SCIENCE INTEGRITY KNOWLEDGE

FINAL REPORT

CLIMATE CHANGE AND HEALTH VULNERABILITY ASSESSMENT OF THE NORTHWEST TERRITORIES

March 2021

Prepared For: **Government of Northwest Territories**
Department of Health and Social Services
5015 49th Street (Tatsaotįne Building - 5)
Yellowknife, NT X1A 2L9

Prepared by:

Dr. Faiza Waheed	Intrinsik Corp.
Anushree Bhatt	Intrinsik Corp.
Elaine Larocque	Intrinsik Corp.
Dr. Elise Ho-Foong	SLR Consulting (Canada) Ltd.
Dr. Xin Qiu	SLR Consulting (Canada) Ltd.
Jennifer Owen	SLR Consulting (Canada) Ltd.
Colleen Healey	Sijja Consulting
Zoë Martos	Sijja Consulting

6605 Hurontario Street, Suite 500, Mississauga, Ontario ▪ L5T 0A3
Tel: 905-364-7800 ▪ Fax: 905-364-7816 ▪ www.intrinsik.com

DISCLAIMER

Intrinsik Corp. (hereafter referred to as Intrinsik) provided this report for the Government of Northwest Territories (GNWT) solely for the purpose stated in the report. Intrinsik does not accept any responsibility for the use of this report for any purpose other than as specifically intended by GNWT. Intrinsik does not have, and does not accept, any responsibility or duty of care whether based in negligence or otherwise, in relation to the use of this report in whole or in part by any third party. Any alternate use, including that by a third party, or any reliance on or decision made based on this report, are the sole responsibility of the alternative user or third party. Intrinsik does not accept responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Intrinsik makes no representation, warranty or condition with respect to this report or the information contained herein other than that it has exercised reasonable skill, care and diligence in accordance with accepted practice and usual standards of thoroughness and competence for the profession of health impact assessment to assess and evaluate information acquired during the preparation of this report. Any information or facts provided by others and referred to or utilized in the preparation of this report, is believed to be accurate without any independent verification or confirmation by Intrinsik. This report is based upon and limited by circumstances and conditions stated herein, and upon information available at the time of the preparation of the report.

ACKNOWLEDGEMENTS

The Project Team would like to thank the following subject matter experts for providing their input to the project and for identifying resources:

(in alphabetical order)

Louise Aubin	Public Health, Health Services, Region of Peel
Dr. Peter Berry	Climate Change and Innovation Bureau, Health Canada
Dr. Christopher Furgal	Indigenous Environmental Studies & Sciences Program, Trent University
Dr. Katie Hayes	Climate Change and Innovation Bureau, Health Canada
Dr. Courtney Howard	Emergency Physician, Yellowknife, NWT Cumming School of Medicine, University of Calgary
Ben Linaker	Climate Change and Health Adaptation Program – North, First Nations and Inuit Health Programs, Indigenous Services Canada

CLIMATE CHANGE AND HEALTH VULNERABILITY ASSESSMENT OF THE NORTHWEST TERRITORIES

Table of Contents

Page

List of Tables

List of Figures

1.0 INTRODUCTION

Intrinsik Corp. (Intrinsik), in association with SLR Consulting (Canada) Ltd. (SLR) and Sijja Consulting (Sijja) provided this report to the Government of Northwest Territories (GNWT) for a Climate Change and Health Vulnerability and Adaptation Assessment of the Northwest Territories (NWT) (hereafter called the 'Project').

Climate change and population health are intrinsically intertwined. In the NWT, where the current rate of climate change is one of the highest globally, climate change will continue to have varied and diverse impacts on the health, safety and wellbeing of its residents. These impacts include fatalities and injuries due to extreme weather events, increase in infectious diseases, including those from water-borne pathogens, heat-related illness and respiratory and cardiovascular disorders, increased UV exposure, and long term mental health impacts including but not limited to impacts from extreme weather events, a loss of traditional way of life, and ecological grief and eco-anxiety. In addition, indirect impacts from extreme weather events on transportation and access routes can have significant implications in relation to access to employment, food, health and other services. Those who are already vulnerable, through existing long-term illness or disability, low income or another social disadvantage, are likely to be disproportionately affected.

With the development of the 2030 NWT Climate Change Strategic Framework (GNWT, 2018c) and the 2030 Energy Strategy (GNWT, 2018d), the GNWT not only has a mandate to champion climate change assessment and mitigation but also the existing relationships and partnerships to address climate change. A significant amount of work has already been undertaken to begin addressing climate change-related impacts (GNWT, 2008; GNWT, 2018c,d; GNWT, 2019a).

The NWT is in a unique position within Canada in that it spans vast geographic areas, with growth in urban areas but significant rural environments with a majority Indigenous population that has a spiritual and cultural connection to the land and water, and rely on the land and water for their livelihood and food security. Within the NWT, there is a wide distribution of economic, socio-demographic and planning patterns. Covering more than 1.17 million square kilometres, the territory is home to approximately 44,000 residents, living in 33 communities (GNWT, 2011). The NWT has the second highest proportion of Indigenous peoples in Canada, and just over half the population is of Indigenous descent (51%): 57% identify as First Nations, 19% as Métis and 21% identify as Inuit (GNWT, 2011). Of the 11 official languages in the territory, nine are Indigenous languages (GNWT, 2011). These statistics are representative of a richly diverse territory. The NWT has a population density of about 0.04 people per square kilometre, and is one of the most sparsely populated regions in the country. The NWT encompasses the traditional territories of the Dene First Nations, Métis and Inuvialuit people (GNWT, 2011).

This assessment was conducted using a collaborative, evidence-based and best practices-based approach that is tailored to the NWT. It includes data and insights collected through engagement with subject matter experts in the NWT and Canada. Research and analysis were carried out to not only identify present-day and future climate change impacts and their potential health consequences, but also to identify and evaluate a variety of adaptation strategies for vulnerable populations. This assessment aims to contribute to the GNWT's wider Climate Change Action Plan (GNWT, 2019a).

It is important to note that Climate Change and Health Vulnerability Assessments, such as this one, should be living documents, and ideally updated every few years to not only identify growing threats and challenges due to climate change, but also to identify the incredible human and community resiliencies displayed in the face of these extraordinary challenges. This is especially true of the NWT, and of the Indigenous peoples within this territory. A running thread through the subject matter interviews conducted for the purposes of informing this assessment highlighted that although the Canadian Arctic has been and will continue to be an area of intense climate change-related impacts, the communities that live here, and especially in the remote regions, are nothing if not resilient, demonstrating a high degree of resilience and adaptation even in the face of long-standing health and socioeconomic inequities. In the NWT, Indigenous populations, on average, face poorer health outcomes primarily due to these long-standing socioeconomic inequities, which are a result of the ongoing legacy of colonialism, the inter-generational trauma of residential schools and inequities in access to health services (GNWT, 2019b). Under such circumstances, climate change acts as a risk magnifier, further exacerbating poor health conditions among vulnerable populations by disturbing the balance of determinants of health.

This report has been organized in the following manner: **Section 1** includes an introduction to the NWT and the assessment; **Section 2** provides an overview of the methodology used in the assessment; **Section 3** is an overview of the ecoregions in the NWT and also provides an overview of the demographics and infrastructure within each region; **Section 4** summarizes current and future climate change impacts in the NWT; **Section 5** is a discussion of the current and potential future health impacts due to the climate change effects identified in **Section 4**; **Section 6** identifies the vulnerable populations within the territory who potentially experience disproportionate health impacts due to climate change, as well as a Gender-Based Analysis Plus (GBA+); **Section 7** provides the adaptation assessment; and the final section, **Section 8** provides a list of references relied upon in the preparation of this assessment.

2.0 METHODOLOGY AND APPROACH

The methodology used in this Climate Change and Health Vulnerability Assessment of the NWT has been adapted from the approach described in the Climate Change and Health Toolkit (MOHLTC, 2016) from the Ontario Ministry of Health and Long-Term Care, as well as the proposal submitted to the GNWT for the Project, and is described below. The assessment was conducted at the territorial level, and includes data and information from the regional level where possible. Three main elements guided the approach used in this assessment:

- Adaptation of the Climate Change and Health Toolkit;
- Information gathered and resources identified by interviewing six subject matter experts in the field of climate change and health, especially from an NWT/Northern Canada perspective; and
- Information gathered from a review of the academic and grey literatures.

