainability (P1)	-3	4	3	**C_I:** The embankment will be constructed according to provincial standards and bridge design codes with runoff draining off the roadway. Equalization cross-culverts will be installed at appropriate intervals along the road to allow for water to pass from upstream to downstream and prevent water levels from rising on one side of the road. Furthermore, cross-culverts will be oversized to reduce potential for blockage and allow for easier maintenance. **G:** Weaken structural integrity of the road embankment due to heavy rainfall can form potholes of which can managed through routine maintenance and repair activities.	**10.2**
		Health and Safety (S1)	-2	3	4	**C_I:** The road will be constructed according to provincial standards with regard to drainage from road surface and ponding is not expected. Slippery conditions are not expected with the gravelly chip seal. **G:** Slippery conditions may result most likely to vehicles veering off-road resulting in first aid and less about hospital visits due to low expected traffic.	**17.3**
	Long-duration freezing rain (ice accumulation)	Health and Safety (S1)	-1	3	4	**C_I:** The road maintenance crew will spread sand to increase traction on the road surface. Pavements are also easier to maintain than aggregate roads. **G:** The most likely outcome of slippery conditions in low traffic conditions is the loss of control off-road resulting in first-aid treatment, although serious accidents may also occur involving head-on collisions.	**9.7**

Table 5-3 (Cont'd): Climate Risks Classified as Low, Moderate or High

Project Component	Climate Hazard	Criteria	Rating (1)			Justifications	Risk (R) (2)
			C_I	G_B	G_C		
Road structure (eastern part)	Freeze-thaw cycles	Sustainability (P1)	-1	4	3	**C_I:** The embankment will be designed according to provincial standards and groundwater will flow underneath. The embankment will be properly drained to reduce the effects of freeze-thaw cycles. **G:** Freeze-thaw can weaken the substructure causing heaving and the formation of potholes over time that could potentially require major repairs. The organic soil has the potential for greater movement.	**10.2**
	Permafrost degradation	Sustainability (P1)	-1	4	4	**C_I:** Since geotechnical investigations have not yet identified the presence of permafrost, the presence of isolated pockets under the road footprint is expected to be low. Any permafrost encountered during construction will be addressed at that time. **G:** Formation of potholes or sinkholes, although mostly localized, might require complex work with localized impact on traffic, but it could be worse with the interruption of traffic.	**13.0**
		Health and Safety (S1)	-1	4	4	**C_I:** Accidents due to the presence of major potholes or sinkholes are considered very rare events and of low probability to occur. **G:** Major accidents normally involving one vehicle (due to low traffic) that could lead to hospitalization, but it could be worse (with multiple cars).	**13.0**
		Natural Environment (E3)	-1	4	4	**C_I:** Since any permafrost encountered during construction will melt during construction, sinkholes or road breaks due to permafrost are not expected. **G:** Sinkholes or road breaks are not expected to create significant problems on the surrounding wetlands.	**11.5**
	Spring and torrential freshets	Sustainability (P1)	-3	4	3	**C_I:** The road is to be elevated at sufficient height that would prevent water from rising over the surface (overtopping). Furthermore, groundwater modelling will determine the appropriate sizing for groundwater drainage components. The presence of geotextile and geogrid under the road is expected to help drainage and stabilize the roadbed. **G:** Depending on location, the road has the potential to break or being damaged requiring extensive work with impact on traffic.	**10.2**
	Spring and torrential freshets	Health and Safety (S1)	-2	2	5	**C_I:** The drivers have the control to avoid driving into a flooded road. It is not probable at worst that an incident due to floods would occur. **G:** Given the low speeds, the gravity on the health of the driver should be limited, although it could be worse depending on extent of flash floods.	**12.8**

Table 5-3 (Cont'd): Climate Risks Classified as Low, Moderate or High

Project Component	Climate Hazard	Criteria	Rating (1)			Justifications	Risk (R) (2)
			C_I	G_B	G_C		
Road structure (eastern part)	Riverbank erosion	Sustainability (P1)	-1	3	3	**C_I:** Being elevated, the road embankment is subject to erosion over time in presence of water but with the presence of cross-culverts, and other appropriate erosion control design measures at waterbody crossings are expected to minimize erosion potential. **G:** Roadside erosion is a slow process that should not create excessive damage to the road but would need regular maintenance work to prevent further problems with time. The maintenance crew is expected to inspect the road and intervene if necessary.	**19.2**
		Natural Environment (E3)	-1	3	3	**C_I:** Local erosion of embankment can impact adjacent wetlands with aggregate accumulations at some locations; however, the road design including equalization and cross culverts, and runoff off management, erosion should be limited. **G:** Erosion and potential deposition of sediment into wetland would be localized and reversible with the help of the maintenance crew.	**19.2**
Roadside ditches and earth cut sections	High-intensity short duration rainfalls	Sustainability (P2)	-2	2	3	**C_I:** Excess sediments and objects deposited into the ditch are expected to be limited. The maintenance crew is expected to make routine inspections and maintain the ditches. **G:** Excess sediments or objects can slow down drainage, but ditches will be maintained to address this.	**10.2**
		Natural Environment (E3)	-2	3	4	**C_I:** Stormwater quantity and quality analyses will be completed to ensure surrounding waterbodies can accommodate discharge from events. Mitigation measures will be incorporated in the design to ensure proper drainage, as per provincial standards. **G:** When runoff is high, the flow into the receiving stream can cause localized damage (including erosion and sedimentation) and can be addressed by the maintenance crew.	**17.3**
		Natural Environment (E4)	-3	4	3	**C_I:** As per provincial regulations, the WSR is to be designed to handle stormwater within the right-of-way areas and not expected to impact areas where harvesting of country foods occur. Also, trapezoidal ditches will be constructed to accommodate runoffs. The maintenance crew will regularly inspect ditches for issues. **G:** When runoff is high, the flow into the receiving stream that is also connected to a sensitive area could cause flooding. No flooding of country-food areas is predicted.	**10.2**

Table 5-3 (Cont'd): Climate Risks Classified as Low, Moderate or High

Project Component	Climate Hazard	Criteria	Rating [(1)]			Justifications	Risk (R) [(2)]
			C_I	G_B	G_C		
Roadside ditches and earth cut sections	High-intensity short duration rainfalls	Build Environment (B2)	-2	3	3	**C_I:** Trapezoidal ditches will be constructed where possible to accommodate runoff. The maintenance crew will regularly inspect ditches for issues and will implement repairs, where applicable to be resolve. Since residences near the road do not exist yet, it is expected that the residents will take the necessary precautions to prevent flooding. **G:** Over-capacity of ditches at residences could potentially flood the plot and bring water to the house, but the impact would remain limited (houses located away from rivers).	**15.4**
	Rain on snow events	Sustainability (P2)	0	2	3	**C_I:** Snow in ditches with rain or melting conditions can impact runoff drainage potentially creating very localized flooding. **G:** Performance of the ditch would be affected but this impact would not be long-lasting. In this event, the maintenance crew is expected to work to alleviate any issue.	**17.9**
	Permafrost degradation	Sustainability (P1)	0	2	4	**C_I:** Although the presence of permafrost under the road footprint is not expected, there is no definite confirmation at this time and no design or construction considerations preventing sinkholes (or equivalent) from forming due to melting permafrost. **G:** Sinkholes and breaks in ditches would require repairs normally not impactful on traffic but depends on event.	**14.4**
	Spring and torrential freshets	Sustainability (P2)	-2	2	3	**C_I:** Excess sediments and objects deposited into the ditch after freshets near streams are expected to be limited and localized. The maintenance crew is expected to make routine inspections and maintain the ditches. **G:** Excess sediments or objects can slow down drainage slightly but not to greater extent.	**10.2**
Bridges (including riverbanks)	High-intensity short duration rainfalls	Natural Environment (E3)	-1	2	3	**C_I:** Runoff from the bridge during heavy rainfall can enter the natural environment. **G:** Impacts to the environment are considered to be minor as runoff water from the bridge is also expected to be free of contamination.	**15.4**
	Blizzards	Health and Safety (S1)	-2	4	3	**C_I:** Blizzards can reduce visibility and traction and lead to windy conditions across the bridge which can be hazardous for the traffic. Road maintenance is anticipated for extreme events i. Also, due to low traffic volume, such event on bridges would be most unlikely. **G:** Slippery conditions can cause mostly accidents on bridges that would be serious in nature.	**11.5**

Table 5-3 (Cont'd): Climate Risks Classified as Low, Moderate or High

Project Component	Climate Hazard	Criteria	Rating (1)			Justifications	Risk (R) (2)
			C_I	G_B	G_C		
Bridges (including riverbanks)	Long-duration freezing rain (ice accumulation)	Health and Safety (S1)	-1	4	3	**C_I:** Traffic is expected to be very low during poor driving conditions. Road maintenance is anticipated for extreme events. **G:** Slippery conditions on bridges would result mostly accidents that would be serious in nature.	**11.5**
	Freeze-thaw cycles	Sustainability (P1)	-1	2	3	**C_I:** The bridge is to be designed according to provincial standards with regard to freeze-thaw degradation of concrete. **G:** Freeze-thaw can create cracks in concrete that would, following inspections, be corrected by the maintenance crew.	**5.1**
	Rain on snow events	Health and Safety (S1)	-3	4	3	**C_I:** The maintenance crew is expected to clear the snow according to provincial standards from the road surface, preventing any issue on that respect. **G:** Slippery conditions can cause mostly accidents on bridges that would be serious in nature.	**9.0**
	Spring and torrential freshets	Sustainability (P1)	-3	4	3	**C_I:** Bridges will be sized to accommodate the 100-year storm plus climate change (+30-40% increase of IDF values). The rise of water at the bridge deck is most unlikely. **G:** The four bridges will be located on streams and waterbodies that have low flow velocities and are not configured to generate high water velocities during freshet events. Lower velocities will not damage the bridge deck (or other structures) to an extent that would require reconstruction.	**10.2**
		Health and Safety (S1)	-2	2	5	**C_I:** The drivers have the control to avoid driving into a flooded road. It is not probable at worst that an incident due to floods would occur. **G:** Given the low speeds, the gravity on the health of the driver should be limited, although it could get worst depending on extent of flash floods.	**12.8**
	Riverbank erosion	Sustainability (P1)	-1	1	5	**C_I:** Riverbanks near the bridges will be revegetated and/or have erosion control measures (e.g., rock/rip rap) following construction to prevent erosion over time. **G:** No significant damages are expected as the piles will be drilled into the ground.	**8.0**
		Natural Environment (E3)	-1	2	4	**C_I:** Riverbanks near the bridges will be revegetated and have erosion control measures installed following construction to limit erosion over time. **G:** Scour caused by piers could affect the normal flow of the waterbody at bridge location, but this will be addressed during design and is not expected to be a major concern. The maintenance crew is also expected to inspect these areas and intervene if necessary.	**14.4**

Table 5-3 (Cont'd): Climate Risks Classified as Low, Moderate or High

Project Component	Climate Hazard	Criteria	Rating (1)			Justifications	Risk (R) (2)
			C_I	G_B	G_C		
Major culverts (including streambanks)	High-intensity short duration rainfalls	Sustainability (P1)	-2	3	4	**C_I:** Drainage system ditches, culverts and bridges will be sized to address climate change with an increase of +30-40% of IDF values for the region. Erosion controls like riprap may be put in place around structures to reduce the long-term damage potential. **G:** Erosion may damage structures potentially requiring preventive repairs depending on the level of damage.	**17.3**
		Sustainability (P2)	-2	2	4	**C_I:** Drainage system and structures will be sized to incorporate increased sizing for climate change with an increase of +30-40% of IDF values for the region. This that should prevent culverts from being at over capacity. **G:** The performance of culverts might be impacted over time as excess sediment or objects can slow down drainage. Localized flooding should recede quickly given that culverts will be sized accordingly (+30-40% of IDFs).	**11.5**
		Natural Environment (E3)	-2	2	4	**C_I:** Drainage system and structures will be increased in size to address climate change with an increase of +30-40% of IDF values for the region. Over-capacity concerns causing local flooding into the stream is not probable. **G:** If flooding occurs, it could impact the upstream section of the culvert although it should remain limited and localized (considering the +30-40% increase of IDFs) and can be reversed naturally or with help from the maintenance crew. Depending on event and location, the extent of damages could be worse.	**11.5**
	Freeze-thaw cycles	Sustainability (P1)	-1	4	3	**C_I:** Repeated freeze-thaw cycle can destabilize the soil and gravel around culverts which will however be designed and constructed according to codes to minimize heave or destabilization. **G:** Soil movement may damage the culverts potentially requiring major repairs (with impact on traffic) depending on the level of damage.	**10.2**
	Rain on snow events	Sustainability (P2)	0	2	3	**C_I:** The presence of snow in ditches may increase runoff drainage and potentially create very localized flooding. **G:** Performance of the culvert would be affected but this impact would not be long-lasting. In this event, like for the ditches, the maintenance crew is expected to work to alleviate any issue.	**17.9**

Table 5-3 (Cont'd): Climate Risks Classified as Low, Moderate or High

Project Component	Climate Hazard	Criteria	Rating (1)			Justifications	Risk (R) (2)
			C_I	G_B	G_C		
Major culverts (including streambanks)	Spring and torrential freshets	Sustainability (P1)	-3	4	3	**C_I:** Like bridges, culverts will be sized considering 100-year storm which and integrate climate change (+30-40% increase of IDF values). Over-capacity of culverts is unlikely. It should limit unwanted infiltration of water into the soil that could potentially move and damage the culvert. **G:** Soil movement may damage culverts potentially requiring major repairs (with impact on traffic) depending on the level of damage.	**10.2**
		Sustainability (P2)	-2	2	4	**C_I:** Like bridges, culverts will be sized considering 100-year storm and integrates climate change (+30-40% increase of IDF values). Over-capacity of culverts is unlikely. The maintenance crew will systematically clean the culverts following freshets. **G:** The performance of culverts might be impacted over time as excess sediment or objects can slow down drainage. Severe cases may result in localized flooding that should recede quickly given that culverts will be sized accordingly (+30-40% of IDFs).	**11.5**
	Riverbank erosion	Sustainability (P2)	-2	1	3	**C_I:** Erosion control measures including bank revegetation following construction will limit erosion over time. The maintenance crew is also expected to clear culverts when necessary. **G:** The presence of sediments may affect the flow through culverts, but it will be managed by maintenance staff in accordance with provincial standards.	**3.2**
Aggregate pit	Wind gust events	Sustainability (P1)	-1	2	4	**C_I:** Most equipment at quarries is heavy and/or must be solidly anchored during operation or inactivity. **G:** Damaged materials (if any) are not expected to be of highest value and can easily be replaced in normal times.	**14.4**
		Health and Safety (S2)	-2	2	5	**C_I:** Most equipment at quarries is heavy and/or must be solidly anchored during operation. Workers are also expected to take appropriate precautions during extreme wind conditions. **G:** Small injuries are to be expected from flying dust or debris, but it can be worst depending on event.	**8.0**
Maintenance and storage facility	Long-duration freezing rain (ice accumulation)	Health and Safety (S2)	-1	3	3	**C_I:** Freezing rain can lead to slippery conditions and ice buildup on roofs which can be hazardous for workers at the MSF . Workers are expected to mitigate in their Health & Safety plan and take proper precautions. Low-priority work activities can be postponed eliminating the hazards. **G:** Slippery conditions can cause slips and falls to workers. These incidents would result in first-aid treatment at worst.	**8.6**

