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Climate Change in Northeastern British Columbia

Northeastern British Columbia (BC) is undergoing tremendous growth, particularly with natural gas and oil development actively expanding in the area. Hydroelectricity, forestry, mining, manufacturing, and tourism are also significant contributors to employment in the booming Northeast region (Figure 1). Oil and gas and other activities depend on many sectors for support and growth (such as services, transportation, and construction), and on common resources like roads and water.

Figure 1  Location of the Northeastern BC region (shading represents topography).
The purpose of this report is to understand what climate change looks like in Northeastern BC, primarily in terms of changes in temperature and precipitation. This information will help people understand the regional impacts of a changing climate, and support a discussion about different risks and opportunities associated with these changes. These discussions will inform the broader Northeastern BC Vulnerability Assessment. The assessment will involve gathering perspectives from the oil and gas sector about climate-related risks and opportunities, as well as determining which tools and resources are required to prepare for these changes.

What is Climate Change?
Climate refers to patterns of weather over long periods of time, usually several decades. Climate change, therefore, refers to changes in temperature, precipitation, and extreme weather events over several decades. This is different from climate variability and weather, which refer to trends and events over shorter time periods. Climate change is also commonly referred to as global warming.

Global average temperatures increased by 0.85°C between 1880–2012, and precipitation has increased in some areas of the world and decreased in others. Significant increases in extreme events (such as heat waves, heavy precipitation events, droughts, and cyclones) have also been documented. Changes are not evenly distributed across the globe; high latitude areas and inland regions are warming much more rapidly than areas near the equator and coastal zones (IPCC, 2013).

Why is Climate Change Important to Resource Industries?
Climate change is expected to affect resource industry operations at all stages, including resource planning, development, distribution, closure, and reclamation (Lemmen et al., 2014). The mining sector, for example, is considered vulnerable to climate change impacts for the following reasons (IMCC, 2013):

- There is a need to plan over long time frames.
- Large supply chains mean that many locations and aspects of the industry can be affected.
- Work often takes place in remote locations, challenging geographies, and harsh climates.
- There is a high reliance on and demand for water and energy.

The impacts of climate change vary by sector and by location. Some general impacts documented in resource sectors and communities in Northern BC include changes to water supply, infrastructure damage, forest disturbances, permafrost degradation, and increased emergency response requirements (Picketts et al., 2013; Lemmen et al., 2014; Kovacs and Thistlethwaite, 2014). Changes in weather conditions are occurring especially rapidly in Northeastern BC (PCIC, 2009). Climate change may increasingly challenge the ability of oil and gas and other resource-related operations to thrive in this region; therefore, it is important to consider the different risks and opportunities associated with climate change and how they may affect Northeastern BC. The first step towards managing climate change risks and opportunities is often the review of past climate trends and future climate projections.

1 **Bolded orange** terms are explained in a glossary on page 17.
Past Climate Trends in Northeastern BC

Until recently, there has been limited information about how the regional climate has already changed and what is expected to happen in the future. Fortunately, more data is becoming available at the regional level to help us understand the past climate trends and future projected changes.

Climate record information is used to explain how weather patterns have changed in the past. Like many northern inland regions, Northeastern BC has experienced a rapid rate of warming over the last hundred years (2.2°C). This is greater than both the global average (0.85°C) and the BC average (1.2°C) (PCIC, 2009). Past climate analysis by the Pacific Climate Impacts Consortium (PCIC) (2013), generated from weather station data, reveals several temperature and precipitation trends for the region.

Temperature Trends

- Annual temperatures increased by 0.22°C per decade from 1901–2009.
- Summer temperatures increased by 0.19°C per decade from 1901–2009 (Figure 2A).
- Winter temperatures increased by 0.33°C per decade from 1901–2009. Winter temperatures have increased rapidly since 1950 (Figure 2B).

Figure 2  Historical summer (A) and winter (B) temperature trends in the Northeastern BC region. Trends are obtained from the weather station-based CANGRID observational dataset (Milewska et al., 2005).
**Precipitation Trends**

- Annual precipitation increased by 12 mm per decade from 1901–2009.
- Summer precipitation increased by 5 mm per decade from 1901–2009. Since 1950, summer precipitation increases were 2 mm per decade (Figure 3A).
- Winter precipitation increased by 2 mm per decade from 1901–2009. Since 1950, winter precipitation has decreased slightly (Figure 3B).