As seen in **Figure 1**, the first step in the assessment is identification of and providing a brief description of the three main ecoregions in the NWT (**Section 3.1**) using information from Northwest Territories Department of Environment and Natural Resources website (GNWT, n.d.). Next, **Section 3** summarizes key demographic and infrastructure information for the communities in each of the regions (**Section 3.2**), as obtained from the GNWT's Bureau of Statistics most recent (2018) Community Profiles, Community Infrastructure Profiles (2013), and Community Survey (2014). The demographic and infrastructure information provided includes data and information on population, income and employment, cost of living, traditional activities, education, transportation infrastructure, health infrastructure, and housing conditions.

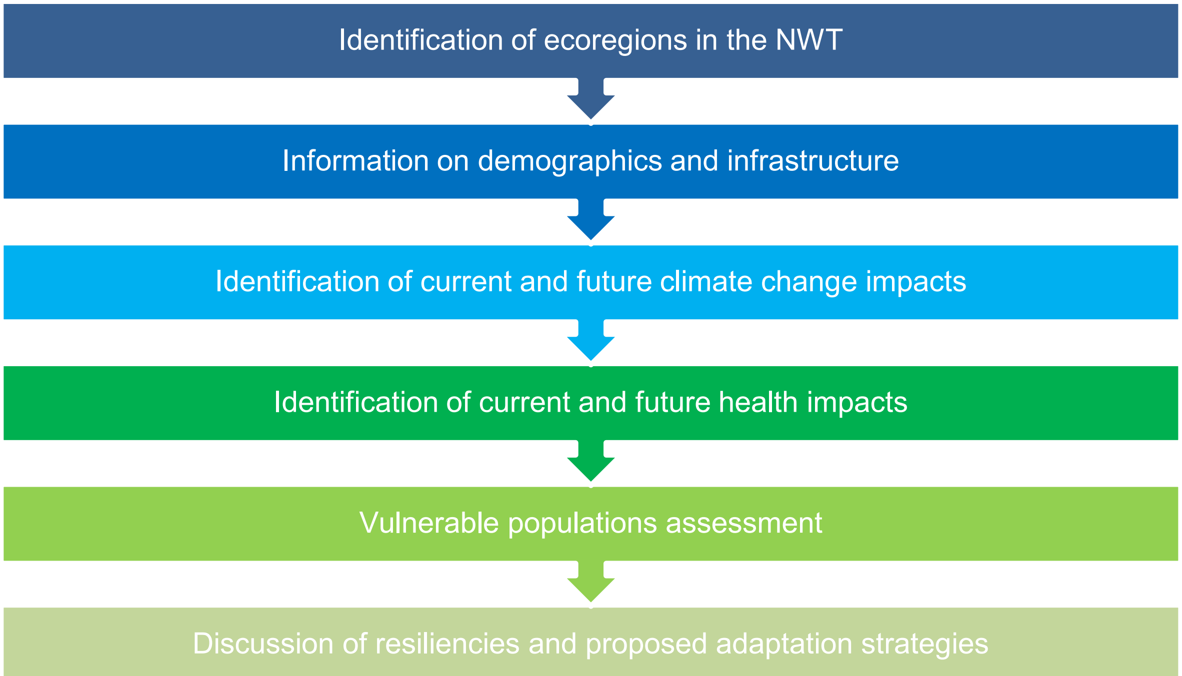

Figure 1 Approach and Methodology used in the Climate Change and Health Vulnerability Assessment of the NWT

The third step in the assessment summarizes available desktop data and information related to climate change impacts in the NWT to provide an overview of the current and future climate change effects and impacts (**Section 4**). Where available, data by region are presented; however, in many cases information is only available for the NWT as a whole, or for the southern portions of the NWT. Each sub-section within **Section 4** also provides a summary of data limitations and gaps.

The fourth step in the assessment (**Section 5**) provides a discussion on the current and potential health impacts due to the climate change effects described in **Section 4** by utilizing data and information from the academic and grey literatures. Where possible, potential climate change-related health impacts specific to the NWT/Northern Canada are discussed. Following this, a discussion is provided on the populations in the NWT that are most vulnerable to the current and potential future health impacts identified in **Section 5**. The vulnerable populations assessment also includes a Gender-Based Analysis (GBA+) approach. Last, **Section 7** provides the adaptation assessment, where NWT-specific and other relevant adaptation strategies are proposed.

It is important to re-iterate that the subject matter experts consulted for this report provided invaluable feedback and insight into the report and helped the Project Team identify resources and information not available in the traditional academic and grey literatures. Finally, a review of the academic and grey literatures was a significant source of information relied upon in this assessment, as well as reports from the GNWT on climate change impacts, health and adaptation strategies.

3.0 REGIONS AND DEMOGRAPHICS

The overall climate trends and published findings on climate change and health projects have been organized in this report by the three ecoregions of the NWT, including: 1) The Northern Arctic, 2) The Southern Arctic, and 3) The Taiga Shield and Plains (see **Figure 2**). When available, data are presented according to those regions. This section includes a geographic overview of each region (including key demographic factors) that helps to further inform this human health assessment.

The ecoregion framework for continental North America includes four levels, from very large Level I ecoregions that represent ecosystems of global extent to relatively small Level IV ecoregions that represent ecosystems of several thousand square kilometers. Taiga Plains, Taiga Shield, Northern Arctic and Southern Arctic are Level II ecoregions (nested within the Level I ecoregions) and they are each are made up of Level III ecoregions, which are further described within each ecoregion section below. This information has been sourced from Ecoregion posters provided on the Northwest Territories Department of Environment and Natural Resources website (GNWT, n.d.).