Table 5-3 (Cont'd): Climate Risks Classified as Low, Moderate or High

Project Component	Climate Hazard	Criteria	Rating (1)			Justifications	Risk (R) (2)
			C_I	G_B	G_C		
Maintenance and storage facility	Freeze-thaw cycles	Sustainability (P1)	0	3	4	**C_I:** Buildings are expected to be designed and constructed according to codes, but there are no indications that specific measures will be taken against freeze-thaw. **G:** Cracks in the foundation can be severe in extreme cases leading to uneven floors and doors that may require moderate repairs.	**17.3**
	Wind gust events	Sustainability (P1)	-1	3	3	**C_I:** The MSF buildings and outside structures will be designed and built to codes. With the exception of these buildings, no elevated structures (e.g. communication towers and electrical lines) vulnerable to wind will be constructed. **G:** Damaged roofs or others would require complex work to the building without impact the road however.	**19.2**
		Health and Safety (S2)	-2	2	5	**C_I:** The MSF building and outside structures will be designed and built to codes in order to prevent damage from high winds. Projections of large debris are not to be expected at the MSF as long as it is operated and maintained following best practices. **G:** Small injuries are to be expected from flying dust or debris, but it can be worst depending on event.	**8.0**
	Permafrost degradation	Sustainability (P1)	-1	4	3	**C_I:** Geotechnical studies at MSF location will be carried out to verify the presence of permafrost underneath and adjust in consequence if any. **G:** Soil movement under the foundation can create cracks and serious damages depending on events.	**11.5**
Rehabilitated sites	High-intensity short duration rainfalls	Natural Environment (E1)	-1	1	5	**C_I:** Heavy rainfalls and runoffs can erode surface soil from rehabilitated sites. Erosion is however expected to be limited after new vegetation becomes established. **G:** Soil erosion is not expected to have a great impact on the environment.	**9.6**
Construction activities	Thick fog conditions	Health and Safety (S2)	-2	3	4	**C_I:** Thick fog reduces visibility on the road and can be hazardous for truckers and construction workers. Workers are expected to take appropriate precautions in their Healthy & Safety plans or shut down activities to reduce or eliminate the potential for accidents due to thick fog. **G:** Low visibility from fog is particularly hazardous on high-speed roads with low traffic. Construction activities during thick fog events can increase the probability of accidents occurring. Accidents might require first-aid treatment while the most serious accidents may involve collisions or vehicle to veer off-road resulting in hospital visits.	**10.8**

Table 5-3 (Cont'd): Climate Risks Classified as Low, Moderate or High

Project Component	Climate Hazard	Criteria	Rating [1]			Justifications	Risk (R) [2]
			C_I	G_B	G_C		
Construction activities	High-intensity short duration rainfalls	Health and Safety (S2)	-2	3	4	**C_I:** Workers are expected to take appropriate precautions in their Healthy & Safety plans or shut down activities to reduce or eliminate the potential for accidents due to poor conditions from heavy rain. **G:** Low visibility and slippery conditions from heavy rainfall can increase the probability of incidents and may require first-aid treatment although more serious incidents are still possible.	**17.3**
	Blizzards	Health and Safety (S2)	-2	3	4	**C_I:** Blizzards can cause poor conditions for construction activities and trucking. Workers are expected to take appropriate precautions in their Healthy & Safety plans or shut down activities to reduce or eliminate the potential for accidents. **G:** Accidents would typically require first-aid treatment but still the potential for serious accidents involving collisions or vehicle to veer off-road.	**9.7**
	Long-duration freezing rain (ice accumulation)	Health and Safety (S2)	-1	3	4	**C_I:** Freezing rain can cause slippery conditions and falling ice for construction activities. Workers are expected to take appropriate precautions in their Healthy & Safety plans or shut down activities to reduce or eliminate the potential for accidents. **G:** Icy conditions are particularly hazardous for workers on-foot. Incidents would require first-aid treatment, with a slight possibility of more serious injuries.	**9.7**
	Rain on snow events	Health and Safety (S2)	-2	3	4	**C_I:** Workers are expected to take appropriate precautions in their Healthy & Safety plans with regard to slippery conditions due to presence of ice on ground or shut down activities to reduce or eliminate the potential for incidents. **G:** Icy conditions are particularly hazardous for workers on-foot. Incidents would require first-aid treatment, with a slight possibility of more serious injuries.	**15.1**
	Wind gust events	Health and Safety (S2)	-2	2	5	**C_I:** Strong winds have the potential to generate flying debris. Workers are expected to take appropriate precautions in their Healthy & Safety plans or shut down activities to reduce or eliminate the potential for incidents. **G:** Small injuries are to be expected from flying dust or debris, but it can be worst depending on event.	**8.0**

Table 5-3 (Cont'd): Climate Risks Classified as Low, Moderate or High

Project Component	Climate Hazard	Criteria	Rating (1)			Justifications	Risk (R) (2)
			C_I	G_B	G_C		
Road maintenance activities	Thick fog conditions	Health and Safety (S2)	-2	3	4	**C_I:** Thick fog reduces visibility on the road and can be hazardous for truckers and the road maintenance crew. Workers are expected to take appropriate precautions in their Healthy & Safety plans (may include use of lights and signs) or shut down activities to reduce or eliminate the potential for accidents due to thick fog. **G:** Low visibility from fog is particularly hazardous on high-speed roads with low traffic. Maintenance activities during thick fog events can increase the probability of accidents occurring. Accidents might require first-aid treatment while the most serious accidents may involve collisions or vehicle to veer off-road resulting in hospital visits.	**10.8**
	High-intensity short duration rainfalls	Health and Safety (S2)	-2	3	4	**C_I:** Workers are expected to take appropriate precautions in their Healthy & Safety plans or shut down activities to reduce or eliminate the potential for accidents due to poor conditions from heavy rain. **G:** Low visibility and slippery conditions from heavy rainfall can increase the probability of incidents and may require first-aid treatment although more serious incidents are still possible.	**17.3**
	Blizzards	Health and Safety (S2)	-2	3	4	**C_I:** Blizzards can cause poor conditions for drivers and the road maintenance crew. Road maintenance vehicles (i.e. snowplows) are equipped to operate in these conditions. Workers are expected to take appropriate precautions and use appropriate lights and signs. Low priority maintenance activities can be postponed eliminating the potential for accidents due to blizzards. **G:** Accidents would typically require first-aid treatment but still the potential for serious accidents involving collisions or vehicle to veer off-road.	**9.7**
	Long-duration freezing rain (ice accumulation)	Health and Safety (S2)	-1	3	4	**C_I:** Icy conditions on the road is hazardous for driver and road maintenance workers. Road maintenance vehicles (i.e. snowplows) are equipped to operate in these conditions. Low priority maintenance activities can be postponed eliminating the potential for accidents. **G:** Icy conditions are particularly hazardous for workers on-foot. Incidents would require first-aid treatment, with a slight possibility of more serious injuries.	**9.7**
	Rain on snow events	Health and Safety (S2)	-2	3	4	**C_I:** Road maintenance vehicles (i.e. snowplows) are equipped to operate in these conditions. Workers are expected to take appropriate precautions and use appropriate lights and signs. Low priority maintenance activities can be postponed eliminating the potential for incidents. **G:** Icy conditions are particularly hazardous for workers on-foot. Incidents would require first-aid treatment, with a slight possibility of more serious injuries.	**15.1**

Table 5-3 (Cont'd): Climate Risks Classified as Low, Moderate or High

Project Component	Climate Hazard	Criteria	Rating (1)			Justifications	Risk (R) (2)
			C_I	G_B	G_C		
Road maintenance activities	Wind gust events	Health and Safety (S2)	-2	2	5	**C_I:** Strong winds have the potential to generate flying debris. Workers are expected to take appropriate precautions in their Healthy & Safety plans or shut down activities to reduce or eliminate the potential for incidents. **G:** Small injuries are to be expected from flying dust or debris, but it can be worst depending on event.	**8.0**

(1) C_I = correction factor on impact probability; G_B = impact consequence rating; G_C = uncertainty correction on G_B rating.

(2) Risk level: $R = (P_A – C_I) \times (1+ 0,2 \times P_C) \times G_B \times (1+ 0,2 \times G_C)$; P_A and P_C ratings are specified in**Table 5-1**.

5.3 Special Case – Wildfires

Dryer conditions due to warmer temperatures may intensify in northern Ontario, especially when considering the SPP-5 scenario, increasing the probability of wildfires in the project area. Although they are destructive events that cause extensive damages to wide geographic areas, the interaction between the Project and wildfires is expected to be limited to the sustainability of its components since health and safety hazards and damages to the environment (natural and built) would be directly impacted by wildfires and not due to the presence of the road.

With the exception of oil stains on the road, the road surface is generally not flammable and direct damages to the road due to fire should remain limited. Wildfire risks on the eastern part of the WSR is anticipated to be low as the peatlands is saturated and not very flammable. For the western part of the WSR, the 35 m ROW on either side of the road should provide sufficient clearance from potential burning trees that fall on the road surface. As such, damage to the road due to a wildfire is expected to be limited to cracks and potholes due to heating. Other components that are made with metal such as road signs, guardrails and culverts are more susceptible to damages from heat and may require repairs following a wildfire event. The same applies to bridges composed of concrete and steel that would also be impacted by heat if it comes near them.

6. Conclusion

According to the climate risk analysis, there are no « moderate » and « high » risks associated with this Project. The interactions for which the risk level is « very low » or « low » represent in general situations where the component is recognized to be sensible, but the impact is considered marginal or sufficiently low considering all available information (final design criteria, construction standards, hydrological/geotechnical attributes, etc.) to not have tangible repercussion on the road integrity. Extra control measures are not considered necessary.

This conclusion is based on the Project adopting, and in some cases exceeding provincial standards, guidelines and codes for the design and operation and maintenance of provincial highways. These standards were developed by the Ministry of Transportation in consultation with other regulatory agencies to ensure that provincial highway standards address environmental and engineering concerns. These standards ensure that the safety and integrity of the highway itself, its users and the surrounding environment is protected today and in the future during the road's lifecycle. Standards for all aspects of the highways planning, design, construction, operation and maintenance have been developed and are updated on a regular basis. Key standards and guidelines include, but are not limited to, the following:

- Design Supplement for Transportation Association of Canada Geometric Design Guide for Canadian Roads, Ontario Ministry of Transportation, October 2023;
- Preliminary Design Report Guideline, Ontario Ministry of Transportation, September 2016;
- Roadside Design Manual, Ontario Ministry of Transportation, July 2023;
- Highway Drainage Design Standards, Ontario Ministry of Transportation, November 2023;
- Pavement Design and Rehabilitation Manual, Ontario Ministry of Transportation, May 2013;
- Road Safety Audit Guidelines, University of New Brunswick, 1999;
- Structural Manual, Ontario Ministry of Transportation, August 2021;
- Canadian Highway Bridge Design Code CSA S6:19, CSA Group, 2019; and
- Maintenance Manual, Ontario Ministry of Transportation, August 2003.

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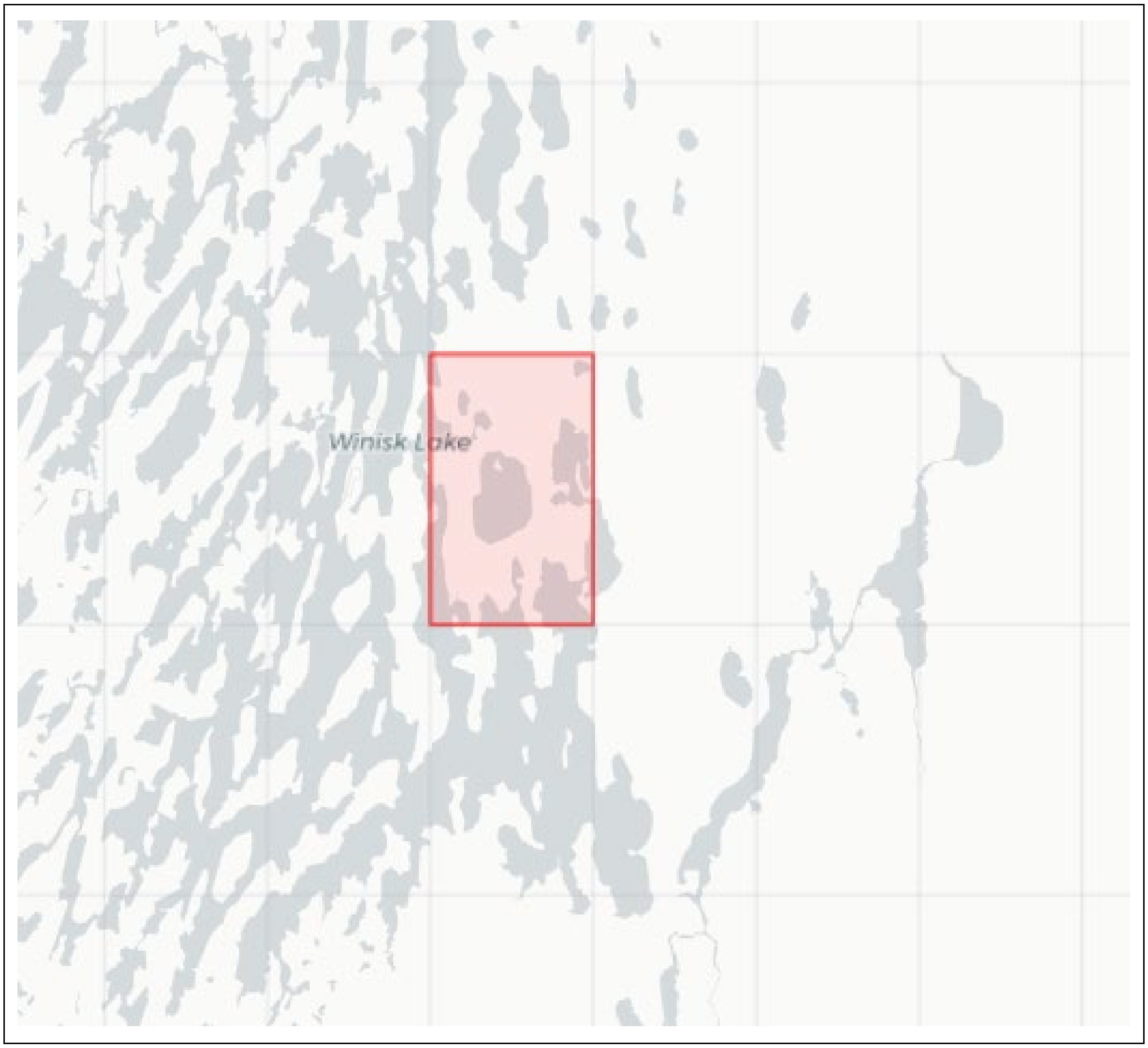
APPENDIX A

Projection of Climate Indicators for the WSR Area

Projection of Climate Indicators for the WSR Area

Prepared based on data extracted from ECCC web platform for different climate indicators in an area where the WSR will be located (represented by the red rectangle below) https://climatedata.ca/download/



Climate Modeling

CMIP6 corresponds to phase 6 of the WCRP (World Climate Research Program) Coupled Model Intercomparison Project, which involves more than twenty climate research groups and aims to establish a global framework for climate change research. CMIP6 has made available more than thirty global circulation models (GCMs) that can be used for research studies and short- and medium-term projections.