![Northeast Region average historical summer precipitation and trends](image)

![Northeast Region average historical winter precipitation and trends](image)

Figure 3 Historical summer (A) and winter (B) precipitation trends in the Northeastern BC region. Trends are obtained from the weather station-based CANGRID observational dataset (Milewska et al., 2005).

**Implications of the Past Trends in Temperature and Precipitation**

- Warming has occurred in all seasons since 1901, particularly in the winter months. Warming trends have increased since 1950. These changes have had many impacts on the region, including a major role in the current mountain pine beetle infestation (Kurz et al., 2008).

- Precipitation has increased in all seasons since 1901, but winter precipitation has decreased since 1950. There is much more variability in precipitation trends because amounts change so much from year to year.

- Due to warming temperatures, more precipitation has been falling as rain (Appendix C displays projected change in precipitation as snow). Lower snowpacks and warmer winters have implications for streamflow, particularly the size and timing of spring floods and low flow levels in late summer and fall.
Future Climate Projections in Northeastern BC

Through the use and application of global climate models (GCMs) we can get an idea of what future conditions are likely to be in Northeastern BC. Projections are made in comparison to baseline climate conditions. Projections can be made for any time period, but all projections in this report are for the 2050s (Technical Note 1 [TN1]). All future projection information in this document has been prepared by PCIC.

This section includes two types of information—text and maps. The information in the bulleted text describes results from several climate models and emissions scenarios put together. It includes a median value and also a (range of values) (see below) (TN2). The range is important to note as it indicates the amount of variability between the future projections. When making decisions about the future, this range of values is a useful reminder that we need to prepare for a range of climate change impacts and an uncertain degree of change.

<table>
<thead>
<tr>
<th>Median value: the middle result from a series of 12 GCM model projections run using 3 emissions scenarios</th>
<th>Range of values: the 10th to the 90th percentile of projections from all models</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.2°C (1.9°C to 4.7°C)</strong></td>
<td>The values are differences from the 1971-2000 baseline</td>
</tr>
</tbody>
</table>

The following maps convey information visually, but describe the results of only one climate model and one emissions scenario, which were chosen for their nearness to the average of all the models and scenarios (TN3). The maps also show how topography and other regional features influence climate. For example, mountainous regions may experience climate change differently from lowland regions, and Fort St. John may experience climate change differently than Fort Nelson.

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2 Projection information and maps for the 2020s and the 2080s, as well as maps for different emissions scenarios, can be readily created.
**Temperature Change Projections**

- Annual temperatures are projected to increase by 3.2°C (1.9°C to 4.7°C) (Figure 4)
- Winter temperatures are projected to increase by 4.0°C (2.3°C to 5.9°C) (Appendix A)
- Summer temperatures are projected to increase by 2.9°C (1.7°C to 5.0°C) (Appendix A)

![Mean Annual Temperature (1971-2000) A](image) ![Mean Annual Temperature (2050s) B](image)

**Figure 4** Annual baseline (A) and future projected (B) mean temperatures for Northeastern BC (TN3).

**Implications of the Projected Changes in Temperature**

- Temperature changes affect road conditions, demands on water availability, agricultural production, streamflow patterns, forest disturbances (such as fires and pests), and whether precipitation falls as rain or snow (see Appendix C).

- The average temperatures at Fort St. John in the 2050s are likely to resemble the temperatures in Quesnel today. The average temperatures at Fort Nelson in the 2050s are likely to resemble temperatures in Prince George today.

- The area with an average annual temperature of less than 0°C will likely shrink to almost zero. This means that permafrost will likely continue to melt in many areas, causing stability and infrastructure issues.
Precipitation Change Projections

- Annual precipitation is projected to increase by 14% (+11% to +19%) (Figure 5)
- Winter precipitation is projected to increase by 16% (+4% to +24%) (Appendix B)
- Summer precipitation is projected to increase by 10% (-1% to +20%) (Appendix B)

Figure 5  Annual baseline (A) and future projected (B) precipitation for Northeastern BC (TN3).