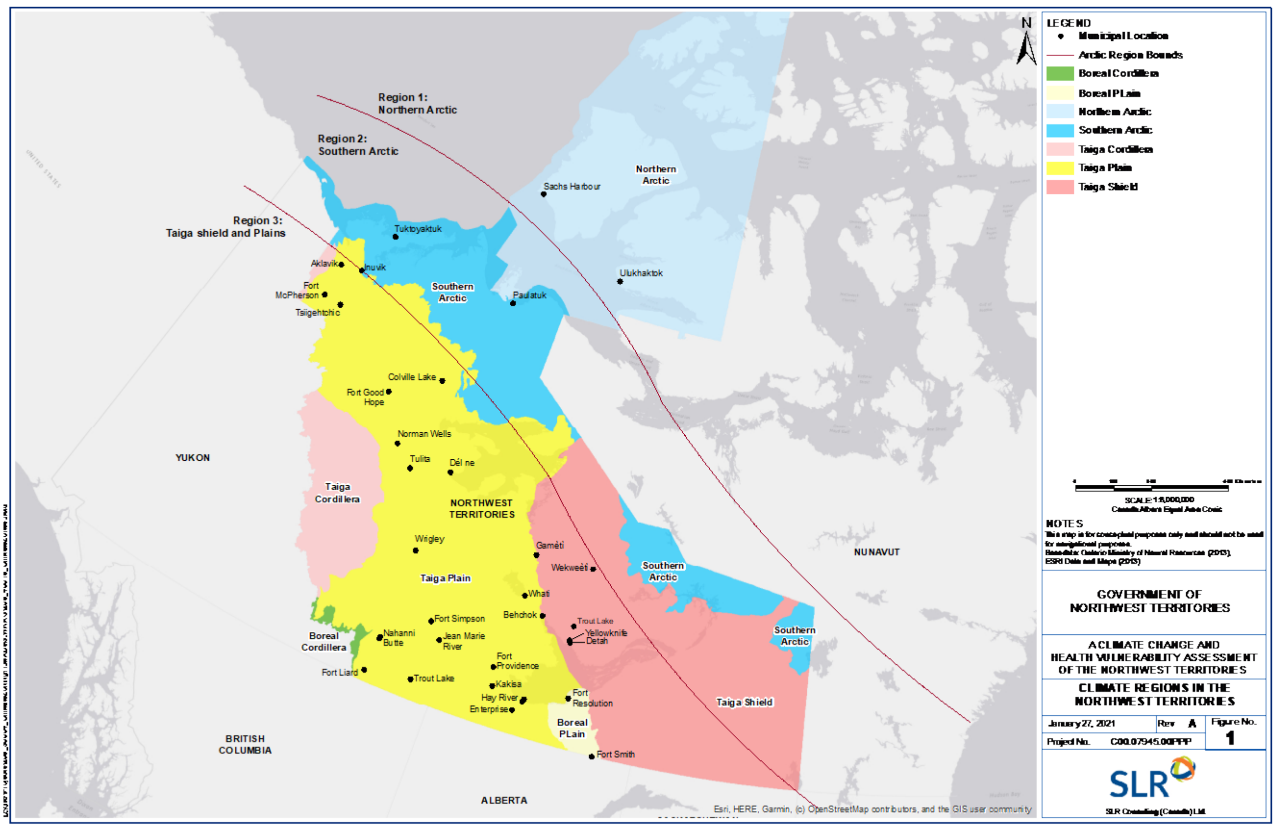

Figure 2 Climatic Regions in the Northwest Territories
Source: SLR, 2021

3.1 Eco-Region Descriptions

Three large, Level II eco-regions are referenced in this report, and include the Northern Arctic, the Southern Arctic, and the Taiga Shield and Plains Regions. This section includes general eco-region descriptions from Environment and Natural Resources Canada (last accessed December 2020) (GNWT, n.d.).

3.1.1 Region 1 – Northern Arctic

The Northern Arctic is made up of the following level III Ecoregions:

- Northern Arctic High Arctic-oceanic (HAo);
- Northern Arctic High Arctic (HA);
- Northern Arctic Mid-Arctic (MA); and
- Northern Arctic Low Arctic-north (LAn).

3.1.1.1 Northern Arctic High Arctic-oceanic (HAo) Ecoregion

This region is a polar desert where vegetation (tundra) is restricted to small areas because of the extremely dry and cold conditions. It has a dense drainage network and most streams are ephemeral or intermittent with only a few narrow, shallow permanent creeks and rivers. The region includes a few scattered small ponds and semi-permanent snow patches (GNWT, n.d.).

3.1.1.2 The Northern Arctic High Arctic (HA) Ecoregion

This region is surrounded by pack ice year-round. The climate is only slightly less extreme than the High Arctic-oceanic Ecoregion. Tundra is absent or limited at high elevations and occurs only in warmer microclimate areas. Permafrost in this Region is continuous and there are several remnant ice caps. Peary caribou (endangered), the smallest North American caribou, are found only in this ecoregion (GNWT, n.d.).

3.1.1.3 The Northern Arctic Mid-Arctic (MA) Ecoregion

This region is a slightly more moderate in climate than the High Arctic Ecoregion. The two areas, Banks and Victoria islands, have distinctly different topography and geology. There are two main tundra including upland sites which have shrub tundra and wetter lowland sites which develop continuous sedge – grass – moss tundra. There is habitat for many mammals and birds, such as Arctic foxes, muskoxen, wolves and nesting and brood rearing habitat for lesser snow geese (GNWT, n.d.).

3.1.1.4 The Northern Arctic Low Arctic-north (LAn) Ecoregion

This region has low-shrub tundra communities and plant species typical of the mainland Low Arctic (GNWT, n.d.).

3.1.2 Region 2 – Southern Arctic

The Southern Arctic is made up of the following level III ecoregions:

- Tundra Plains (Low Arctic north (LAn), and
- The Tundra Shield (Low Arctic south (LAs).

3.1.2.1 The Tundra Plains (LAn) Ecoregion

This ecoregion is cold and dry and is made up of a landscape of coastal plains. It also has wet shrub and sedge tundra and dry rolling uplands and hills, and one of the highest concentrations of pingos (intrapermafrost ice-cored hills) in the world. There are also areas of continuous permafrost. This ecoregion has the calving grounds of three caribou herds:

- The Tuktoyaktuk Peninsula,
- The Cape Bathurst and
- The Bluenose West.

Cape Bathurst and Baillie Islands have a globally rare plant, the Hairy Northern Rockcress (Braya Pilosa). In Cape Parry, there is the only thick-billed murre bird colony in the western Canadian Arctic. The ecoregion has several major rivers including the Horton, Hornaday and Brock (GNWT, n.d.).

3.1.2.2 The Tundra Shield (LAs) Ecoregion

This region is slightly warmer and moister than the Tundra Plains. The main vegetation cover is the shrub tundra, and there is lichen tundra dominating extensive dry till deposits in the southeast. It supports taller and more diverse tundra vegetation than much of the Tundra Plains (LAn) Ecoregion. It is part of three major drainage areas, including the:

- Arctic,
- Mackenzie, and
- Hudson Bay.

Species of concern in this region include wolverines and grizzly bears.

3.1.3 Region 3 – Taiga Shield and Plains

3.1.3.1 Taiga Shield

The Taiga Shield is made up of the following ecoregions:

- Taiga Shield High Subarctic (HS),
- The Taiga Shield Low Subarctic (LS),
- The Taiga Shield High Boreal (HB), and
- The Taiga Shield Mid-Boreal (MB).

Taiga Shield High Subarctic (HS) Ecoregion

This region contains a variety of vegetation including open white and black spruce woodlands, shrub and lichen tundra, and sedge marshes and polygonal peat plateaus. Permafrost is continuous along the northern boundary but discontinuous where bedrock is interspersed with mineral soils. There are several large rivers including the Coppermine, Snare, Snowdrift, Taltson, Thelon and Dubawnt, and numerous smaller lakes. The Taiga Shield provides important fall and winter habitat for several major herds of barren-ground caribou which is a “keystone” species (GNWT, n.d.).

The Taiga Shield Low Subarctic (LS) Ecoregion

This region has black spruce-lichen woodlands and forests, and large burned areas regenerating with dwarf birch and black spruce. Drumlins can also be found in this region. The peatlands in the region are underlain by permafrost. Approximately one-quarter of the ecoregion is covered by water. The largest lakes are the East Arm of Great Slave Lake and Hottah Lake. The largest rivers include Snare, Lockhart, Snowdrift, Taltson, and Dubawnt. Some animal species present include White-crowned Sparrows and muskoxen (GNWT, n.d.).

The Taiga Shield High Boreal (HB) Ecoregion
This region contains mixed white spruce and trembling aspen forests, young jack pine stands on huge burns and open jack pine-spruce woodlands and lichen-shrub. Permafrost is discontinuous and typically associated with peatlands and fine-textured soils. Approximately one third of the area is covered by lakes. Major rivers include the Camsell, Snare, Yellowknife, Beaulieu, Snowdrift, Taltson and Tazin rivers. Animal and bird species include Timber wolves and Tundra wolves, barren-ground Caribou and Chipping Sparrows (GNWT, n.d.).

The Taiga Shield Mid-Boreal (MB) Ecoregion
It has a relatively warmer climate than the Taiga Shield (HS), (LS) and (HB) Ecoregions. Vegetation includes mixed wood, deciduous and coniferous forests and wetlands. Permafrost is less common compared to the Taiga Shield (HS), (LS) and (HB) Ecoregions. Peatlands cover approximately one-third of the Ecoregion.

The only large river is the Taltson River. The region supports the highest density of moose within the Taiga Shield and has the most northerly breeding population of American White Pelicans (GNWT, n.d.).

3.1.3.2 Taiga Plains
Taiga Plains is made up of the following Level III Ecoregions:

- Northern Great Bear Plains High Subarctic (HS),
- The Central Great Bear Plains Low Subarctic (LS),
- The Great Slave Uplands High Boreal (HB), and
- The Mackenzie and Slave Lowlands Mid-Boreal (MB).

Northern Great Bear Plains High Subarctic (HS) Ecoregion
There are some active permafrost features in this region. There are also slow-growing white and black spruce forests and regenerating ground birch resulting from extensive fires. This region has Canada’s largest delta, the Mackenzie delta. It also has the largest lake entirely within Canada, Great Bear Lake. There are various animal species including red foxes, muskoxen and boreal caribou (GNWT, n.d.).