Several profiles of changes in atmospheric GHG concentrations can be incorporated into these models, enabling us to modulate radiative forcing (the amount of radiation energy added to the planet) up to 2100 and to establish a range of scenarios in terms of GHG emissions. Some of these have been developed and integrated into models for the following situations:

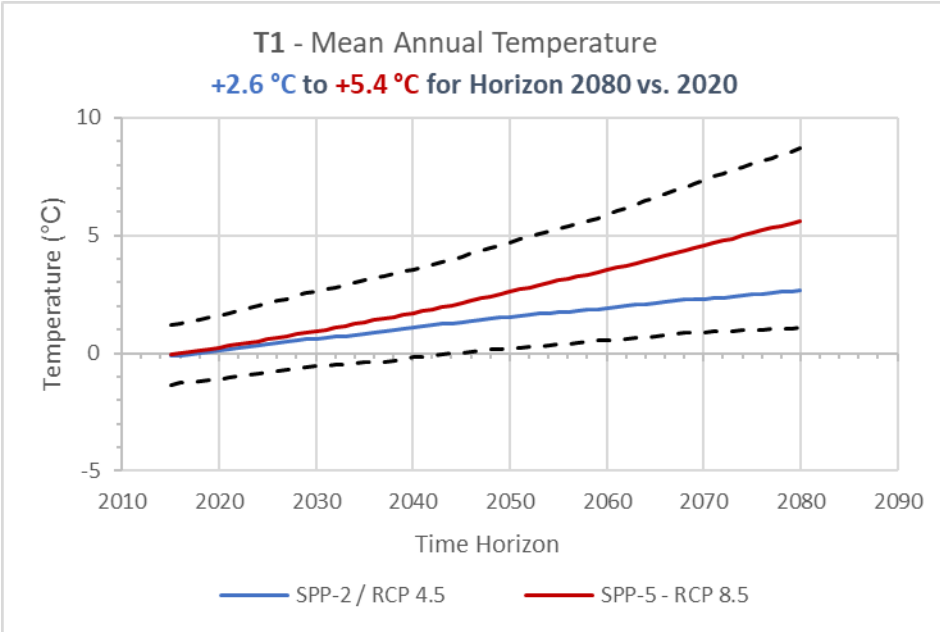
- optimistic scenario (SPP (*Shared Socioeconomic Pathways*)-1 considered equivalent to RCP (*Representative Concentration Pathways*)-2.6 in CMIP5) for which the world is moving in a generalized way towards sustainability.
- middle scenario (SPP-2 considered equivalent to RCP-4.5 in CMIP5) for which global institutions are working towards sustainable development goals but are making slow progress.
- pessimistic scenario (SPP-5 considered equivalent to RCP8.5 in CMIP4) for which global GHG emissions continue to rise, due in part to the growth of the global economy.

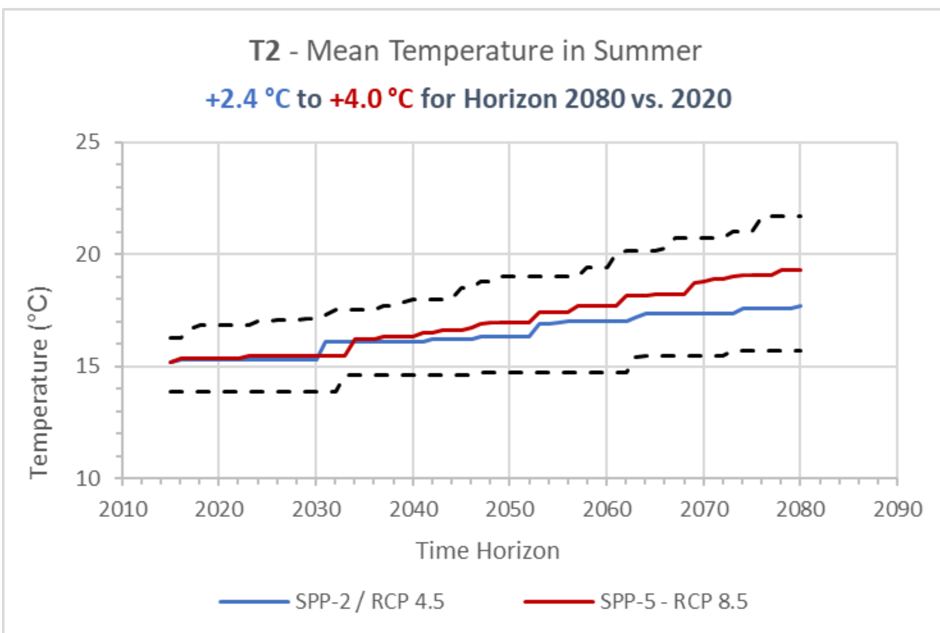
The SPP-2 scenario is the most realistic target at present, but following the precautionary principle in the adaptation approach, the worst-case scenario (SPP-5) must also be considered, since there is no guarantee that measures to reduce GHG emissions will achieve the SPP-2 scenario targets. Moreover, the trend over the last 20 years in CO_2 concentration in the upper atmosphere does not suggest that SPP-2 is the most likely scenario at this stage, despite global agreements and targets for reducing GHG emissions. Thus, the SPP-5 scenario should be prioritized, until further notice, when planning long-term infrastructure construction. The future projections presented in this report therefore highlight the modelling results according to the two emission scenarios, which will also show the impact of GHG emissions on the various climate indicators over time.

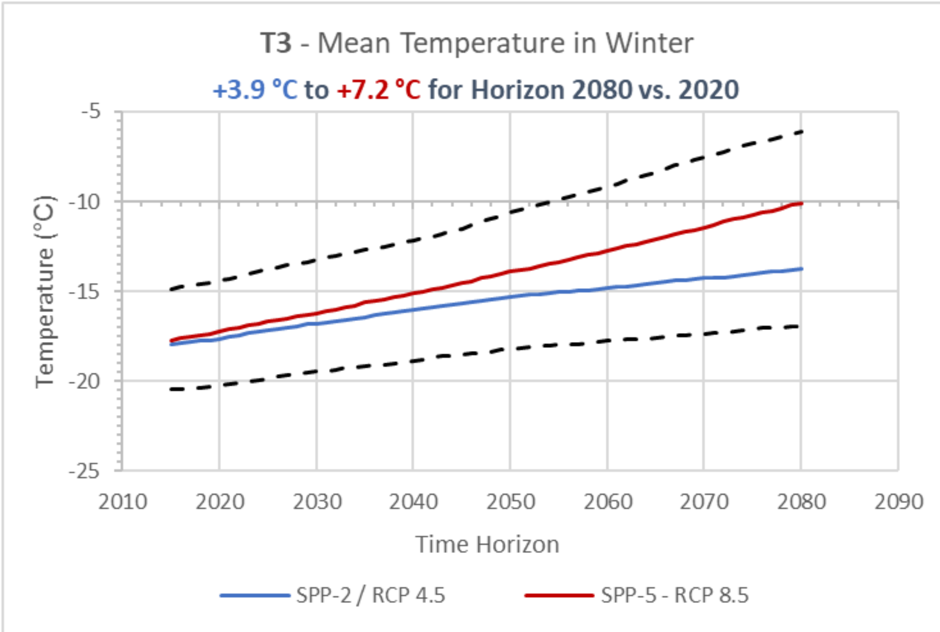
The CMIP6 GCM model results shown in the figures below were first downscaled and corrected for bias using the BCCAQv2 method (a statistical scaling approach for GCM model outputs developed by the Pacific Climate Impacts Consortium).

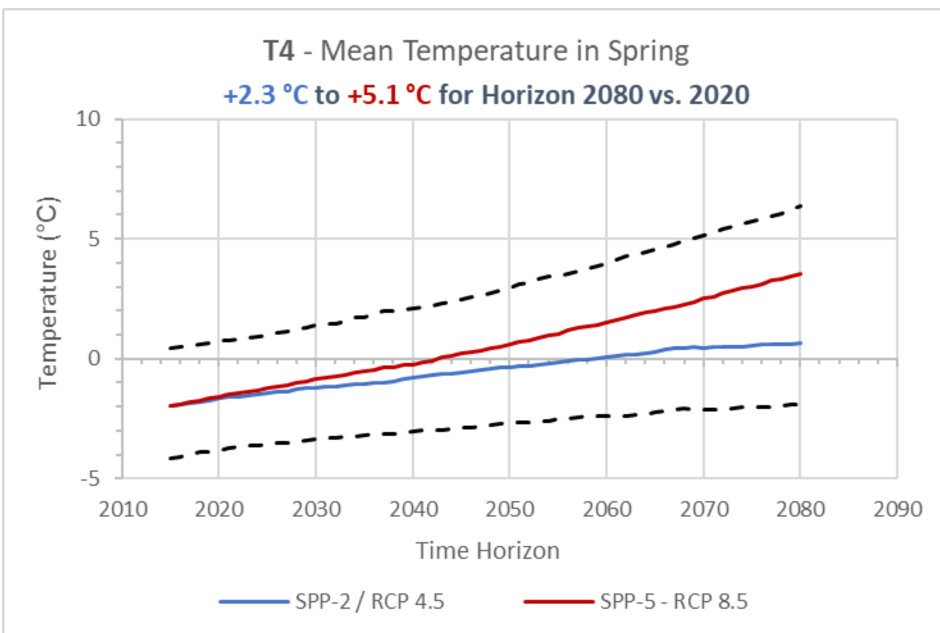
The values in the SPP-2 and SPP-5 emission scenario curves correspond to the 30-year moving average (or maximum/minimum, as the case may be) of the median results of all CMIP6 climate models, thus smoothing out results that tend to fluctuate from year to year. The convention is to use an average ranging from year *x-9* to year *x+20* inclusive for horizon *x* (e.g. for horizon 2050, the range between 2041 and 2070 is used in the average).

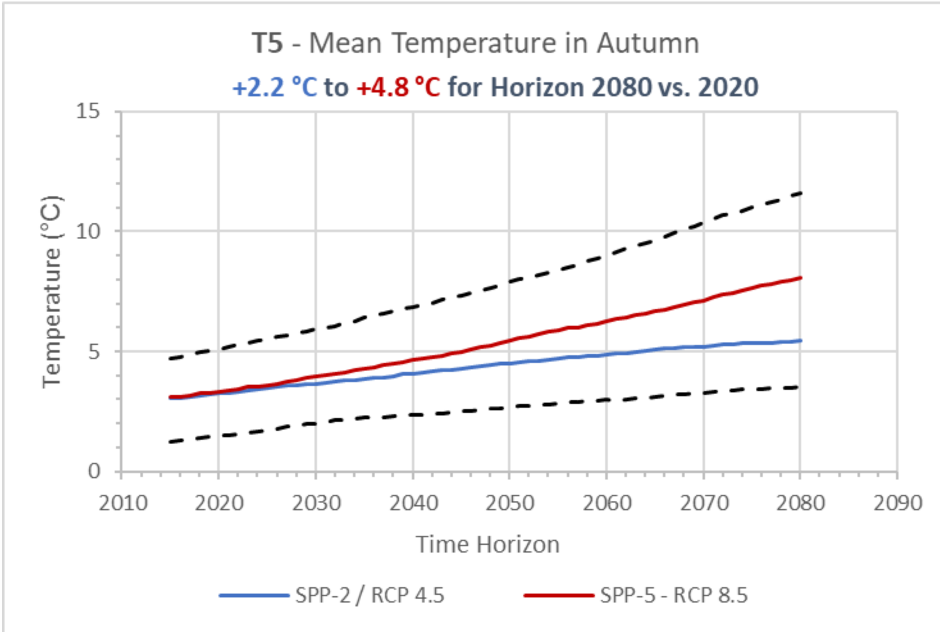
The values making up the minimum curves in the following figures correspond to the 30-year moving average (or maximum/minimum as the case may be) of the 10^{e} percentile of the results from all CMIP6 climate models. The lowest value is used among the results with emission scenarios SPP-2 and SPP-5. An equivalent approach is applied for maximum curves, using the 90^{e} percentile of model results.

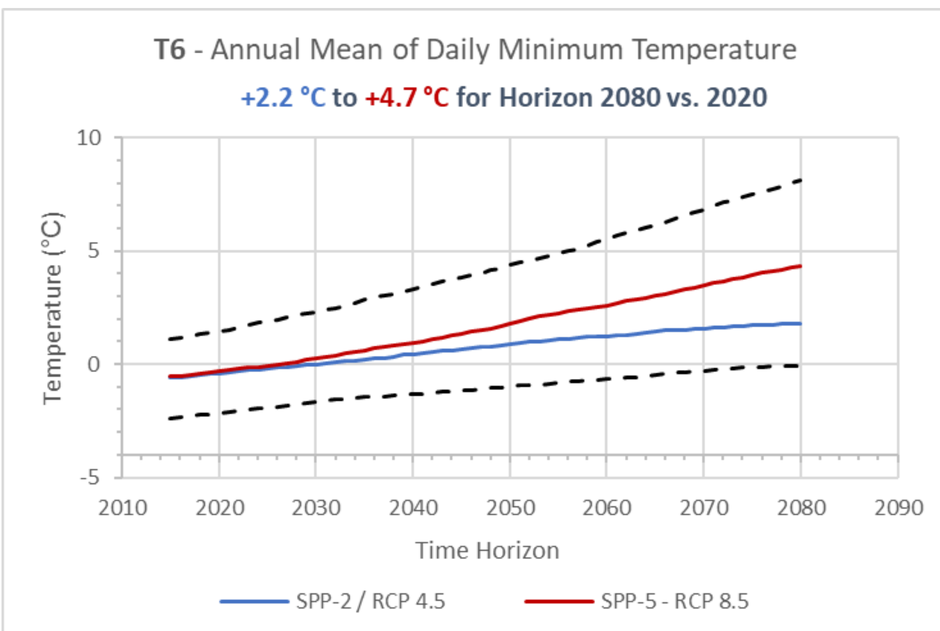

T1 - Mean Annual Temperature
+2.6 °C to +5.4 °C for Horizon 2080 vs. 2020
Temperature (°C)
10
5
0
-5
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