Implications of the Projected Changes in Precipitation

- Precipitation changes have the potential to affect road conditions, hydroelectric power generation, water availability, streamflow patterns, flooding, and agricultural production.

- Precipitation varies naturally by a large amount from year to year and by location. Precipitation projections also have larger uncertainties than temperature projections. Therefore, it is important to prepare for a range of future conditions. However, the general trend for most areas is increased precipitation in the future.
Frost-free Projections
- The number of frost-free days is projected to increase by 29 days (25 to 43 days) (Figure 6)

Figure 6  Annual baseline (A) and future projected (B) frost-free periods for Northeastern BC (TN3).

Implications of the Projected Changes in Frost-Free Days
- Increases in frost-free days can lengthen growing seasons, affect winter roads and winter access, and alter spring break-up timing and length
Extreme Event Projections

Understanding long-term trends is highly useful for activities like agriculture and hydroelectric generation. However, in some other sectors, it is changes to the frequency (i.e., how often) and magnitude (i.e., how much) of extreme or unusual events (like heavy rains, floods, and heat waves) that may have the biggest impacts because these can damage infrastructure, disrupt operations, and put people in danger.

The extreme temperature and precipitation events described below are those that could currently be expected to occur—or return—once every 20 years. In other words, these events have a “20-year return period.” These events can also be thought of as having a 5% chance of happening each year. This information is conveyed in text and maps (TN4). Changes in infrequent or extreme events are projected to be far greater than changes in average events (IPCC, 2013). For example, all of the projected changes for 20-year return periods are greater than the annual changes in northeastern BC.

Extreme Temperature Projections

- Minimum winter night-time temperatures (coldest temperatures) over a 20-year return period are projected to warm by **5.7°C (4.4°C to 7.5°C)** (Figure 7)
- Maximum summer daytime temperatures (hottest temperatures) over a 20-year return period are projected to warm by **4.0°C (2.4°C to 8.1°C)** (Figure 8)

![Figure 7](image.png) Baseline (A) and future projected (B) minimum night-time temperature (coldest temperature) for 20-year return period events for Northeastern BC (TN4).
Implications of the Projected Changes in Extreme Temperature

- In many areas, future minimum extreme temperatures are not expected to go below -40°C (Figure 7). This affects mountain pine beetle, as very cold winter temperatures are necessary to keep populations under control.

- Hotter extreme summer temperatures can affect worker health and safety, increase forest fire risk, and lead to warmer water temperatures and lower water levels (that affect fish, agriculture, and hydroelectric activities).
Extreme Precipitation Projections

- Maximum precipitation events over a 20-year return period are projected to increase by 34% (+19% to +54%) (Figure 9).

![Figure 9 Baseline (A) and future projected (B) 20-year return period precipitation events for Northeastern BC (TN4).](image)

Implications of the Projected Changes in Extreme Precipitation

- Increases in extreme precipitation events can lead to river flooding, rapid erosion, road washouts, road closures, adverse driving conditions, and stresses on municipal resources (such as storm-water infrastructure and snow removal services).
Streamflow Analysis for Northeastern BC

Streamflow relates closely to both precipitation and temperature. Changing precipitation patterns can directly affect flow levels, and temperatures dictate if precipitation falls as rain or snow (Appendix C) and when the snow melts. However, streamflow trends are influenced by additional factors, and cannot be calculated directly from precipitation and temperature trends alone.

Some analysis has been completed on future streamflow in the Peace Watershed in Northeastern BC by PCIC (Schnorbus et al., 2014; Werner et al., 2011). Streamflow projections were created for the 2050s on seven sub-basins of the Peace River Basin (Figure 10 and Table 1) (TN5). Values from two sub-basins listed in Table 1 are visualized in Figure 11 (graphs) along with the range of projections; the graphs demonstrate the variability of streamflow projections through the year.