The Central Great Bear Plains Low Subarctic (LS) Ecoregion
There are some permafrost features in this region. There is a mosaic of low-canopy black or white spruce and successional shrub lands and regenerating forests. There are extensive peatlands in poor drainage areas and mixed-wood, deciduous or conifer forests growing on warm and well-drained sites. Large lakes in this region include Lac la Martre, Keller and Blackwater lakes. Peregrin falcon and Willow ptarmigan occur seasonally in the region (GNWT, n.d.).

The Great Slave Uplands High Boreal (HB) Ecoregion
This region also contains some permafrost areas. Wet, poorly drained sites have low-canopy open black spruce, treed bogs, horizontal fens and peat plateaus. Mixed-wood, deciduous and conifer stands are on warmer and better-drained slopes. There are very few named lakes and no major rivers in the region. The cold-sulphur springs produce sparsely vegetated mineral plains with rare plant species (GNWT, n.d.).

The Mackenzie and Slave Lowlands Mid-Boreal (MB) Ecoregion

This region has the mildest climate in the Taiga Plains. There are deposits of peat on permanently frozen organic soils. There is black spruce and lichen cover on frozen soils, as well as moss, sedge and shrubby / treed fens. On better drained upland areas, there is a mix of deciduous, mixed-woods and coniferous forests. The Mackenzie, Liard, Slave and Hay rivers are the main watercourses. It has almost all of the optimal habitat and current populations of bison of the Northwest Territory (GNWT, n.d.).

3.2 Demographic and Infrastructure Information

The communities in the NWT are largely located within the Taiga Shield and Plains Region, though communities exist within all three regions. This section summarizes key demographic information for the communities in each of the regions, as obtained from the GNWT's Bureau of Statistics most recent (2018a) Community Profiles, Community Infrastructure Profiles (2013), and Community Survey (2014). A full data set can be found in **Appendix A.**

3.2.1 Region 1 – Northern Arctic

3.2.1.1 Population

The populations in the Northern Arctic communities are relatively low, and these communities are predominantly comprised of Indigenous people. From 2008 to 2018, the population in Sachs Harbour has been declining and aging, whereas the population in Ulukhaktok has been slightly increasing and is also aging.

Table 1 Northern Arctic Communities – Population and Aboriginal Identity

	Population (2018)								
	Total	Males	% of Total	Females	% of Total	Aboriginal	% of Total	Non-Aboriginal	% of Total
Northwest Territories	44541	22912	51%	21629	49%	22369	50%	22172	50%
Sachs Harbour	111	57	51%	54	49%	99	89%	12	11%
Ulukhaktok	444	216	49%	228	51%	402	91%	42	9%

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

Table 2 Northern Arctic Communities – Average Annual Growth

	Average Annual Growth (2008-2018)		
	Total Population	< 15 Yrs.	60 Yrs. & Older
Northwest Territories	-0.3	-0.5	5.2
Sachs Harbour	-1.1	-3.0	4.4
Ulukhaktok	0.3	-0.5	3.8

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

3.2.1.2 Income and Employment

Labour force data indicate that when compared to the NWT average, the communities in the Northern Arctic have lower participation and employment rates and higher unemployment rates. Data for Ulukhaktok indicate that in that community, there was a higher proportion of families with less than $30K in annual income and fewer families with greater than $75K annual income (GNWT, 2018a).

Table 3	Northern Arctic Communities – Labour Force		
	Labour Force (2016)		
	Participation Rate	Unemployment Rate	Employment Rate
Northwest Territories	74.1	10.6	66.2
Sachs Harbour	70.6	16.7	58.8
Ulukhaktok	60.3	22.9	48.3

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

Table 4	Northern Arctic Communities – Family Income	
	Family Income (2017)	
	% Families less than $30K	% Families more than $75K
Northwest Territories	12.9	66.2
Sachs Harbour	..	..
Ulukhaktok	25.0	25.0

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

3.2.1.3 Cost of Living

In the Northern Arctic communities, underemployment and lower incomes are further exacerbated by relatively high costs of living. Both communities face a 75% to nearly 100% increase in the cost of living compared to Edmonton and Yellowknife (GNWT, 2018a).

Table 5	Northern Arctic Communities – Cost of Living	
	Cost of Living	
	2018 Living Cost Diff. (Edm = 100)	2015 Food Price Index (YK = 100)
Sachs Harbour	192.5	174.6284
Ulukhaktok	192.5	186.4242

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

3.2.1.4 Traditional Activities

Community members in the Northern Arctic, on average, tend to engage more in traditional activities when compared to the average participation rates for the NWT. Hunting and fishing, spending time on the land, producing arts and crafts, and consuming country foods are generally more common in these communities than the Territorial average (GNWT, 2018a).

Table 6	Northern Arctic Communities – Traditional Activities			
	Traditional Activities (2014)			
	Hunted & Fished (%)	Trapped (%)	Produced Arts & Crafts (%)	Households Consuming Country
Northwest Territories	44.7	6.1	23.3	26.3
Sachs Harbour	68.7	9.1	40.3	61.2
Ulukhaktok	80.4	5.7	40.4	56.4

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

Table 7	Northern Arctic Communities – Traditional Activities from Community Survey (2014)		
	Did you know? Of People Aged 15+		
	Spent Nights on the Land	Hunted or Fished	Gathered Berries
Sachs Harbour	57%	69%	2%
Ulukhaktok	64%	80%	53%

Source: GNWT Bureau of Statistics, NWT Community Survey Results, 2014 (GNWT, 2014)

3.2.1.5 Education

On average, there are fewer individuals in the Northern Arctic Communities with a high school diploma or greater.

Table 8 Northern Arctic Communities - Education

	Education
	% with High School Diploma or More (2016)
Northwest Territories	72.6
Sachs Harbour	50
Ulukhaktok	46.6

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

3.2.1.6 Transportation and Infrastructure

As stated earlier, the communities in the Northern Arctic Regions are accessible by air, with no winter or all-season road access. Both communities do have, however, marine re-supply facilities for the shipping of goods and supplies during the ice-free season.

Table 9 Northern Arctic Communities – Transportation Infrastructure

	Transportation Infrastructure				
	All Weather Access Road	Winter Access Road	Marine Re-Supply Facility	Airport	Air Terminal Building
Sachs Harbour	No	No	Yes	Yes	Yes
Ulukhaktok	No	No	Yes	Yes	Yes

Source: GNWT Bureau of Statistics, Community Infrastructure Profiles, 2013 (GNWT, 2013)

3.2.1.7 Health Infrastructure

The communities in the Northern Arctic region are serviced by health centers, which offer varied levels of medical, dental, and mental health services across the Territory.

Table 10 Northern Arctic Communities – Health Infrastructure

	Health Infrastructure				
	Hospital	Medical Clinic	Health Centre	Health Cabin	Women's Shelter/Transition House
Sachs Harbour	No	No	Yes	No	No
Ulukhaktok	No	No	Yes	No	No

Source: GNWT Bureau of Statistics, Community Infrastructure Profiles, 2013

3.2.1.8 Housing Condition

Home ownership rates are lower in Northern Arctic Communities, compared to the average across the NWT. More houses are in need of major repair and house six people or more, and are in core need, compared the average reported across the NWT. Housing in core need could refer to houses that need major repair, do not contain enough bedrooms for the residents, or have costs that are higher than can be afforded by the residents.

Table 11 Northern Arctic Communities – Housing Condition

	Housing Condition, % of Households			
	Owned	In Core Need	Needing Major Repair	With Six or More Persons

Table 11	Northern Arctic Communities – Housing Condition			
	Housing Condition, % of Households			
	Owned	In Core Need	Needing Major Repair	With Six or More Persons
Northwest Territories	51%	20%	12%	6%
Sachs Harbour	20%	33%	20%	14%
Ulukhaktok	30%	34%	26%	11%

Source: GNWT Bureau of Statistics, NWT Community Survey Results, 2014

3.2.2 Region 2 – Southern Arctic

3.2.2.1 Population

The populations in the Southern Arctic communities are relatively low, and these communities are predominantly comprised of Indigenous people. From 2008 to 2018, the population in Paulaktuk has been declining but has experienced growth among children and youth and even some growth in older populations. The population in Tuktoyaktuk has been increasing and has experienced greater growth among older populations and some growth in younger populations (GNWT, 2018a).