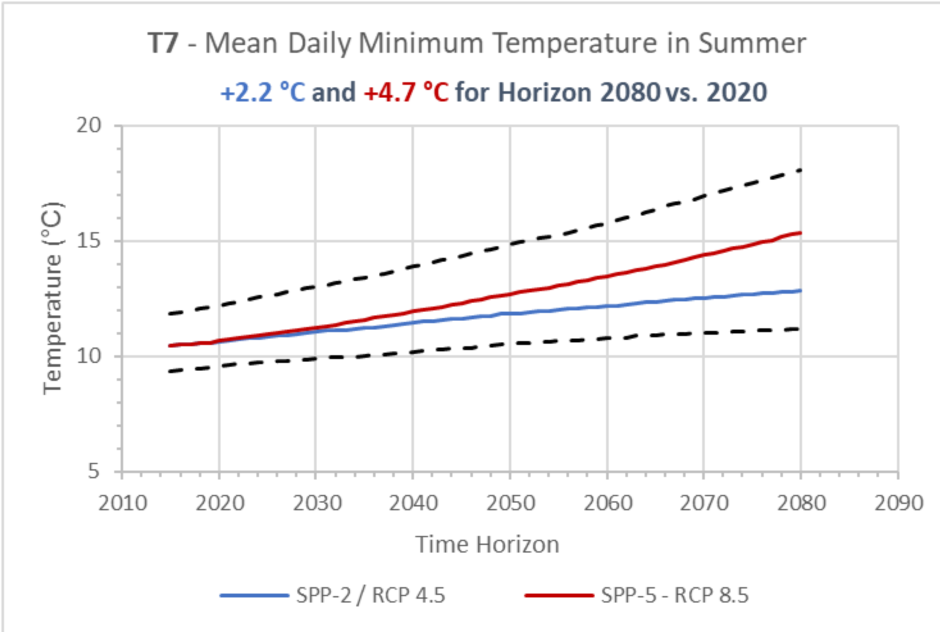

T2 - Mean Temperature in Summer
+2.4 °C to +4.0 °C for Horizon 2080 vs. 2020
Temperature (°C)
25
20
15
10
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

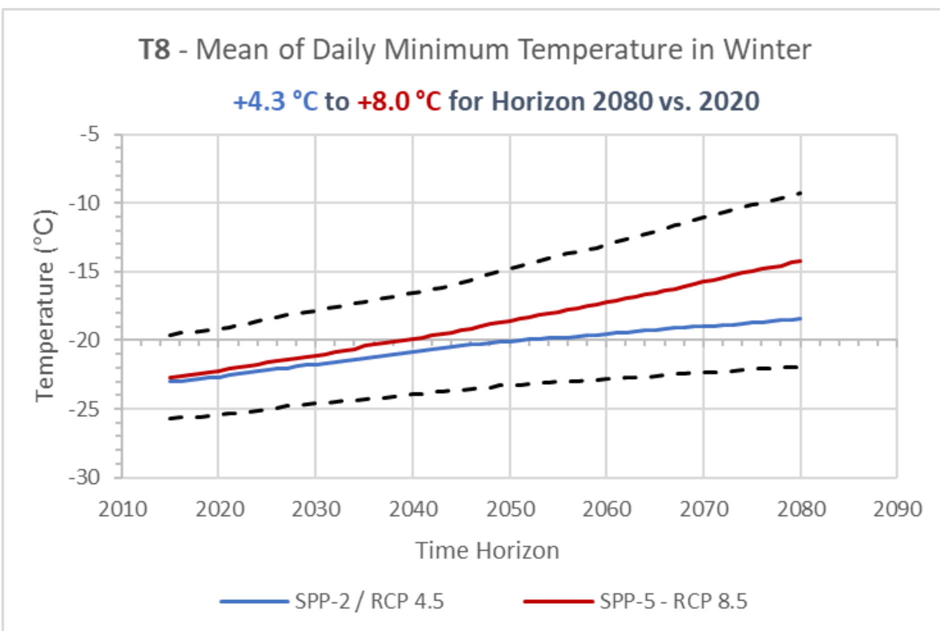

T3 - Mean Temperature in Winter
+3.9 °C to +7.2 °C for Horizon 2080 vs. 2020
Temperature (°C)
-5
-10
-15
-20
-25
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

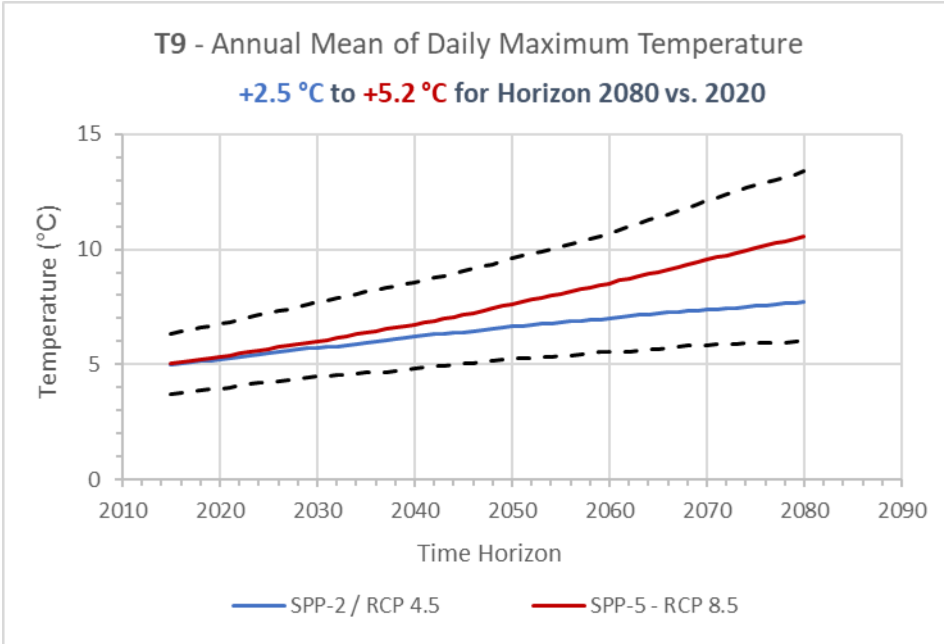

T4 - Mean Temperature in Spring
+2.3 °C to +5.1 °C for Horizon 2080 vs. 2020
Temperature (°C)
10
5
0
-5
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

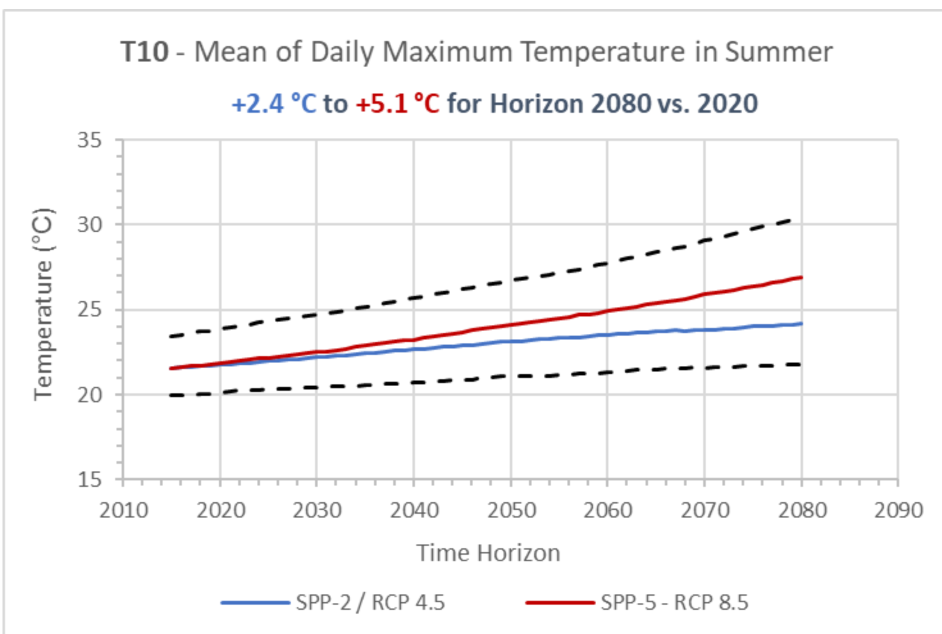

T5 - Mean Temperature in Autumn
+2.2 °C to +4.8 °C for Horizon 2080 vs. 2020
15
10
5
0
Temperature (°C)
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

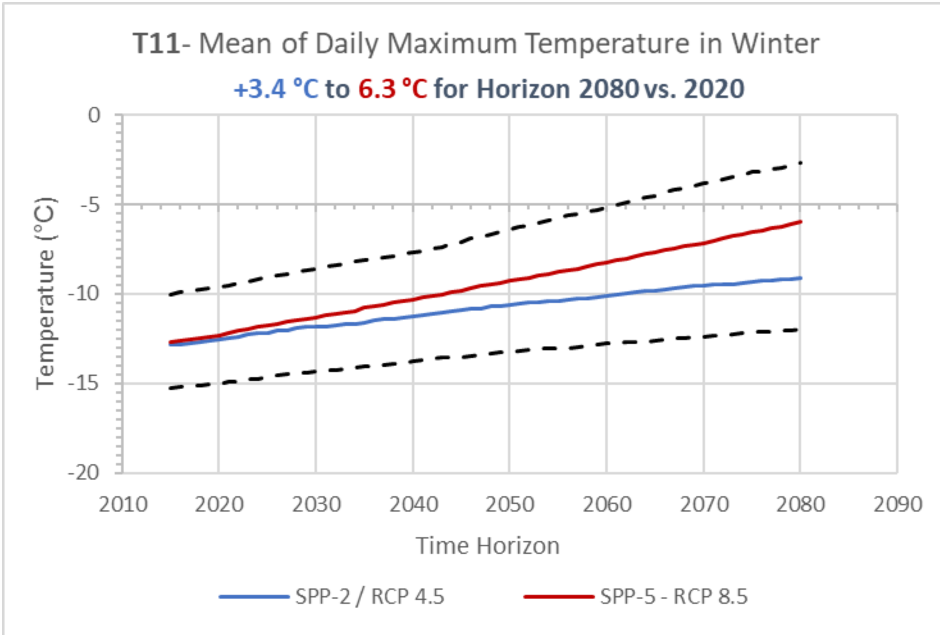

T6 - Annual Mean of Daily Minimum Temperature
+2.2 °C to +4.7 °C for Horizon 2080 vs. 2020
10
5
0
-5
Temperature (°C)
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

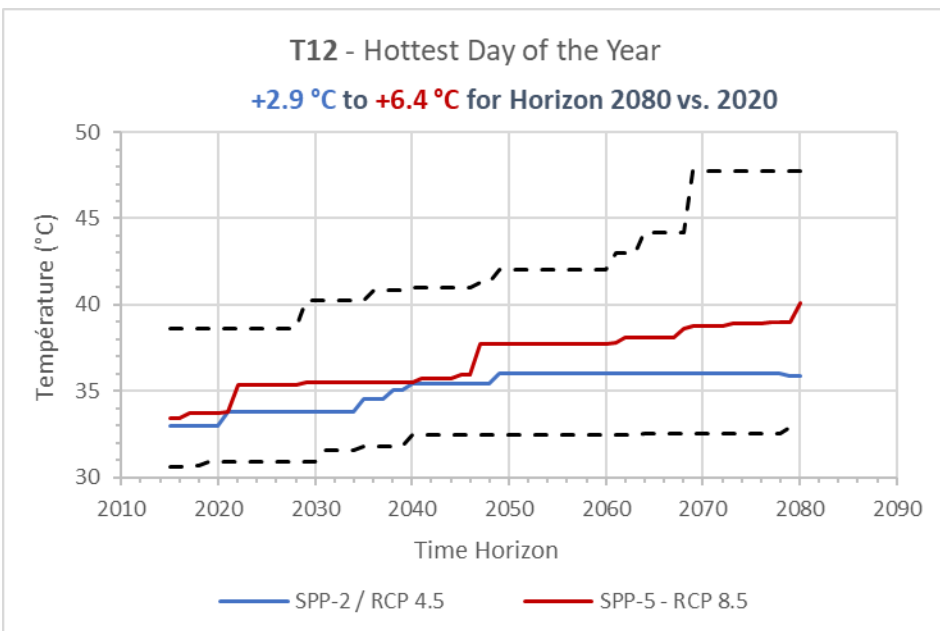

T7 - Mean Daily Minimum Temperature in Summer
+2.2 °C and +4.7 °C for Horizon 2080 vs. 2020
Temperature (°C)
20
15
10
5
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

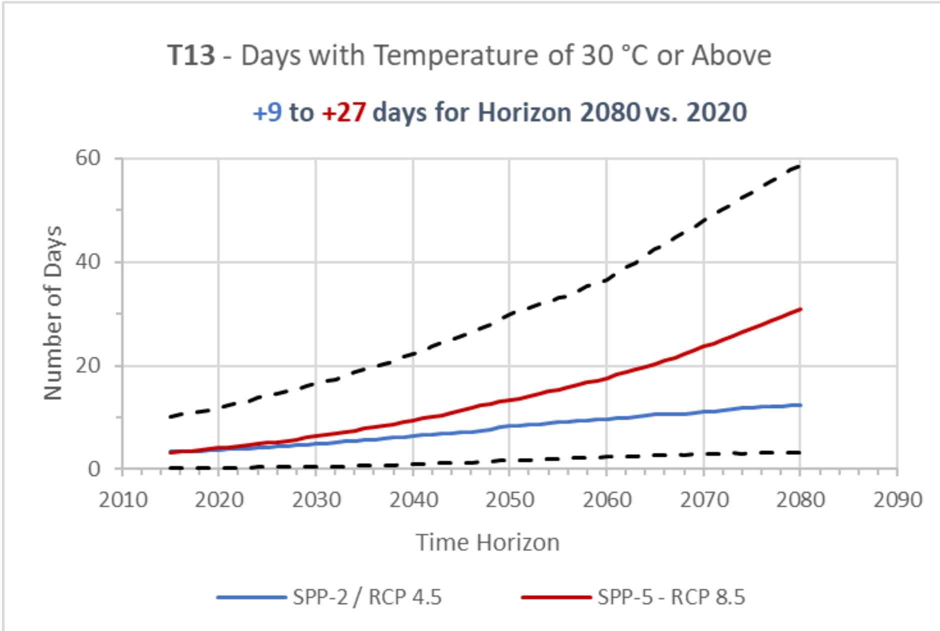

T8 - Mean of Daily Minimum Temperature in Winter
+4.3 °C to +8.0 °C for Horizon 2080 vs. 2020
Temperature (°C)
-5
-10
-15
-20
-25
-30
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

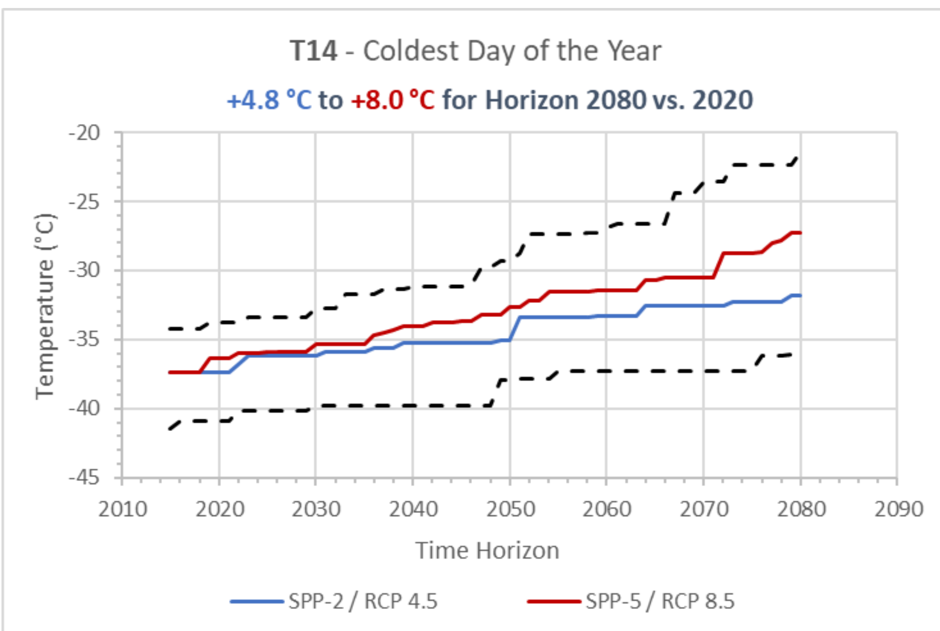

T9 - Annual Mean of Daily Maximum Temperature
+2.5 °C to +5.2 °C for Horizon 2080 vs. 2020
Temperature (°C)
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