Figure 10  Map of the seven sub-basins of the Peace Watershed (see Table 1) (TN5). All of these sub-basins are without dams.
The projections vary from basin to basin due to many factors such as elevation, basin size, flow volume, and forest cover. There are some clear patterns of change consistent among the basins:

- Flows increase from November through May due to more winter precipitation falling as rain rather than snow.
- Flows decrease from June to September due to lower amounts of snowpack and earlier spring freshet floods.

As these are results from only a portion of the Peace River, they do not strictly represent how streamflow is projected to change throughout all watersheds of the Northeastern BC region. However, the general trends are expected to be similar throughout the region; similar analysis can be applied to other basins to inform future decision making.

<table>
<thead>
<tr>
<th>Sub-basin</th>
<th>Projected monthly change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jan</td>
</tr>
<tr>
<td>Northeast Graham River at Colt Creek (GRAHM)</td>
<td>35</td>
</tr>
<tr>
<td>Halfway River Above Graham River (HALGR)</td>
<td>31</td>
</tr>
<tr>
<td>Halfway River near Farrell Creek (HALFA)</td>
<td>29</td>
</tr>
<tr>
<td>Southeast Murray River above Wolverine River (MURWV)</td>
<td>54</td>
</tr>
<tr>
<td>Murray River near the Mouth (MURMO)</td>
<td>53</td>
</tr>
<tr>
<td>Sukunka River near the mouth (SUKMO)</td>
<td>67</td>
</tr>
<tr>
<td>Pine River East Pine (PINPN)</td>
<td>63</td>
</tr>
</tbody>
</table>

Table 1  Projected change in monthly streamflows for the 2050s versus 1961-1990 (TN5).
Table 2 shows the projected change in extreme streamflow for the Peace River sub-basins. In the future, sub-basins are generally projected to experience greater magnitudes of streamflow during 20-year return period extreme (high-flow) events. In comparison, 10-year return period extreme low-flow events (TN6) show considerable decreases in magnitude. Table 3 is based on the same information as Table 2, but it is presented in terms of how often the 20-year and 10-year return period events are projected to occur. (For example, in the 2050s at Graham River 20-year return period high-flow events are expected to occur every 19 years and 10-year return period low-flow events are expected to occur more than once every 2 years.) More analysis will need to be done to see how changes in return periods relate to frequencies of events such as water restrictions.
<table>
<thead>
<tr>
<th>Station name</th>
<th>20-year return period extreme (high-flow) events % change</th>
<th>10-year return period extreme (low-flow) events % change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graham River at Colt Creek</td>
<td>2</td>
<td>-22</td>
</tr>
<tr>
<td>Halfway River above Graham River</td>
<td>2</td>
<td>-34</td>
</tr>
<tr>
<td>Halfway River near Farrell Creek</td>
<td>23</td>
<td>-27</td>
</tr>
<tr>
<td>Murray River above Wolverine River</td>
<td>14</td>
<td>-65</td>
</tr>
<tr>
<td>Murray River near the mouth</td>
<td>25</td>
<td>-48</td>
</tr>
<tr>
<td>Sukunka River near the mouth</td>
<td>11</td>
<td>-27</td>
</tr>
<tr>
<td>Pine River East Pine</td>
<td>14</td>
<td>-37</td>
</tr>
</tbody>
</table>

Table 2  Projected (2050s) streamflow change in 20-year high-flow events and 7-day 10-year July-September low-flow events for Peace River sub-basins (TNS).

<table>
<thead>
<tr>
<th>Station name</th>
<th>20-year return period extreme (high-flow) events return period change</th>
<th>10-year return period extreme (low-flow) events return period change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graham River at Colt Creek</td>
<td>19</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Halfway River above Graham River</td>
<td>19</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Halfway River near Farrell Creek</td>
<td>11</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Murray River above Wolverine River</td>
<td>12</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Murray River near the mouth</td>
<td>9</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Sukunka River near the mouth</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Pine River East Pine</td>
<td>10</td>
<td>&lt;2</td>
</tr>
</tbody>
</table>

Table 3  Projected (2050s) return period change in 20-year high-flow events and 7-day 10-year July-September low-flow events for Peace River sub-basins (TNS).

Implications of the Projected Changes in Streamflow

- Streamflow changes affect surface and subsurface water quality, availability, and temperatures.