Table 12	Southern Arctic Communities - Population and Aboriginal Identity								
	Population (2018)								
	Total	**Males**	**% of Total**	**Females**	**% of Total**	**Aboriginal**	**% of Total**	**Non-Aboriginal**	**% of Total**
Northwest Territories	44541	22912	51%	21629	49%	22369	50%	22172	50%
Paulatuk	302	160	53%	142	47%	265	88%	12	4%
Tuktoyaktuk	982	516	53%	466	47%	898	91%	42	4%

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

Table 13	Southern Arctic Communities – Average Annual Growth		
	Average Annual Growth (2008-2018)		
	Total Population	**< 15 Yrs.**	**60 Yrs. & Older**
Northwest Territories	0.3	-0.5	5.2
Paulatuk	-0.1	2.6	0.3
Tuktoyaktuk	0.8	0.5	2.9

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

3.2.2.2 Income and Employment

Labour force data indicate that when compared to the NWT average, the communities in the Southern Arctic have lower participation and employment rates and higher unemployment rates. Data indicate that in these communities, there are higher proportions of families with less than $30K in annual income and fewer families with greater than $75K annual income (GNWT, 2018a).

Table 14	Southern Arctic Communities – Labour Force		
	Labour Force (2016)		
	Participation Rate	Unemployment Rate	Employment Rate
Northwest Territories	74.1	10.6	66.2

Table 14	Southern Arctic Communities – Labour Force		
	Labour Force (2016)		
	Participation Rate	Unemployment Rate	Employment Rate
Paulatuk	69.0	24.1	52.4
Tuktoyaktuk	56.2	26.4	43.0

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

Table 15	Southern Arctic Communities - Family Income	
	Family Income (2017)	
	% Families less than $30K	% Families more than $75K
Northwest Territories	12.9	66.2
Paulatuk	33.3	33.3
Tuktoyaktuk	26.1	30.4

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

3.2.2.3 Cost of Living

In the Southern Arctic communities, underemployment and lower incomes are further exacerbated by relatively high costs of living. Both communities face a 60% to 90% increase in the cost of living compared to Edmonton and Yellowknife (GNWT, 2018a).

Table 16	Southern Arctic Communities – Cost of Living	
	Cost of Living	
	2018 Living Cost Diff. (Edm = 100)	2015 Food Price Index (YK = 100)
Paulatuk	192.5	184.9
Tuktoyaktuk	162.5	162.0

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

3.2.2.4 Traditional Activities

Community members in the Southern Arctic, on average, tend to engage more in traditional activities when compared to the average participation rates for the NWT. Hunting and fishing, spending time on the land, producing arts and crafts, and consuming country foods are generally more common in these communities than the Territorial average (GNWT, 2018a).

Table 17	Southern Arctic Communities – Traditional Activities			
	Traditional Activities (2014)			
	Hunted & Fished (%)	Trapped (%)	Produced Arts & Crafts (%)	Households Consuming Country
Northwest Territories	44.7	6.1	23.3	26.3
Paulatuk	71.7	5.5	34.8	74.5
Tuktoyaktuk	66.0	8.4	28.0	61.1

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

Table 18	Southern Arctic Communities – Traditional Activities from Community Survey (2014)	
	Did you know? Of People Aged 15+		
	Spent Nights on the Land	Hunted or Fished	Gathered Berries
Paulatuk	65%	72%	28%
Tuktoyaktuk	65%	66%	55%

Source: GNWT Bureau of Statistics, NWT Community Survey Results, 2014

3.2.2.5 Education

On average, there are fewer individuals in the Southern Arctic Communities with a high school diploma or greater.

Table 18 Southern Arctic Communities - Education

	Education
	% with High School Diploma or More (2016)
Northwest Territories	72.6
Paulatuk	38.1
Tuktoyaktuk	39.8

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

3.2.2.6 Transportation and Infrastructure

Paulatuk is accessible by air only, with no winter or all-season road access. The community does have a marine re-supply facility for the shipping of goods and other supplies during the ice-free season. Tuktoyaktuk is also accessible by air and has a marine re-supply facility. It is also accessible year round by road from Inuvik, approximately 138 km away (GNWT, 2018a).

Table 19 Southern Arctic Communities – Transportation Infrastructure

	Transportation Infrastructure				
	All Weather Access Road	Winter Access Road	Marine Re-Supply Facility	Airport	Air Terminal Building
Paulatuk	No	No	Yes	Yes	Yes
Tuktoyaktuk	Yes	No	Yes	Yes	Yes

Source: GNWT Bureau of Statistics, Community Infrastructure Profiles, 2013
Note - the winter ice road in Tuktoyaktuk permanently closed in 2017 and has been replaced by an all-season road.*

3.2.2.7 Health Infrastructure

Paulatuk is serviced by a health center, which offers some medical, dental, and mental health services. Tuktoyaktuk has a women's shelter/transition house and a medical clinic which is staffed with four nurses.

Table 20 Southern Arctic Communities - Health Infrastructure

	Health Infrastructure				
	Hospital	Medical Clinic	Health Centre	Health Cabin	Women's Shelter/ Transition House
Paulatuk	No	No	Yes	No	No
Tuktoyaktuk	No	Yes (4 Nurses)	No	n/a	Yes

Source: GNWT Bureau of Statistics, Community Infrastructure Profiles, 2013

3.2.2.8 Housing Condition

Home ownership rates are lower in Southern Arctic Communities, compared to the average across the NWT. In Paulatuk, more houses are in need of major repair and house six people or more, and are in core need, compared the average reported across the NWT. Housing in core need could refer to houses that need major repair, do not contain enough bedrooms for the residents, or have costs that are higher than can be afforded by the residents. In Tuktoyaktuk, home ownership rates are lower than the Territorial average, but the housing needs are also lower.

Table 21	Southern Arctic Communities – Housing Condition			
	Housing Condition, % of Households			
	Owned	In Core Need	Needing Major Repair	With Six or More Persons
Northwest Territories	51%	20%	12%	6%
Paulatuk	33%	30%	29%	8%
Tuktoyaktuk	22%	17%	11%	8%

Source: GNWT Bureau of Statistics, NWT Community Survey Results, 2014

3.2.3 Region 3 – Taiga Shield and Plains

There are 29 communities in the Taiga Shield and Plans Region, including the largest community of Yellowknife. The following sections summarize some key statistics for these two communities.

3.2.3.1 Population

The populations in the Taiga Shield and Plains communities are quite varied, as this is the region with the greatest number of communities. Most communities have a relatively low population with the exceptions of Forth Simpson, Fort Smith, Hay River, Behchokǫ̀, and Inuvik, each of which have anywhere from 1,000 to 4,000 residents. Yellowknife is the most densely populated area, with a population of over 20,000. The areas with lower populations also tend to be comprised predominantly of Indigenous people. As populations increase in these settlement areas, the populations tend to be comprised of an increasing number of non-Indigenous people (GNWT, 2018).

The population across these communities tend to experience a slight decline and an aging population. However, this trend is not uniform across the Taiga Shield and Plains communities. Norman Wells and Yellowknife have experienced the highest rates of growth in older populations from 2008 to 2018 and Tsiigehtchic has experienced the highest rates of growth among children and youth for the same time period (GNWT, 2018a).