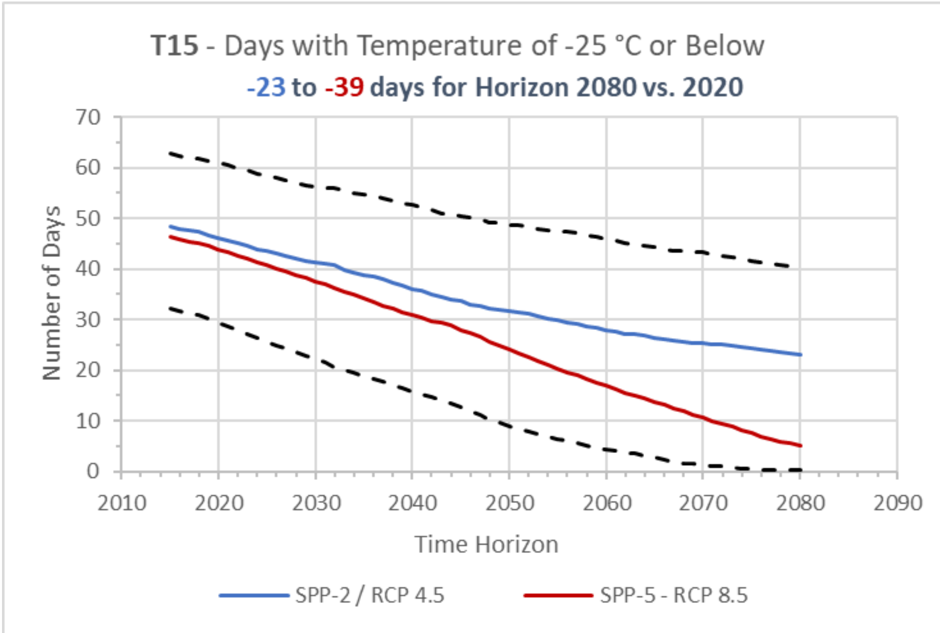

T10 - Mean of Daily Maximum Temperature in Summer
+2.4 °C to +5.1 °C for Horizon 2080 vs. 2020
Temperature (°C)
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

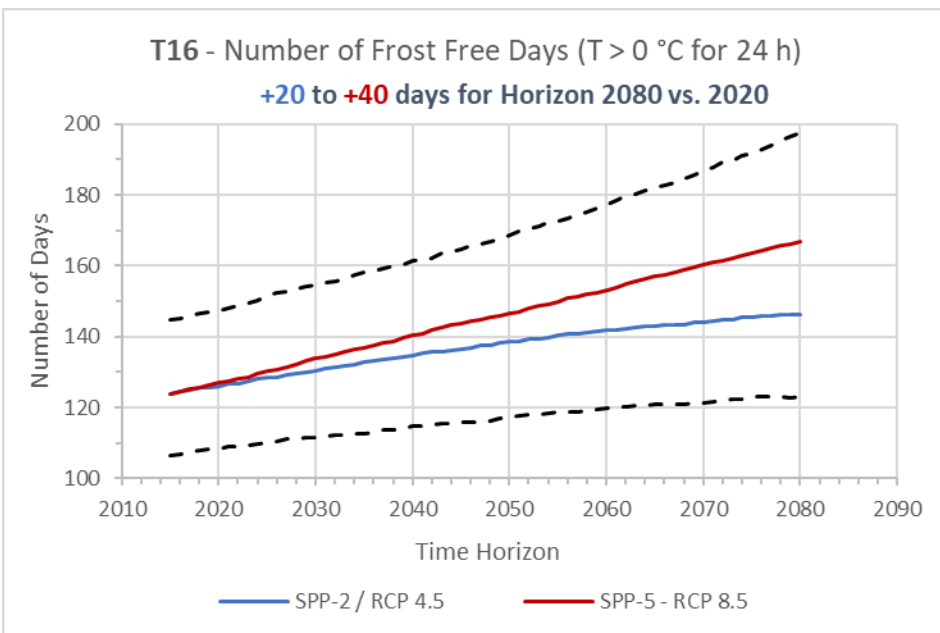

T11- Mean of Daily Maximum Temperature in Winter
+3.4 °C to 6.3 °C for Horizon 2080 vs. 2020
Temperature (°C)
0
-5
-10
-15
-20
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

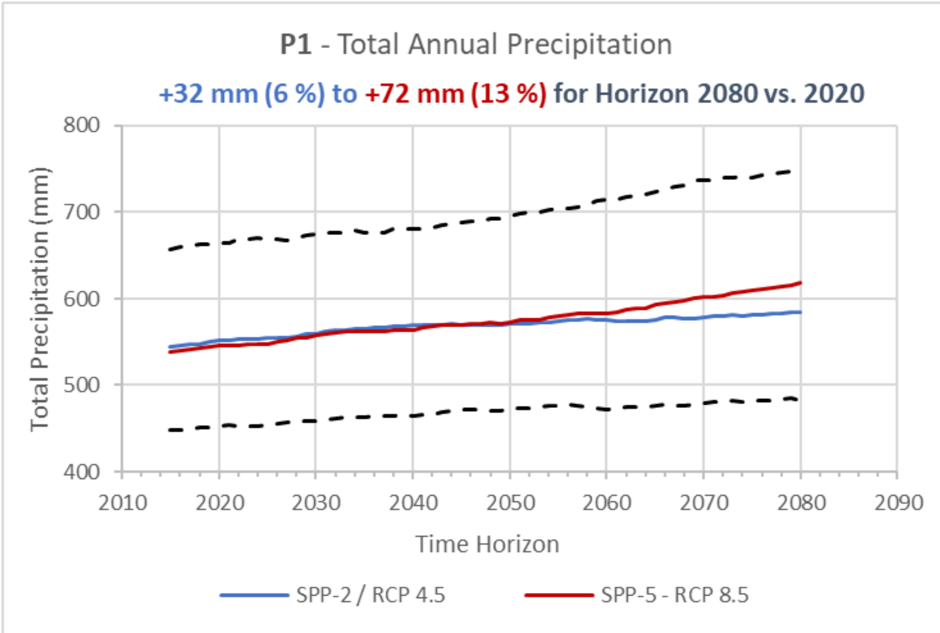

T12 - Hottest Day of the Year
+2.9 °C to +6.4 °C for Horizon 2080 vs. 2020
Température (°C)
50
45
40
35
30
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

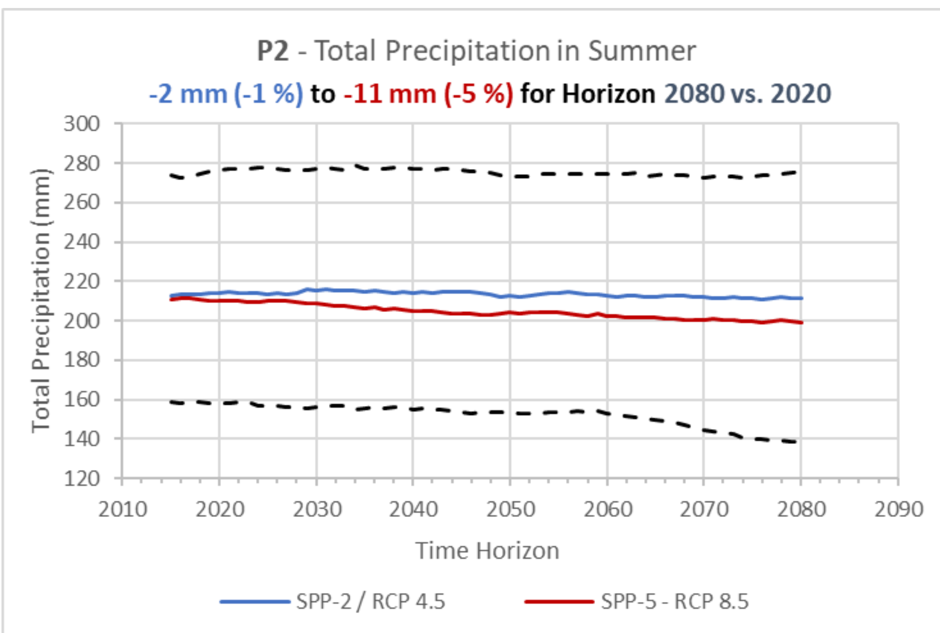

T13 - Days with Temperature of 30 °C or Above
+9 to +27 days for Horizon 2080 vs. 2020
Number of Days
60
40
20
0
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

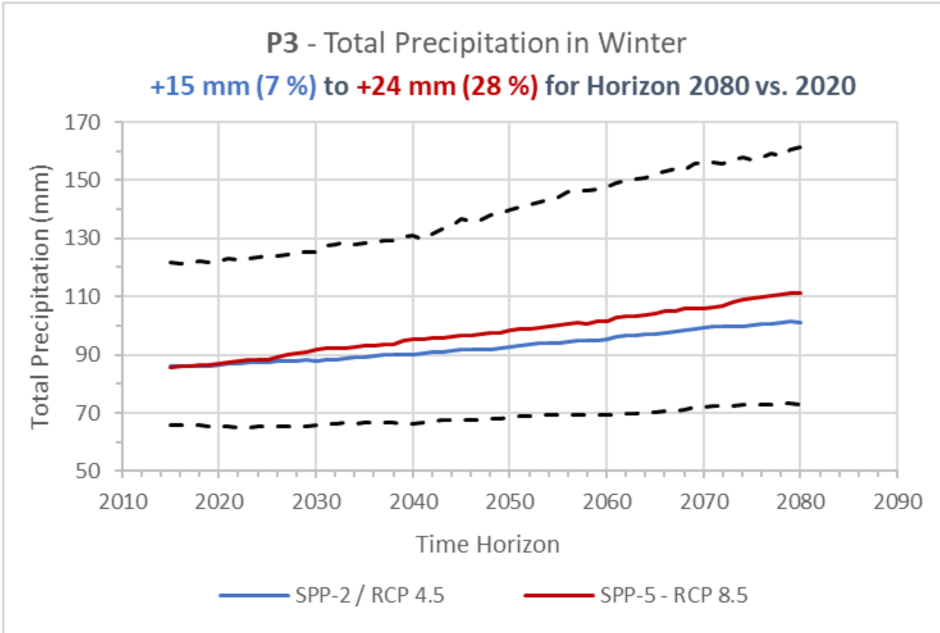

T14 - Coldest Day of the Year
+4.8 °C to +8.0 °C for Horizon 2080 vs. 2020
Temperature (°C)
-20
-25
-30
-35
-40
-45
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 / RCP 8.5

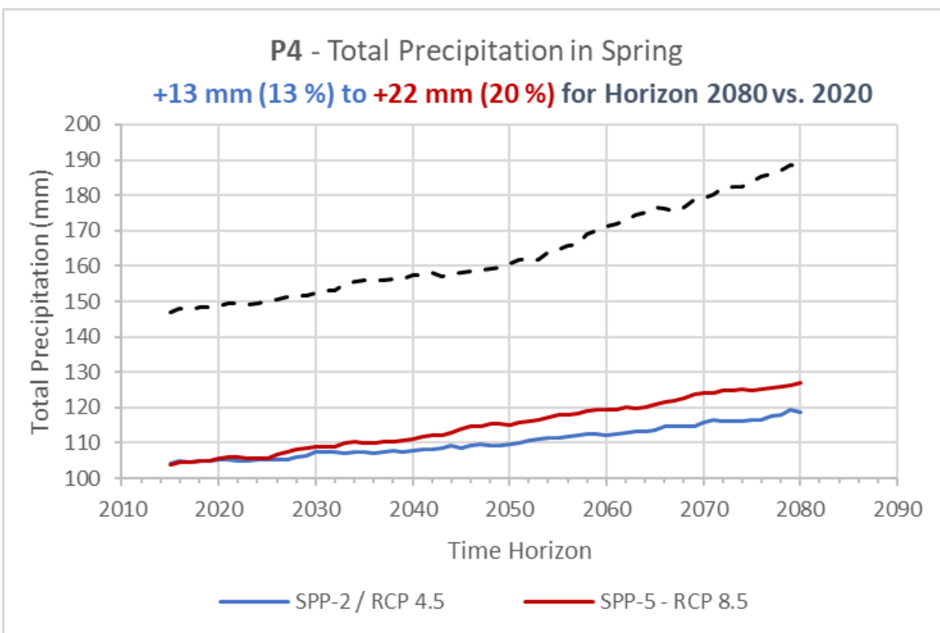

T15 - Days with Temperature of -25 °C or Below
-23 to -39 days for Horizon 2080 vs. 2020
Number of Days
70
60
50
40
30
20
10
0
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

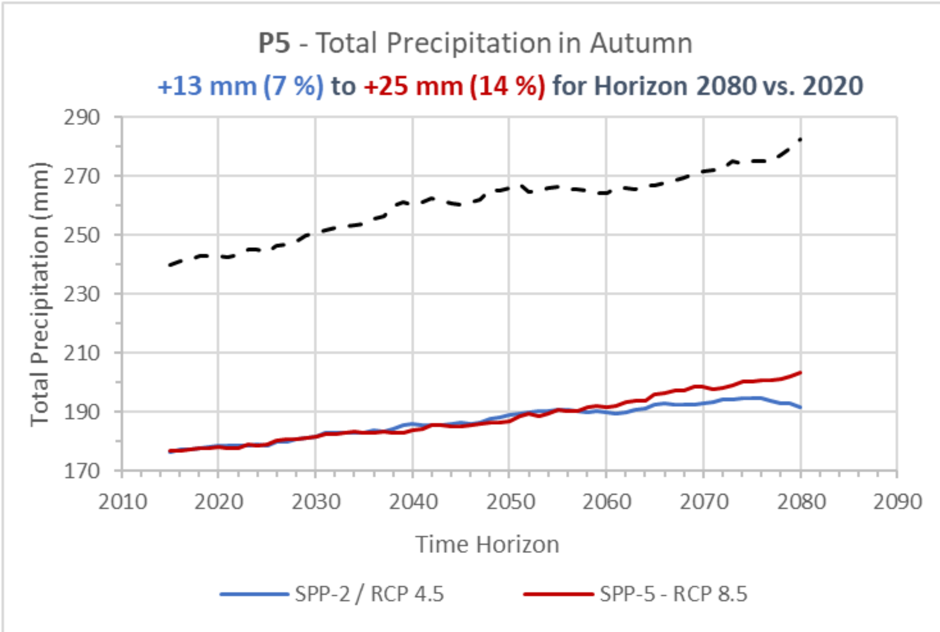

T16 - Number of Frost Free Days (T > 0 °C for 24 h)
+20 to +40 days for Horizon 2080 vs. 2020
Number of Days
200
180
160
140
120
100
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