- Future monthly streamflow projections show higher flows in winter and spring and lower flows in summer. There are large projected increases in winter flows in the more southeasterly sub-basins of the Peace Basin, upstream of Taylor, BC.

- Future extreme streamflow projections show increases in unusually high flow events (spring) and decreases in unusually low flow events (summer). Both of these changes are potentially important to resource industries as they imply more incidents of flooding, and also drought and water scarcity.
What Happens Now?
Climate changes in Northeastern BC have already occurred. Over the last century, the region has experienced a 2.2°C increase in average temperatures. Warming has occurred in all seasons, particularly in the winter months. Precipitation has increased in all seasons as well, but winter precipitation has decreased since 1950. Due to warming temperatures, more precipitation has been falling as rain. There are more frost-free days, melting permafrost, warmer water temperatures, and the mountain pine beetle has spread to an unprecedented level (Lemmen et al., 2014; PCIC, 2009; Kurz et al., 2008) Researchers have shown relationships between climate change (rising precipitation, warming temperatures, and more unpredictable weather patterns) and recent increases in flooding, highway washouts, slope failures, and less predictable animal behaviour (Vanessa Foord, pers comm). Such disturbances illustrate how climate change is not just a future problem, and also give us insights into how future changes in temperature, precipitation and streamflow (both in averages and extremes) may further alter natural and human-made landscapes in Northeastern BC.

By analyzing the outputs of climate models, researchers expect temperatures to increase by approximately 3°C in the 2050s compared to baseline conditions, and precipitation is projected to increase by about 14%. These changes relate closely to projected increases in frost-free days (p8) and streamflow (p12). Detailed streamflow analysis is limited to one area, but the projections indicate that flow rates may double in some areas in winter months, and decrease by nearly half in summer months. Perhaps most importantly, increases in infrequent events, such as the 20-year return period for minimum and maximum temperatures (p6), maximum precipitation events (p7) and peak flow events (p14) can potentially delay, disturb, or otherwise affect resource operations.

It is important to consider how long-term weather patterns will change and what can be done to prepare for and adjust to these changes. This practice is commonly known as climate change adaptation. Adaptation is fundamentally a process of managing the risks and opportunities brought by climate change, and preparing for uncertainty. Adaptation is different from climate change mitigation, which focuses on how humans can decrease their long-term effect on the climate—mainly by reducing greenhouse gas (GHG) emissions. Mitigation has not been discussed in this report.

Temperature and precipitation projections indicate that climate change will impact resources industries in Northeastern BC, though we have yet to determine the range and extent of such impacts. The next step in this process will be to continue the Northeastern BC Vulnerability Assessment by exploring these impacts in detail. Identifying the kinds of risks and opportunities brought by climate change will help inform planning and decision making in the Northeastern BC region.
References


Glossary

Baseline climate conditions: measured averages in weather (i.e., temperature or precipitation) over a period of time. This information represents an average (or baseline) from which future changes can be compared.

Climate change: long term changes (generally over at least 30 years) in temperature and precipitation regimes, and/or the number of and severity of events.

Climate change adaptation: responding to (or preparing for) the effects of climate change. Adaptations can be made by natural systems, individuals, communities and/or higher orders of government.

Climate change mitigation: actions that limit long term climate change by reducing the concentration of GHGs in the atmosphere. This is done by reducing the amount of GHGs emitted, or by enhancing earth’s ability to sequester GHGs by increasing the capacity of carbon sinks (such as forests).

Climatic variability: changes in temperature and precipitation regimes, and/or the number of and severity of events, over periods of weeks to years.

Emissions scenarios: plausible future amounts of GHGs emitted into the atmosphere by humans. These have a large effect on long-term climate change (i.e., if humans are to rapidly decrease their emissions then warming and other temperatures will be significantly less over the long term). However, emissions do not have a big impact on climate change over shorter time scales, as this is mostly influenced by GHGs already in the atmosphere. See also: greenhouse gases (GHGs).

Global Climate Models (GCMs): computer-based, mathematical representations of the climate system. They are used (or ‘run’) to provide quantitative estimations of future climates, and climate change. The models are based on well-established physical and chemical principles of the actual climate system.