Table 22	Taiga Shield and Plains Communities - Population and Aboriginal Identity								
	Population (2018)								
	Total	**Males**	**% of Total**	**Females**	**% of Total**	**Aboriginal**	**% of Total**	**Non-Aboriginal**	**% of Total**
Northwest Territories	4454 1	22912	51%	21629	49%	22369	50%	22172	50%
Aklavik	623	311	50%	312	50%	584	94%	39	6%
Behchokǫ̀	2,010	1,028	51%	982	49%	1,865	93%	145	7%
Colville Lake	142	69	49%	73	51%	133	94%	x	n/a
Délı̨ne	576	315	55%	261	45%	526	91%	50	9%
Detah	233	120	52%	113	48%	227	97%	x	n/a
Enterprise	131	65	50%	66	50%	59	45%	72	55%
Fort Good Hope	570	307	54%	263	46%	511	90%	59	10%
Fort Liard	537	302	56%	235	44%	469	87%	68	13%
Fort McPherson	684	352	51%	332	49%	653	95%	31	5%
Fort Providence	719	406	56%	313	44%	641	89%	78	11%

Table 22 Taiga Shield and Plains Communities - Population and Aboriginal Identity

	Population (2018)								
	Total	Males	% of Total	Females	% of Total	Aboriginal	% of Total	Non-Aboriginal	% of Total
Fort Resolution	561	315	56%	246	44%	485	86%	76	14%
Fort Simpson	1,296	716	55%	580	45%	901	70%	395	30%
Fort Smith	2,709	1,376	51%	1,333	49%	1,598	59%	1,111	41%
Gamètì	301	158	52%	143	48%	293	97%	x	n/a
Hay River	3,824	1,963	51%	1,861	49%	1,759	46%	2,065	54%
Hay River Reserve	331	162	49%	169	51%	325	98%	x	n/a
Inuvik	3,536	1,754	50%	1,782	50%	2,293	65%	1,243	35%
Jean Marie River	89	x	n/a	x	n/a	x	n/a	x	n/a
Kakisa	41	x	n/a	x	n/a	x	n/a	x	n/a
Lutselk'e	319	180	56%	139	44%	280	88%	39	12%
Nahanni Butte	99	x	n/a	x	n/a	x	n/a	x	n/a
Norman Wells	818	430	53%	388	47%	299	37%	519	63%
Sambaa K'e (Trout Lake)	89	x	n/a	x	n/a	x	n/a	x	n/a
Tsiigehtchic	198	109	55%	89	45%	167	84%	31	16%
Tulita	531	299	56%	232	44%	441	83%	90	17%
Wekweètì	132	59	45%	73	55%	128	97%	x	n/a
Whatì	501	262	52%	239	48%	462	92%	39	8%
Wrigley	114	64	56%	50	44%	109	96%	x	n/a
Yellowknife	20,607	10,454	51%	10,153	49%	5,037	24%	15,570	76%

x - Data Suppressed
Source: GNWT Bureau of Statistics, Community Profiles, 2018a

Table 23 Taiga Shield and Plains Communities – Average Annual Growth

	Average Annual Growth (2008-2018)		
	Total Population	< 15 Yrs.	60 Yrs. & Older
Northwest Territories	0.3	-0.5	5.2
Aklavik	-0.1	1.6	2.6
Behchokǫ̀	0.1	-1.0	2.6
Colville Lake	-0.2	-2.3	x
Délı̨ne	0.7	-2.3	5.7
Detah	-0.5	-2.5	3.3
Enterprise	2.3	x	x
Fort Good Hope	0.2	1.8	0.0
Fort Liard	-0.6	-1.5	3.9
Fort McPherson	-1.6	-3.4	0.0
Fort Providence	-0.3	-4.6	5.5
Fort Resolution	0.9	-0.4	4.7
Fort Simpson	0.4	-2.2	4.7
Fort Smith	1.0	0.5	3.6
Gamètì	0.8	-1.4	3.7
Hay River	0.2	-1.8	4.1
Hay River Reserve	0.5	-1.6	x
Inuvik	-0.2	-0.8	4.8
Jean Marie River	x	x	x

Table 23	Taiga Shield and Plains Communities – Average Annual Growth		
	Average Annual Growth (2008-2018)		
	Total Population	**< 15 Yrs.**	**60 Yrs. & Older**
Kakisa	x	x	x
Lutselk'e	-0.3	-2.7	3.7
Nahanni Butte	x	x	x
Norman Wells	0.5	-0.8	8.1
Sambaa K'e (Trout Lake)	x	x	x
Tsiigehtchic	2.2	3.3	-0.7
Tulita	0.2	-1.5	6.0
Wekweètì	-0.8	-5.1	6.5
Whatì	0.4	-0.4	4.3
Wrigley	-1.2	x	x
Yellowknife	0.4	0.1	7.7
x - Data Suppressed			

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

3.2.3.2 Income and Employment

Labour force data indicate that when compared to the NWT average, most communities in the Taiga Shield and Plains have lower participation and employment rates and higher unemployment rates. These rates are relatively higher in the communities of Inuvik and Yellowknife, which are also government administration centers for the NWT and the Inuvialuit Settlement Region (GNWT, 2018).

Data indicate that there are some families with less than $30K in annual income and fewer families with greater than $75K annual income when compared to the Territorial average. There are also, however, a number of communities with fewer than average families with incomes less than $30K per year and more with annual incomes greater than $75K. These communities include: Norman Wells, Hay River, and Yellowknife (GNWT, 2018a).

Table 24	Taiga Shield and Plains Communities – Labour Force		
	Labour Force (2016)		
	Participation Rate	Unemployment Rate	Employment Rate
Northwest Territories	77.8	10.6	66.2
Aklavik	62.2	28.6	45.6
Behchokǫ̀	47.7	24.4	36.4
Colville Lake	61.1	18.2	50.0
Délı̨ne	67.9	29.8	47.6
Detah	63.9	34.8	44.4
Enterprise	64.7	18.2	52.9
Fort Good Hope	63.2	22.9	48.7
Fort Liard	51.9	32.5	36.4
Fort McPherson	60.9	25.4	44.5
Fort Providence	63.8	35.1	41.4
Fort Resolution	58.7	18.2	49.3
Fort Simpson	72.0	14.4	61.7
Fort Smith	67.8	12.4	59.9
Gamètì	59.5	16.0	50.0
Hay River	72.5	8.3	66.3

Table 24	**Taiga Shield and Plains Communities – Labour Force**		
	Labour Force (2016)		
	Participation Rate	Unemployment Rate	Employment Rate
Hay River Reserve	56.5	19.2	45.7
Inuvik	74.9	8.8	68.5
Jean Marie River	66.7	37.5	33.3
Kakisa	..	..	..
Lutselk'e	56.5	19.2	45.7
Nahanni Butte	66.7	20.0	53.3
Norman Wells	82.2	5.2	78.0
Sambaa K'e (Trout Lake)	76.9	30.0	53.8
Tsiigehtchic	69.6	25.0	56.5
Tulita	64.5	14.3	53.9
Wekweètì	55.6	20.0	61.1
Whatì	52.9	16.2	44.3
Wrigley	61.1	36.4	38.9
Yellowknife	82.5	5.9	77.6

.. Not available
Source: GNWT Bureau of Statistics, Community Profiles, 2018a

Table 25	**Taiga Shield and Plains Communities - Family Income**	
	Family Income (2017)	
	% Families less than $30K	% Families more than $75K
Northwest Territories	12.9	66.2
Aklavik	14.3	35.7
Behchokǫ̀	25.9	44.4
Colville Lake	..	..
Délı̨ne	14.3	42.9
Detah	..	..
Enterprise	..	..
Fort Good Hope	15.4	38.5
Fort Liard	26.7	20.0
Fort McPherson	30.0	40.0
Fort Providence	27.3	31.8
Fort Resolution	15.4	38.5
Fort Simpson	16.2	59.5
Fort Smith	13.2	64.7
Gamètì	37.5	50.0
Hay River	12.0	70.4
Hay River Reserve	..	..
Inuvik	18.5	59.8
Jean Marie River	..	..
Kakisa	..	..
Lutselk'e	37.5	25.0
Nahanni Butte	..	..
Norman Wells	11.1	77.8
Sambaa K'e (Trout Lake)	..	..
Tsiigehtchic	..	..
Tulita	23.1	38.5
Wekweètì	..	..