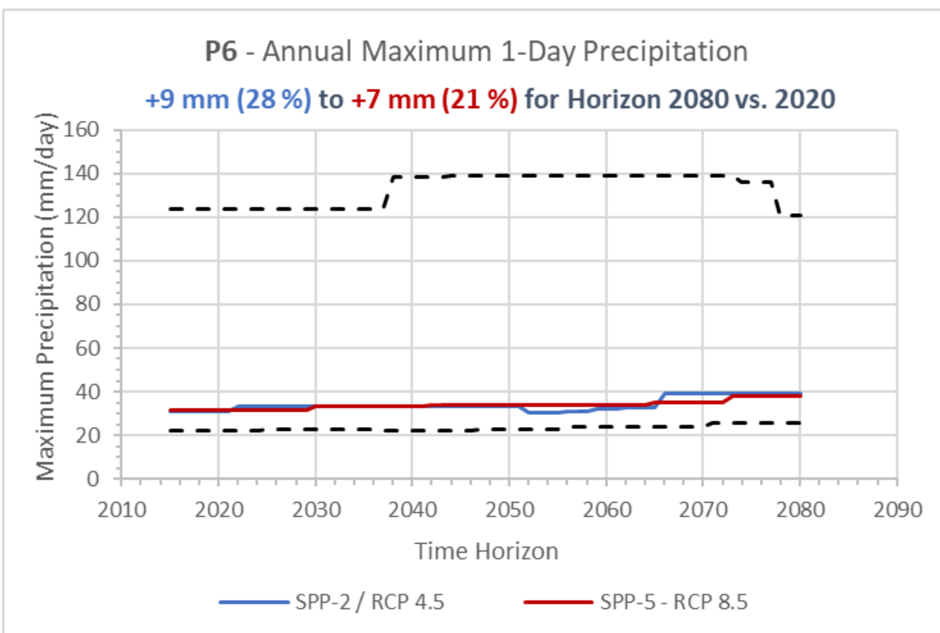

P1 - Total Annual Precipitation
+32 mm (6 %) to +72 mm (13 %) for Horizon 2080 vs. 2020
Total Precipitation (mm)
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

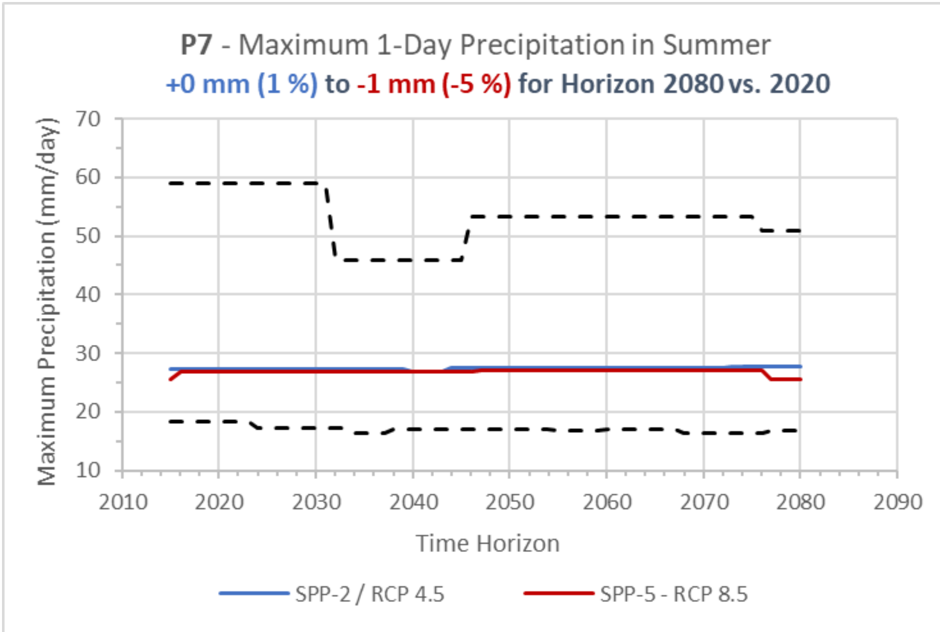

P2 - Total Precipitation in Summer
-2 mm (-1 %) to -11 mm (-5 %) for Horizon 2080 vs. 2020
Total Precipitation (mm)
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

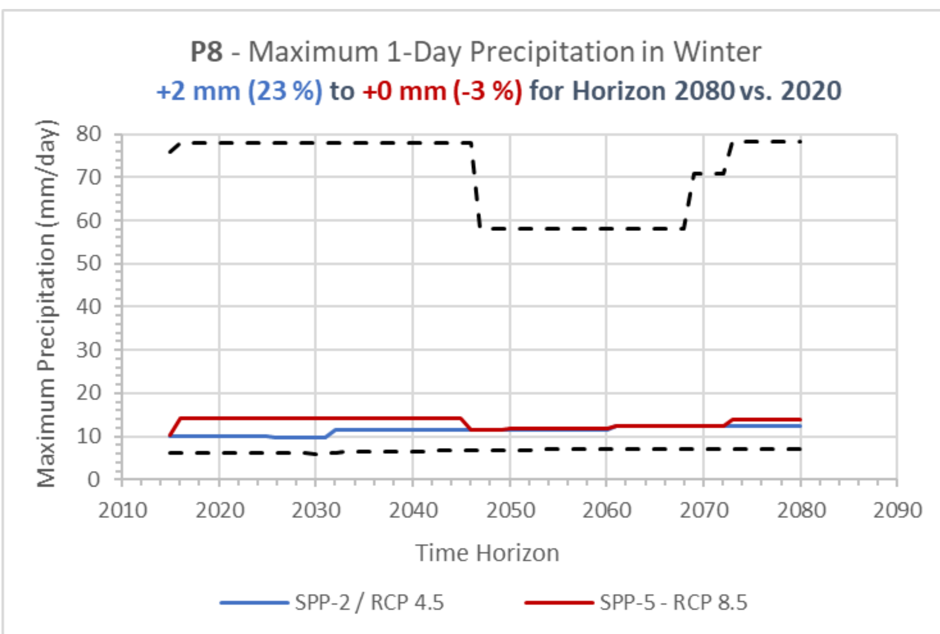

P3 - Total Precipitation in Winter
+15 mm (7 %) to +24 mm (28 %) for Horizon 2080 vs. 2020
Total Precipitation (mm)
170
150
130
110
90
70
50
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

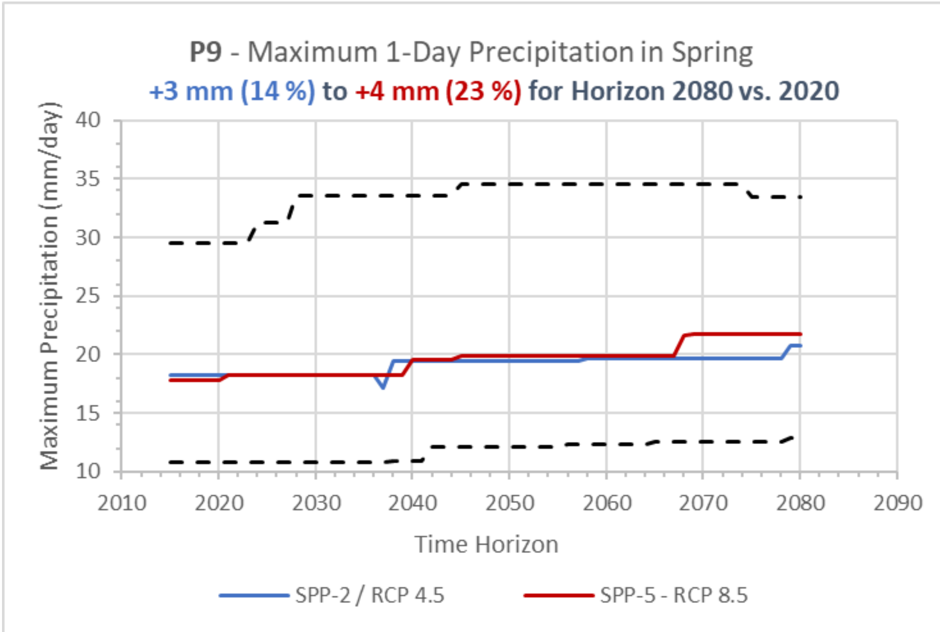

P4 - Total Precipitation in Spring
+13 mm (13 %) to +22 mm (20 %) for Horizon 2080 vs. 2020
Total Precipitation (mm)
200
190
180
170
160
150
140
130
120
110
100
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

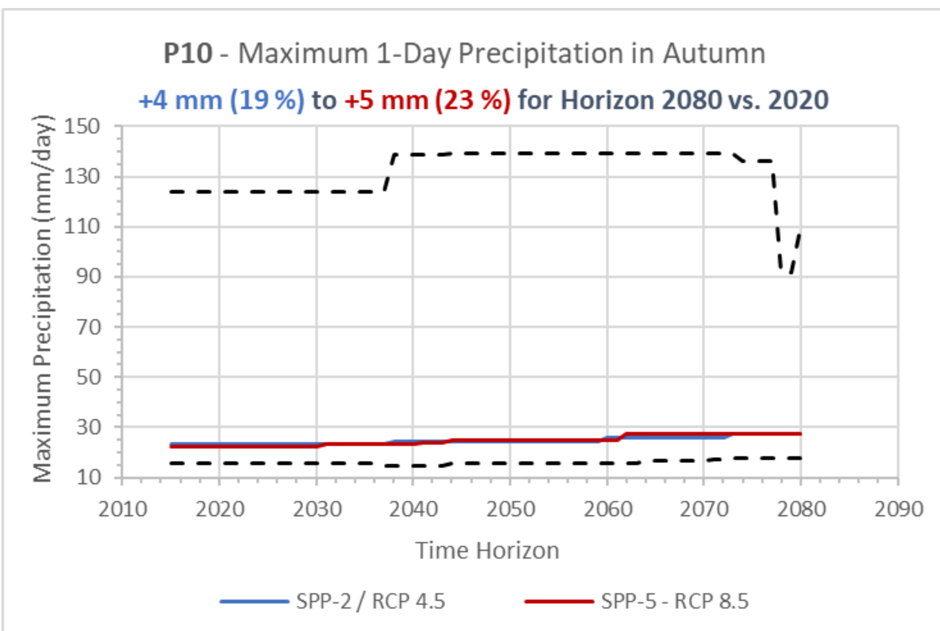

P5 - Total Precipitation in Autumn
+13 mm (7 %) to +25 mm (14 %) for Horizon 2080 vs. 2020
Total Precipitation (mm)
290
270
250
230
210
190
170
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

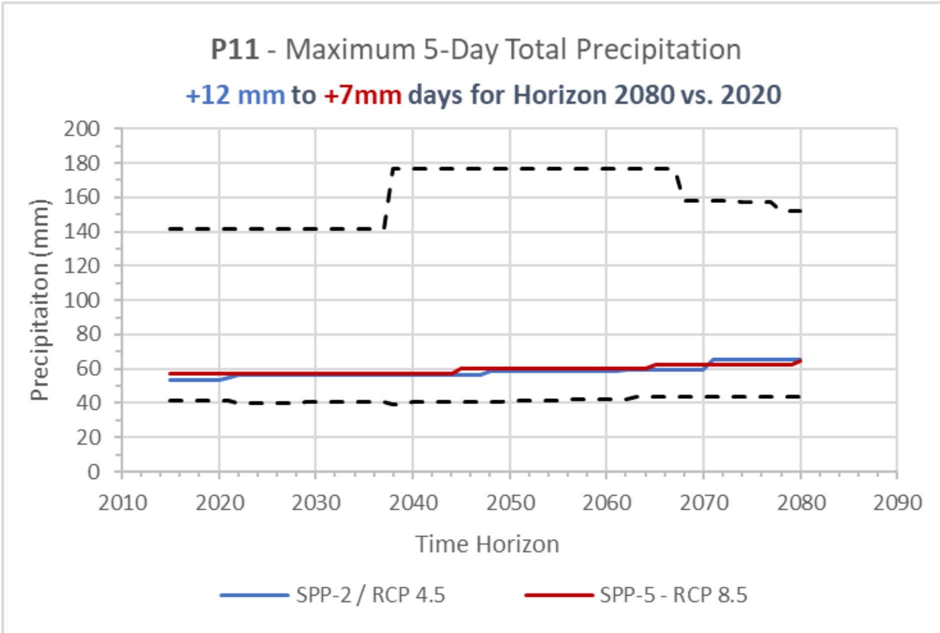

P6 - Annual Maximum 1-Day Precipitation
+9 mm (28 %) to +7 mm (21 %) for Horizon 2080 vs. 2020
Maximum Precipitation (mm/day)
160
140
120
100
80
60
40
20
0
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

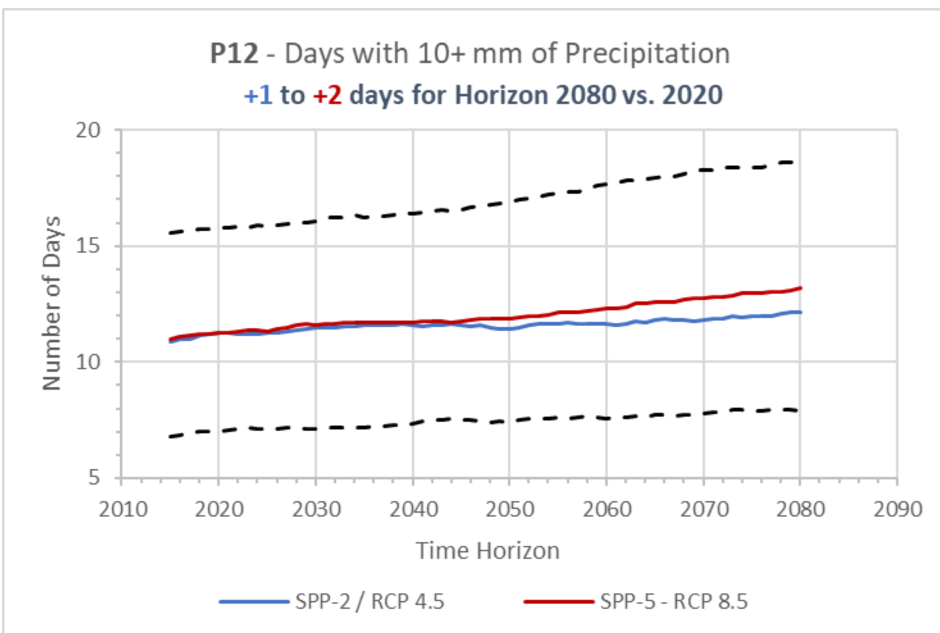

P7 - Maximum 1-Day Precipitation in Summer
+0 mm (1 %) to -1 mm (-5 %) for Horizon 2080 vs. 2020
Maximum Precipitation (mm/day)
70
60
50
40
30
20
10
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