Greenhouse gases (GHGs): atmospheric gases that absorb and emit solar radiation, and affect the temperatures of earth. The primary GHGs are water vapour, carbon dioxide, methane, nitrous oxide, and ozone.

Pacific Climate Impacts Consortium (PCIC): a group based out of the University of Victoria that specializes in using, and helping people to use, climate information and climate models to help make decisions about climate variability and climate change.

Projection: a description of the future that allows for certain conditions to develop (such as increases in GHG emissions). Therefore, projections are expectations that are conditional on certain things happening.

Vulnerability: the extent to which climate change may affect a community, region (or larger area). Vulnerability is a measurement of how sensitive a community is to changes, and also how able they are to adapt to new conditions.

Weather: the state of the atmosphere at a particular time and place (or what you see out your window!). Weather can refer to a range of timescales, from minutes up to weeks.
Technical Notes

**TN1:** All projections for temperature and precipitation in this report are made for the 2050s – which is actually the period from 2041-2070. All projections in this backgrounder are made in comparison to 1971-2000 baseline conditions, except for the streamflow projections (see TN5). The 2050s is often considered a good time period to examine as: this is a reasonable time period to consider and plan for (i.e., 40 years), and projections do not change greatly based on the emissions scenarios used. This means that the expected changes to 2050 are fairly similar, regardless of how many greenhouse gases (GHGs) humans emit over the next 40 years. For longer time periods (such as the 2080s) the projected changes largely depend on the emissions scenario used, making the range of possible change quite large and the choice of emissions scenario highly important.

**TN2:** The bulleted text represents the outputs of an ensemble of 12 GCMs, each run multiple times using three different emissions scenarios. These emissions scenarios are RCP 8.5, RCP 4.5, and RCP 2.6. For more information about the emissions scenarios please see: [http://www.wmo.int/pages/themes/climate/emission_scenarios.php](http://www.wmo.int/pages/themes/climate/emission_scenarios.php)

**TN3:** The information in these high resolution maps shows the (a) baseline conditions and (b) future projection for the 2050s from one GCM (CNRCM-CM5) for one emissions scenario: RCP 8.5. Data sources: PRISM 800 m 1971-2000 climatology (Anslow et al. 2014) and downscaled (bias-corrected and elevation-corrected using ClimateBC software (Hamann et al. 2013).

**TN4:** The maps showing extreme temperature projections show the average results from an ensemble of 12 GCMs, each run using just one emissions scenario (RCP8.5). Data sources: ANUSPLIN (McKenney et al. 2011) historical data and ensemble of 12 BCCAQ (Cannon et al. 2014) downscaled climate model runs. There are greater uncertainties with modelling extreme events than changes in average conditions. Also, projections for return periods greater than 20-years are not feasible due to the limited GCM simulation length.

**TN5:** The values presented for streamflow use slightly different baseline climate conditions (1961-1990) because they are based on existing analysis. They also use a different emissions scenario: A2 (which is very similar to the RCP8.5 scenario). (See link in TN2 for more information.) The median value and range from 8 GCM runs under the A2 emissions scenario are used. Station labels indicate the Water Survey of Canada (WSC) station ID and sub-basin boundaries are as implemented in the Variable Infiltration Capacity (VIC) hydrology model.

**TN6:** Extreme low-flow projections are estimated from 7-day average discharge during the summer (July-September) period. The emphasis is on summer as low flows during this period are anticipated to represent the major constraint on current and future water availability.
Appendix A: Winter and Summer Temperature Projections

Figure 12 Annual baseline (A) and future projected (B) mean winter temperatures, and baseline (C) and future projected (D) mean summer temperatures for Northeastern BC (TN3).
Appendix B: Winter and Summer Precipitation Projections

Figure 13 Annual baseline (A) and future projected (B) winter precipitation, and baseline (C) and future projected (D) summer precipitation for Northeastern BC (TN3).
Appendix C: Precipitation as Snow Projections

Figure 14 Baseline (A) and future projected (B) precipitation as snow for Northeastern BC (TN3).