Table 25	Taiga Shield and Plains Communities - Family Income	
	Family Income (2017)	
	% Families less than $30K	% Families more than $75K
Whatì	15.4	53.8
Wrigley	..	..
Yellowknife	6.9	78.9

.. Not available
Source: GNWT Bureau of Statistics, Community Profiles, 2018a

3.2.3.3 Cost of Living

For most of the Taiga Shield and Plains communities, underemployment and lower incomes are further exacerbated by relatively high costs of living, though the spread is quite wide. Most communities face an 18% to nearly 100% increase in the cost of living compared to Edmonton and Yellowknife. Yellowknife itself has the lowest cost of living differential to Edmonton (GNWT, 2018).

Table 26	Taiga Shield and Plains Communities – Cost of Living	
	Cost of Living	
	2018 Living Cost Diff. (Edmonton = 100)	2015 Food Price Index (YK = 100)
Aklavik	162.5	170.5
Behchokǫ̀	127.5	143.9
Colville Lake	..	196.3
Délı̨ne	177.5	164.5
Detah	..	..
Enterprise	..	..
Fort Good Hope	177.5	166.9
Fort Liard	132.5	139.6
Fort McPherson	162.5	157.7
Fort Providence	137.5	134.7
Fort Resolution	152.5	144.0
Fort Simpson	142.5	129.2
Fort Smith	132.5	117.8
Gamètì	..	123.3
Hay River	127.5	121.3
Hay River Reserve	..	116.2
Inuvik	147.5	156.6
Jean Marie River	..	..
Kakisa	..	..
Lutselk'e	157.5	166.0
Nahanni Butte	147.5	139.4
Norman Wells	162.5	170.6
Sambaa K'e (Trout Lake)	..	144.1
Tsiigehtchic	167.5	170.3
Tulita	172.5	165.8
Wekweètì	..	144.8
Whatì	152.5	145.7
Wrigley	..	173.6
Yellowknife	122.5	100.0

.. Not available

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

3.2.3.4 Traditional Activities

Community members in the smaller communities in the Taiga Shield and Plains communities, on average, tend to engage more in traditional activities when compared to the average participation rates for the NWT. These rates were lowest in Yellowknife (GNWT, 2018a).

Table 27 Taiga Shield and Plains Communities – Traditional Activities

	Traditional Activities (2014)			
	Hunted & Fished (%)	Trapped (%)	Produced Arts & Crafts (%)	Households Consuming Country
Northwest Territories	44.7	6.1	23.3	26.3
Aklavik	59.8	14.9	24.3	71.6
Fort McPherson	54.0	7.6	23.5	76.9
Tsiigehtchic	63.1	15.2	28.3	76.5
Délı̨ne	57.5	16.6	36.7	80.1
Fort Good Hope	43.9	15.2	21.4	72.8
Norman Wells	39.4	2.8	27.3	26.7
Tulita	57.0	8.7	23.3	59.8
Fort Liard	62.7	14.5	29.7	64.6
Fort Providence	53.9	15.9	26.9	57.7
Fort Simpson	52.2	7.3	30.9	35.8
Hay River Reserve	55.0	9.1	20.4	62.1
Jean Marie River	71.6	45.1	54.9	73.3
Nahanni Butte	63.9	9.8	23.3	85.5
Sambaa K'e (Trout Lake)	84.8	47.7	47.1	84.8
Wrigley	76.8	23.4	31.5	62.5
Enterprise	45.8	3.5	27.5	6.9
Fort Resolution	62.2	19.3	23.3	56.0
Fort Smith	41.3	5.0	23.5	17.9
Hay River	48.0	5.6	23.0	14.7
Kakisa	57.5	27.6	25.9	86.7
Lutselk'e	79.9	19.2	34.8	77.5
Behchokǫ̀	40.5	10.7	25.4	58.9
Gamètì	52.9	13.5	33.0	82.0
Wekweètì	73.8	16.8	33.7	88.6
Whatì	55.4	16.3	36.1	59.8
Detah	37.2	15.7	30.9	78.9
Yellowknife	37.1	2.1	19.6	10.3
Inuvik	44.9	7.0	24.6	22.5
Colville Lake	78.6	45.1	37.4	81.8

Source: GNWT Bureau of Statistics, Community Profiles, 2018a

Table 28 Taiga Shield and Plains Communities – Traditional Activities from Community Survey (2014)

	Traditional Activities (2014)			
	Hunted & Fished (%)	Trapped (%)	Produced Arts & Crafts (%)	Households Consuming Country
Northwest Territories	44.7	6.1	23.3	26.3
Aklavik	59.8	14.9	24.3	71.6

Table 28 Taiga Shield and Plains Communities – Traditional Activities from Community Survey (2014)

	Traditional Activities (2014)			
	Hunted & Fished (%)	Trapped (%)	Produced Arts & Crafts (%)	Households Consuming Country
Behchokǫ̀	40.5	10.7	25.4	58.9
Colville Lake	78.6	45.1	37.4	81.8
Délı̨ne	57.5	16.6	36.7	80.1
Detah	37.2	15.7	30.9	78.9
Enterprise	45.8	3.5	27.5	6.9
Fort Good Hope	43.9	15.2	21.4	72.8
Fort Liard	62.7	14.5	29.7	64.6
Fort McPherson	54.0	7.6	23.5	76.9
Fort Providence	53.9	15.9	26.9	57.7
Fort Resolution	62.2	19.3	23.3	56.0
Fort Simpson	52.2	7.3	30.9	35.8
Fort Smith	41.3	5.0	23.5	17.9
Gamètì	52.9	13.5	33.0	82.0
Hay River	48.0	5.6	23.0	14.7
Hay River Reserve	55.0	9.1	20.4	62.1
Inuvik	44.9	7.0	24.6	22.5
Jean Marie River	71.6	45.1	54.9	73.3
Kakisa	57.5	27.6	25.9	86.7
Lutselk'e	79.9	19.2	34.8	77.5
Nahanni Butte	63.9	9.8	23.3	85.5
Norman Wells	39.4	2.8	27.3	26.7
Sambaa K'e (Trout Lake)	84.8	47.7	47.1	84.8
Tsiigehtchic	63.1	15.2	28.3	76.5
Tulita	57.0	8.7	23.3	59.8
Wekweètì	73.8	16.8	33.7	88.6
Whatì	55.4	16.3	36.1	59.8
Wrigley	76.8	23.4	31.5	62.5
Yellowknife	37.1	2.1	19.6	10.3

Source: GNWT Bureau of Statistics, NWT Community Survey Results, 2014

3.2.3.5 Education

On average, high school or equivalent educational attainment is lower in most of the Taiga Shield and Plains communities, when compared to the Territorial average. The exceptions to this include: Norman Wells, Enterprise, Hay River, Fort Smith, and Yellowknife (GNWT, 2018a).

Table 29 Taiga Shield and Plains Communities - Education

	Education
	% with High School Diploma or More (2016)
Northwest Territories	72.6
Aklavik	54.4
Behchokǫ̀	41.9
Colville Lake	33.3
Délı̨ne	51.2
Detah	36.1
Enterprise	76.5

Table 29	**Taiga Shield and Plains Communities - Education**
	Education
	% with High School Diploma or More (2016)
Fort Good Hope	46.8
Fort Liard	48.7
Fort McPherson	49.1
Fort Providence	45.7
Fort Resolution	50.7
Fort Simpson	74.6
Fort Smith	74.1
Gamètì	34.1
Hay River	75.0
Hay River Reserve	39.1
Inuvik	70.9
Jean Marie River	69.2
Kakisa	..
Lutselk'e	47.8
Nahanni Butte	33.3
Norman Wells	82.2
Sambaa K'e (Trout Lake)	61.5
Tsiigehtchic	65.2
Tulita	50.0
Wekweètì	57.9
Whatì	34.3
Wrigley	38.9
Yellowknife	85.5

.. Not available
Source: GNWT Bureau of Statistics, Community Profiles, 2018a

3.2.3.6 Transportation and Infrastructure

Like many small communities in the north, many of the small communities in the Taiga Shield and Plains communities are accessible by air, with some coastal communities having access to marine re-supply facilities for the delivery of goods and supplies during the ice-free season. However, a number of communities are also accessible by winter access road and all-season access road.