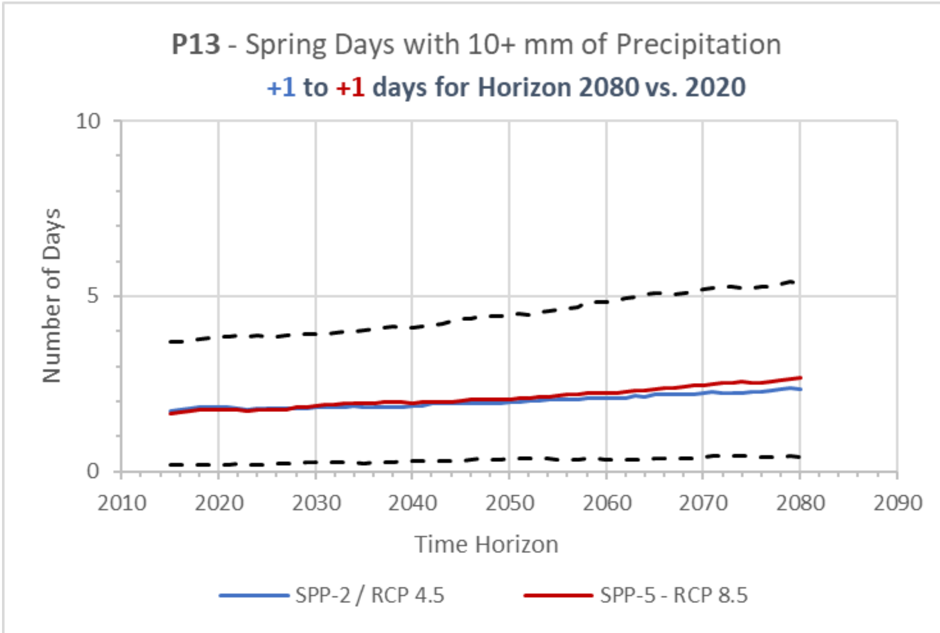

P8 - Maximum 1-Day Precipitation in Winter
+2 mm (23 %) to +0 mm (-3 %) for Horizon 2080 vs. 2020
Maximum Precipitation (mm/day)
80
70
60
50
40
30
20
10
0
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

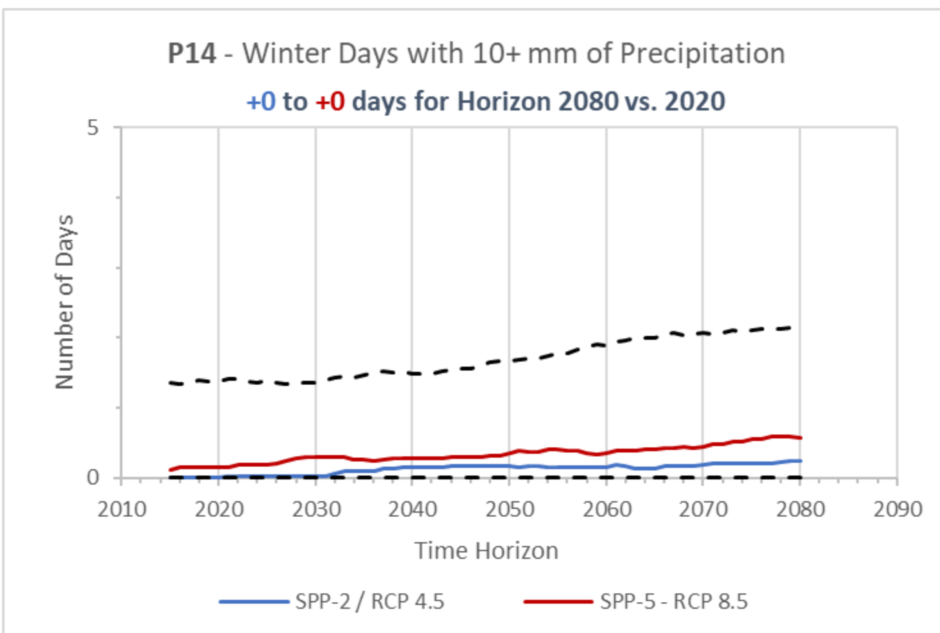

P9 - Maximum 1-Day Precipitation in Spring
+3 mm (14 %) to +4 mm (23 %) for Horizon 2080 vs. 2020
Maximum Precipitation (mm/day)
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

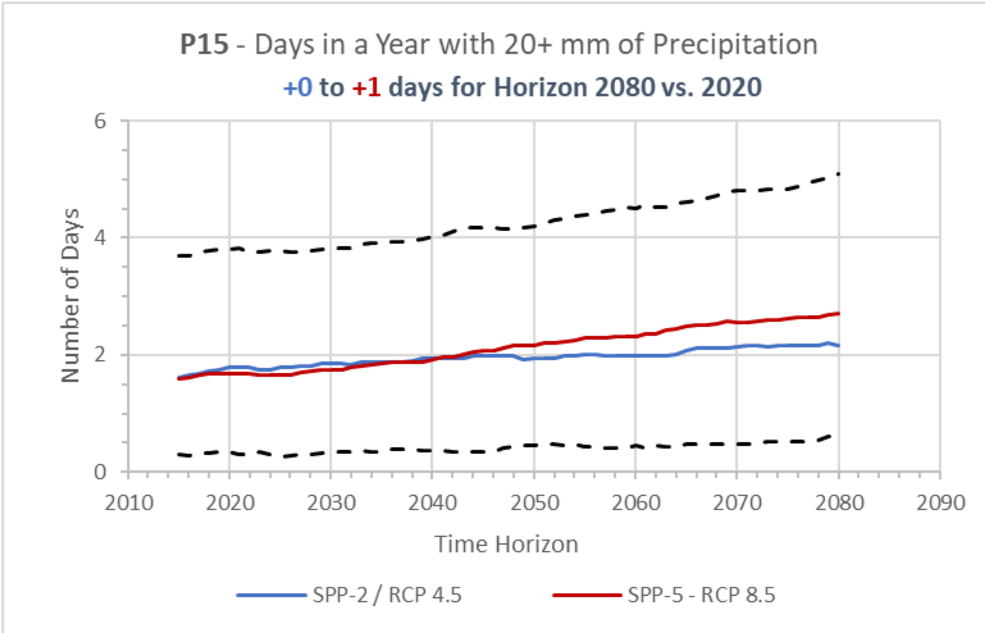

P10 - Maximum 1-Day Precipitation in Autumn
+4 mm (19 %) to +5 mm (23 %) for Horizon 2080 vs. 2020
Maximum Precipitation (mm/day)
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

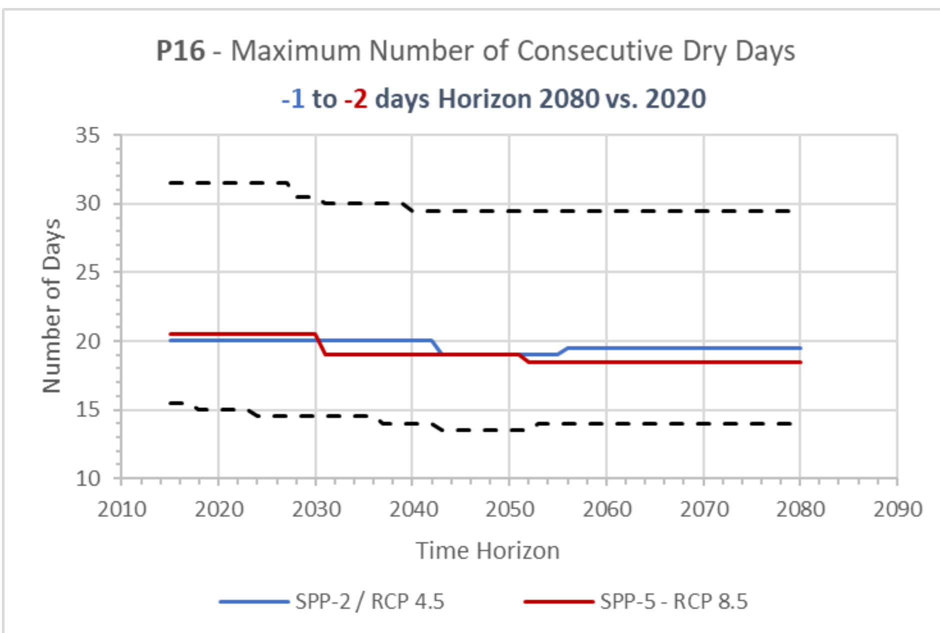

P11 - Maximum 5-Day Total Precipitation
+12 mm to +7mm days for Horizon 2080 vs. 2020
Precipitaiton (mm)
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

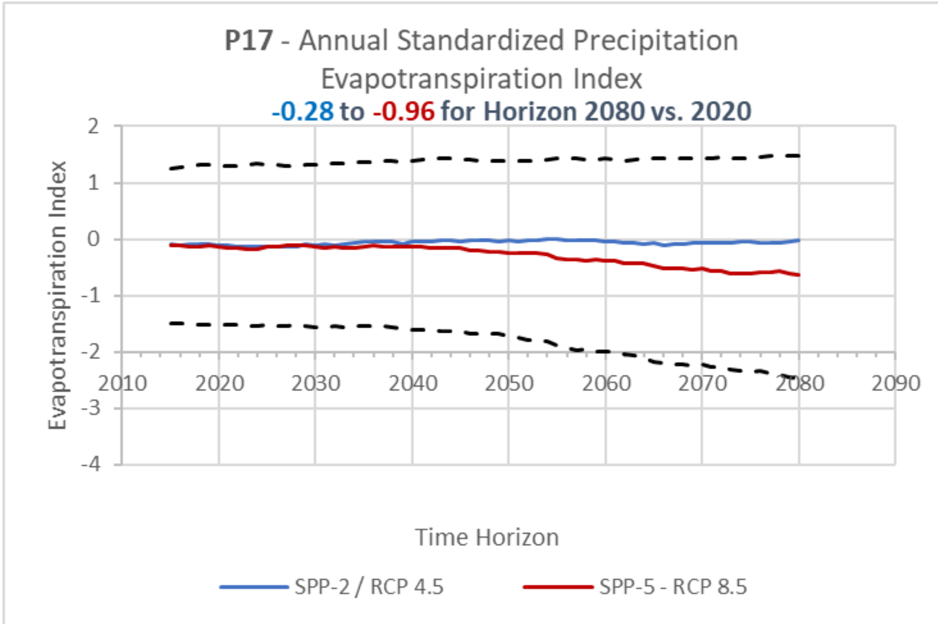

P12 - Days with 10+ mm of Precipitation
+1 to +2 days for Horizon 2080 vs. 2020
Number of Days
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

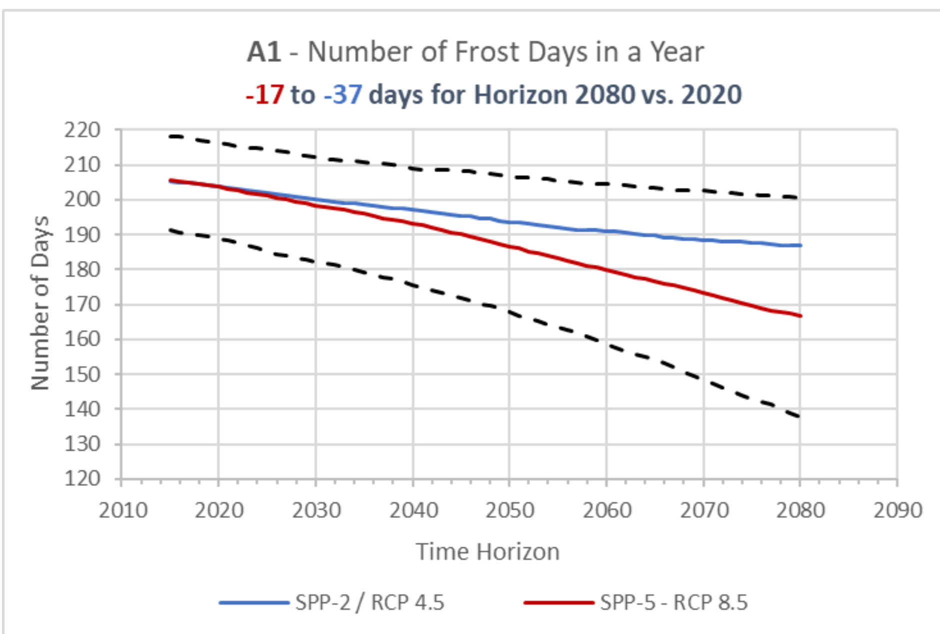

P13 - Spring Days with 10+ mm of Precipitation
+1 to +1 days for Horizon 2080 vs. 2020
10
5
0
Number of Days
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

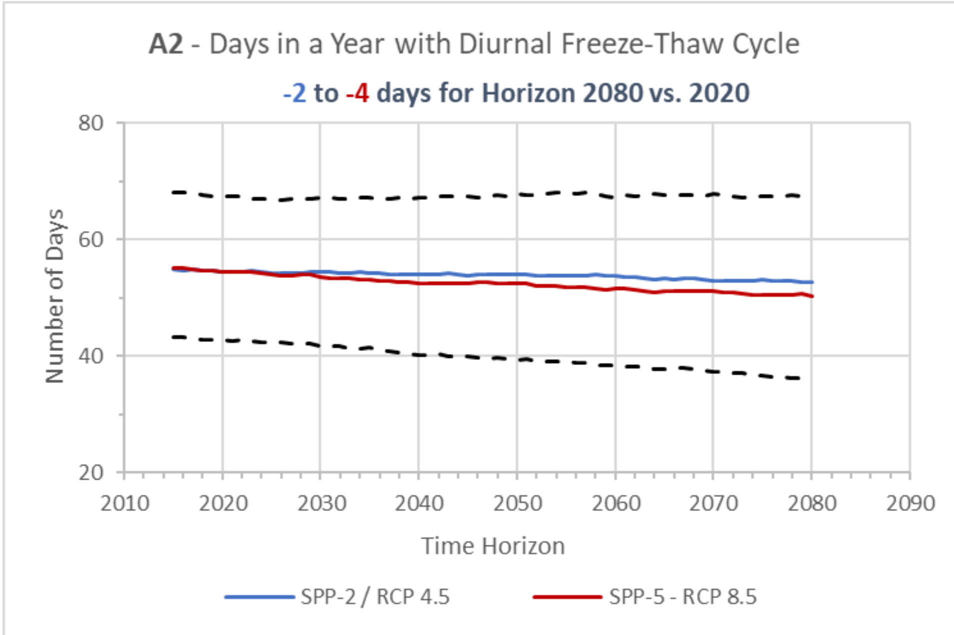

P14 - Winter Days with 10+ mm of Precipitation
+0 to +0 days for Horizon 2080 vs. 2020
5
0
Number of Days
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5


P15 - Days in a Year with 20+ mm of Precipitation
+0 to +1 days for Horizon 2080 vs. 2020
Number of Days
0
2
4
6
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

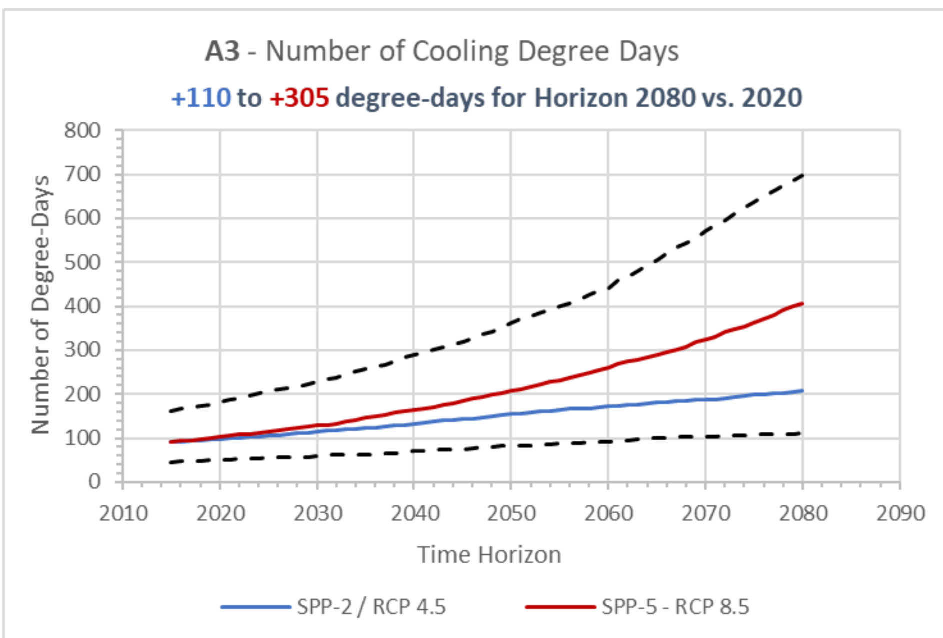

P16 - Maximum Number of Consecutive Dry Days
-1 to -2 days Horizon 2080 vs. 2020
Number of Days
10
15
20
25
30
35
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5


P17 - Annual Standardized Precipitation Evapotranspiration Index
-0.28 to -0.96 for Horizon 2080 vs. 2020
Evapotranspiration Index
2
1
0
-1
-2
-3
-4
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5


A1 - Number of Frost Days in a Year
-17 to -37 days for Horizon 2080 vs. 2020
Number of Days
220
210
200
190
180
170
160
150
140
130
120
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5



A2 - Days in a Year with Diurnal Freeze-Thaw Cycle
-2 to -4 days for Horizon 2080 vs. 2020
Number of Days
80
60
40
20
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5



A3 - Number of Cooling Degree Days
+110 to +305 degree-days for Horizon 2080 vs. 2020
Number of Degree-Days
800
700
600
500
400
300
200
100
0
2010
2020
2030
2040
2050
2060
2070
2080
2090
Time Horizon
SPP-2 / RCP 4.5
SPP-5 - RCP 8.5

APPENDIX B

Climate Risk Analysis Approach

Climate Risk Analysis Approach

The method used is based on five (5) distinct steps:

1. Selection of climate hazards and their probability of occurrence ratings.
2. Determining the "potential" vulnerabilities of the component towards each climatic hazard.
3. Determining the net probability of an impact over the component's lifetime.
4. Determining the consequence of the impact on the component.
5. Calculating risk levels and prioritizing control measures.

Probability of Occurrence of Climate Hazards

The first step is to establish the level of likelihood that the frequency and/or intensity of a climate hazard will increase over the lifetime of the project. The probability (P_A) is established on a scale of 1 to 5, where "1" represents extremely unlikely and "5" represents highly probable, along the lines defined in the table below. For the purposes of this study, the probability scale applies to an increase in the frequency, strength and/or duration of a given climate hazard, compared to conditions currently prevailing (reference period). It is therefore recognized that the project promoter is already considering the current climate in its decisions.

Rating	Definition of the probability of occurrence of a climate hazard (P_A)	
1	Extremely unlikely	Isolated event whose frequency will not increase
2	Unlikely	An event that has occurred in the past and is unlikely to increase in frequency and/or intensity in the future.
3	Possible	An event that has occurred in the past and will possibly increase in frequency and/or intensity in the future.
4	Probable	An event that has occurred in the past and is likely to increase in frequency and/or intensity in the future.
5	Highly probable	An event for which an increase in frequency and/or intensity is expected without being absolutely certain.

The selection of the P_A rating may involve a number of uncertainties as to what will actually happen in the future, since models, climate projections, studies, etc. do not necessarily come to the same findings. In a risk analysis approach, it is important to take uncertainties into account so as not to underestimate the risks. Thus, in the event that the P_A rating is subject to high uncertainties, it is increased according to the following scaling, based on the approach from the IPCC (Mastrandrea et al., 2010).

$$P_N = (P_A + C_I) \times (1 + 0{,}2 \times P_C) \quad (1)$$

P_N: net probability of an impact of the climate hazard on the component
P_A: probability of occurrence of climate hazard
C_I: correction factor on the probability of occurrence based on the component's natural adaptation capacity.
P_C: correction factor on the probability of occurrence of an impact according to the confidence level associated with the probability of occurrence factor for the climate hazard.

Rating	Level of confidence (P_C) of the probability of occurrence rating (P_A)	
1	Very high	Good agreement between projections and studies; sufficient evidence
2	High	Good agreement between projections and studies; mixed evidences
3	Medium	Good agreement between projections and studies; limited evidences
2	High	Moderate agreement between projections and studies; sufficient evidence
3	Medium	Moderate agreement between projections and studies; mixed evidence
4	Low	Moderate agreement between projections and studies; limited evidence
3	Medium	Poor agreement between projections and studies; sufficient evidence
4	Low	Poor agreement between projections and studies; mixed evidence
5	Very low	Poor agreement between projections and studies; limited evidence

The selection of P_A and P_C ratings for a given climate hazard is based on climate history and projections for the project area, while considering the findings from relevant technical studies on climate change. It should be noted that the severity of an event is independent of the probability of the event occurring, otherwise the probability/severity distinction would lose its meaning. As a result, the P_A and P_C ratings are kept constant for all project components.

Determining Climate Vulnerabilities

A component can be defined as vulnerable if it may suffer or cause harm from projected climate change over its lifetime. In short, a climate vulnerability is the result of the interaction of three factors:

- Exposure to the climate hazard in terms of variation, extreme, magnitude and/or frequency.
- The sensitivity of the component, when exposed to the climate hazard.
- The component's inherent capacity to adapt to the climate hazard minimizing negative effects. This excludes additional mitigation measures at this point.

This step therefore consists of establishing whether a component can potentially be affected by a given climate hazard for any of the following criteria. If so, an actual risk analysis is performed on the "component / hazard / criterion" combination. Otherwise, the analysis stops at this stage.

- **Sustainability and operation (S):** Can the climate hazard cause damages requiring repairs; affect the integrity or performance of the component; or add significant operating costs?
- **Health and safety (H):** Can the interaction between the climate hazard and the component cause dangerous conditions for people's safety?
- **Natural environment (E):** Can the interaction between the climate hazard and the component cause damage to the environment? For this project, this may include wetlands, culturally sensitive areas, soils, and runoff water.

- **Built environment (B):** Can the interaction between the climate hazard and the component cause damage to existing structures and infrastructures? For this project, this may include the Webequie air strip and dwellings that will be built nearby the road.

Determining the Net Probability of an Impact

This step differs from the "probability of occurrence of the climate hazard" as it adds the natural or design-integrated adaptive capacity of the component exposed to the climate hazard. The aim here is to establish, for each component identified as potentially vulnerable in the previous step, a probability of impact from the climate hazard based on the probability of occurrence rating of the climatic hazard (P_A) and a correction rating (C_I) (see equation 1), which can be negative (by integrating the adaptive capacity) or positive (by integrating the increased sensitivity of the component to the climate hazard). A zero correction ($C_I = 0$) indicates the absence of mitigating factors. The resulting of “$P_A + C_I$ " representing the "net impact probability" always stays within the range of 1 to 5.

Determining the Impact Consequence

The consequence scale is used to establish the extent of damage and harm that the climate hazard may have on the potentially vulnerable component. It is based on a scale of 1 to 5, where "1" represents a negligible impact, while "5" represents a major impact. A definition for each severity rating (G_B) considered in this analysis for each criterion (sustainability and operation, health and safety, natural environment, built environment) is provided below. As with the probability rating, the choice of the severity rating may involve some uncertainties since the level of damage or harm may vary according to the event. These uncertainties are therefore considered by increasing the base rating (G_B) according to the following equation and correction scale. Severity ratings were selected on the basis of all available information on the component's location, attributes, and design criteria.

$$G_N = G_B \times (1 + 0{,}2 \times G_C) \qquad (2)$$

G_N: net severity rating of the impact of the climate hazard on the component
G_B: severity rating expected by the risk assessor
G_C: confidence rating of the severity expected by the assessor, according to the following scale

Rating	Confidence level (G_C) of impact severity rating (G_B)	
3	Little uncertainty about selected severity rating	Maximum severity level (depending on the definition of the G_B rating chosen) independent of the event
4	Consequences expected, but with certain uncertainties	Expected level of severity (according to the G_B rating definition chosen) but could possibly be higher depending on the event.
5	Typical consequences, but they vary from case to case	Typical severity level (according to the G_B rating definition chosen) but could clearly be higher depending on the event.

Rating	Definition of ratings (G_B) for criterion: Sustainability	
1	Negligible	Cosmetic work / performance impairment or imperceptible additional operating costs
2	Minor	Relatively simple, inexpensive repair work / performance impairment or additional operating costs are minor and do not require intervention
3	Moderate	Complex repair work of short duration / poor system performance that may require intervention when necessary / substantial additional operating costs that can be absorbed
4	Serious	Complex, time-consuming and/or costly repair work / poor system performance requiring direct intervention / significant additional operating costs
5	Major	Replacement required or prohibitive cost / poor performance requiring system upgrade / prohibitive operating cost leading to overhaul
Rating	**Definition of ratings (G_B) for criterion: Health and safety**	
1	Negligible	Event that does not result in injury, but can be described as a quasi-incident
2	Minor	Superficial injury or symptom at most
3	Moderate	Minor injury or symptom requiring first aid for one or more people without a hospital visit.
4	Serious	Severe injury or symptoms resulting in a hospital visit for an individual
5	Major	Severe injury or symptoms in a group of people resulting in a hospital visit
Rating	**Definition of ratings (G_B) for criterion: Natural environment**	
1	Negligible	Minimal localized impact of no great significance
2	Minor	Impact causing minor environmental damage that can be rapidly mitigated (reversible impact)
3	Moderate	Impact causing moderate but localized environmental damage that can be rapidly mitigated (reversible impact)
4	Serious	Impact causing moderate and widespread environmental damage that can be mitigated over time (reversible impact)
5	Major	Impact causing widespread or non-extensive environmental damage that is not easily reversible
Rating	**Definition of ratings (G_B) for criterion: Built environment and continuity of operations**	
1	Negligible	Possible interaction between the component and the built element, but with no major impact
2	Minor	Interaction of little consequence, but would require the intervention of a party on the ground to control the situation
3	Moderate	Interaction resulting in damage requiring certain non-critical repairs with no particular impact on operations
4	Serious	Interaction may cause significant damage to the built element (costs, operation, etc.) with possible short-term interruption of activities
5	Major	Interaction that could cause significant damage to the built element (costs, operation, etc.) with uninsured interruption of activities in the short to medium term

Calculating the Risk Level

Once the product of probability and consequence has been calculated, a risk rating is obtained for each potentially vulnerable component, according to the climate hazard and criterion considered. A risk level from "very low" to "high" can then be assigned according to the result using the following criteria.

Risk threshold (R) = Net probability (P_N) x Net consequence (G_N)	
≤ 10	Very low risk
10 - 20	Low risk
20 - 40	Moderate risk
40 - 100	High risk

For risks categorized as "moderate" and "high", control measures should preferably be considered, depending on the level of risk acceptable for the project promoter. Control measures may also be proposed when the severity rating is at its highest (G_B = 5), notwithstanding the level of risk obtained, since these situations, even if the probability of occurrence is low, can be very damaging.

APPENDIX C

Vulnerability and Risk Analysis – Justifications

Potential vulnerability assessment **Thick fog events**

Probability (PA)	3	An event that has occurred in the past and will possibly increase in frequency and/or intensity in the future	**PC**	5	Poor agreement between projections and studies; limited evidence

Justifications: Some areas of the WSR already undergo thick fog during early summer at least, supposedly during snow melting. To a minimum, it is possible that these events will increase in frequency due to rising temperatures, but it also depends on multiple conditions which increase uncertainty.

Are the components "potentially" vulnerable to "thick fog events" according to the criteria below?

Assessment criteria	P	S	E	B	Justifications
WSR layout		S1			P: Not applicable; the layout is not a tangible structure. S: Thick fog can affect visibility leading to road accidents. Thick fog can also be a hazard on bridges, especially for traffic in narrow lanes. E: No particular interaction noted between the hazard, component and criteria. Excludes fuel/oil or other contaminants spills from accidented vehicles. B: No particular interaction noted between the hazard, component and criteria.
Road structure (western part)					P: Fog does not have a physical impact on structures. S: No particular interaction noted between the hazard, component and criteria. E: No particular interaction noted between the hazard, component and criteria. B: No particular interaction noted between the hazard, component and criteria.
Road structure (eastern part)					P: Fog does not have a physical impact on structures. S: No particular interaction noted between the hazard, component and criteria. E: No particular interaction noted between the hazard, component and criteria. B: No particular interaction noted between the hazard, component and criteria.
Roadside ditches and earth cut sections					P: Fog does not have a physical impact on structures. S: No particular interaction noted between the hazard, component and criteria. E: No particular interaction noted between the hazard, component and criteria. B: No particular interaction noted between the hazard, component and criteria.
Bridges (including riverbanks)					P: Fog does not have a physical impact on structures. S: No particular interaction noted between the hazard, component and criteria. E: No particular interaction noted between the hazard, component and criteria. B: No particular interaction noted between the hazard, component and criteria.
Major culverts (including streambanks)					P: Fog does not have a physical impact on structures. S: No particular interaction noted between the hazard, component and criteria. E: No particular interaction noted between the hazard, component and criteria. B: No particular interaction noted between the hazard, component and criteria.
Aggregate pit					P: Fog does not have a physical impact on structures. S: No particular interaction noted between the hazard, component and criteria. E: No particular interaction noted between the hazard, component and criteria. B: No particular interaction noted between the hazard, component and criteria.
Maintenance and storage facility					P: Fog does not have a physical impact on structures and buildings. S: No particular interaction noted between the hazard, component and criteria. E: No particular interaction noted between the hazard, component and criteria. B: No particular interaction noted between the hazard, component and criteria.
Rehabilitated sites					P: Fog does not have a physical impact on structures and buildings. S: No particular interaction noted between the hazard, component and criteria. E: No particular interaction noted between the hazard, component and criteria. B: No particular interaction noted between the hazard, component and criteria.
Construction activities		S2			P: Not applicable; activities are not tangible structures. S: Thick fog can affect visibility leading to road accidents during construction activities on or beside the road. E: No particular interaction noted between the hazard, component and criteria during construction. Excludes potential fuel/oil spills from major accidents. B: No particular interaction noted between the hazard, component and criteria.

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