Table 30	**Taiga Shield and Plains Communities – Transportation Infrastructure**				
	Transportation Infrastructure				
	All Weather Access Road	Winter Access Road	Marine Re-Supply Facility	Airport	Air Terminal Building
Aklavik	No	Yes	No	Yes	Yes
Behchokǫ̀	Yes	No	No	No	No
Colville Lake	No	Yes	No	Yes	Yes
Délı̨ne	No	Yes	No	Yes	Yes
Detah	Yes	Yes	No	No	No
Enterprise	Yes	No	No	No	No
Fort Good Hope	No	Yes	No	Yes	Yes
Fort Liard	Yes	No	No	Yes	Yes
Fort McPherson	Yes	No	Yes	Yes	Yes

Table 30	Taiga Shield and Plains Communities – Transportation Infrastructure				
	Transportation Infrastructure				
	All Weather Access Road	Winter Access Road	Marine Re-Supply Facility	Airport	Air Terminal Building
Fort Providence	Yes	No	No	Yes	No
Fort Resolution	Yes	No	No	Yes	Yes
Fort Simpson	Yes	No	Yes	Yes	Yes
Fort Smith	Yes	No	No	Yes	Yes
Gamètì	No	Yes	No	Yes	Yes
Hay River	Yes	No	Yes	Yes	Yes
Hay River Reserve	Yes	No	No	No	No
Inuvik	Yes	No	Yes	Yes	Yes
Jean Marie River	Yes	No	Np	Yes	No
Kakisa	Yes	No	No	No	No
Lutselk'e	No	No	Yes	Yes	Yes
Nahanni Butte	No	Yes	No	Yes	No
Norman Wells	No	Yes	Yes	Yes	Yes
Sambaa K'e (Trout Lake)	No	Yes	No	Yes	No
Tsiigehtchic	Yes	No	Yes	No	No
Tulita	No	Yes	No	Yes	Yes
Wekweètì	No	No	No	Yes	Yes
Whatì	No	Yes	No	Yes	Yes
Wrigley	Yes	No	Yes	Yes	Yes
Yellowknife	Yes	No	No	Yes	Yes

Source: GNWT Bureau of Statistics, Community Infrastructure Profiles, 2013

3.2.3.7 Health Infrastructure

Health infrastructure in the Taiga Shield and Plains communities is varied, with the main medical center and hospital located in Yellowknife.

Table 31	Taiga Shield and Plains Communities - Health Infrastructure				
	Health Infrastructure				
	Hospital	Medical Clinic	Health Centre	Health Cabin	Women's Shelter/Transition House
Aklavik	No	No	Yes	No	No
Behchokǫ̀	No	No	Yes	No	No
Colville Lake	No	No	No	Yes	No
Déljne	No	No	Yes	No	No
Detah	No	No	No	No	No
Enterprise	No	No	No	No	No
Fort Good Hope	No	No	Yes	No	No
Fort Liard	No	No	Yes	No	No
Fort McPherson	No	No	Yes	No	No
Fort Providence	No	No	Yes	No	No
Fort Resolution	No	No	Yes	No	No
Fort Simpson	No	No	Yes	No	No
Fort Smith	No	Yes	Np	No	Yes
Gamètì	No	No	Yes	No	No
Hay River	Yes	Yes	No	No	Yes
Hay River Reserve	No	No	No	Yes	No
Inuvik	Yes	Yes	No	No	Yes

Table 31 Taiga Shield and Plains Communities - Health Infrastructure

	Health Infrastructure				
	Hospital	Medical Clinic	Health Centre	Health Cabin	Women's Shelter/Transition House
Jean Marie River	No	No	No	Yes	No
Kakisa	No	No	No	Yes	No
Lutselk'e	No	No	Yes	No	No
Nahanni Butte	No	No	No	Yes	No
Norman Wells	No	No	Yes	No	No
Sambaa K'e (Trout Lake)	No	No	No	Yes	No
Tsiigehtchic	No	No	Yes	No	No
Tulita	No	No	Yes	No	No
Wekweètì	No	No	No	Yes	No
Whatì	No	No	Yes	No	No
Wrigley	No	No	No	Yes	No
Yellowknife	Yes	Yes	No	No	Yes

Source: GNWT Bureau of Statistics, Community Infrastructure Profiles, 2013

3.2.3.8 Housing Condition

Housing stock is also varied across the Taiga Shield and Plains communities, with the lowest rates of core housing need being in Norman Wells, Hay River, Yellowknife, Inuvik, Fort Simpson, Fort Smith, and Wekweètì.

Table 32 Taiga Shield and Plains Communities – Housing Condition

	Housing Condition, % of Households			
	Owned	In Core Need	Needing Major Repair	With Six or More Persons
Northwest Territories	51%	20%	12%	6%
Aklavik	32%	24%	21%	8%
Behchokǫ̀	51%	44%	37%	28%
Colville Lake	75%	39%	39%	28%
Délı̨ne	34%	34%	21%	6%
Detah	55%	38%	38%	7%
Enterprise	79%	21%	14%	11%
Fort Good Hope	55%	34%	39%	11%
Fort Liard	66%	31%	22%	5%
Fort McPherson	46%	24%	21%	9%
Fort Providence	48%	31%	25%	7%
Fort Resolution	57%	25%	28%	8%
Fort Simpson	52%	19%	9%	5%
Fort Smith	61%	17%	12%	6%
Gamètì	63%	49%	46%	20%
Hay River	66%	8%	10%	3%
Hay River Reserve	76%	40%	42%	12%
Inuvik	35%	14%	6%	3%
Jean Marie River	76%	27%	13%	13%
Kakisa	68%	31%	37%	0%
Lutselk'e	41%	30%	34%	8%
Nahanni Butte	83%	24%	13%	3%
Norman Wells	38%	9%	12%	3%
Sambaa K'e (Trout Lake)	85%	35%	6%	6%
Tsiigehtchic	47%	31%	29%	0%
Tulita	41%	24%	15%	10%
Wekweètì	78%	18%	18%	12%

Table 32 Taiga Shield and Plains Communities – Housing Condition

	Housing Condition, % of Households			
	Owned	In Core Need	Needing Major Repair	With Six or More Persons
Whatì	69%	48%	39%	22%
Wrigley	71%	46%	41%	10%
Yellowknife	52%	18%	7%	4%

Source: GNWT Bureau of Statistics, NWT Community Survey Results, 2014

3.2.4 Summary of Data Limitation and Gaps

The information and data collected and presented in this section was from the GNWT's Bureau of Statistics. Other sources, such as government reports and presentations, might be able to supplement these profiles. Outreach and interviews would also be able to verify and update the inventory of health, community, and other infrastructure in each community.

4.0 CURRENT AND FUTURE CLIMATE CHANGE EFFECTS AND IMPACTS

This section summarizes available desktop data and information related to climate change impacts in the NWT. Where possible, data by region are presented. However, in many cases information is only available for the NWT as a whole, or for the southern portions of the NWT. This is a key data gap.

We recognize that this section draws solely on western scientific sources of data, through scientific reports and government data sources. We also recognize that Indigenous Knowledge is a key source of information that may complement or refute this western body of knowledge. However due to limited access to these records and the limited scope of this study, we regretfully cannot include Indigenous Knowledge of climate change in the NWT in this report. We recommend that future work consider how to best draw on and learn from Indigenous Knowledge to supplement this report.

4.1 Air Quality

According to the NWT Air Quality Monitoring Network reports, air quality in the NWT, in general, is good compared to other regions in Canada. However, human activities and natural events, such as forest fires, can cause the amount of particulate matter and chemicals such as nitrogen dioxide (NO_2) in the ambient air to increase. Particularly, the frequency and intensity of Canadian wildfires is increasing as a consequence of the changing global climate, as well as long-standing forest management practices (Flannigan et al., 2013). This is also true for the NWT. Due to limited data on air quality in the NWT, these data are presented here as a whole as opposed to by region.

4.1.1 Wildfires

According to the National Forestry Database for forest fires (Canadian Council of Forest Ministers, 2020), in the past 20 years, total forest area burned and number of forest fires in the NWT has shown an increasing trend. **Figure 3** indicates the trend of wildfires from 2000-2019, and, in particular, indicates an increase in forest area burned.

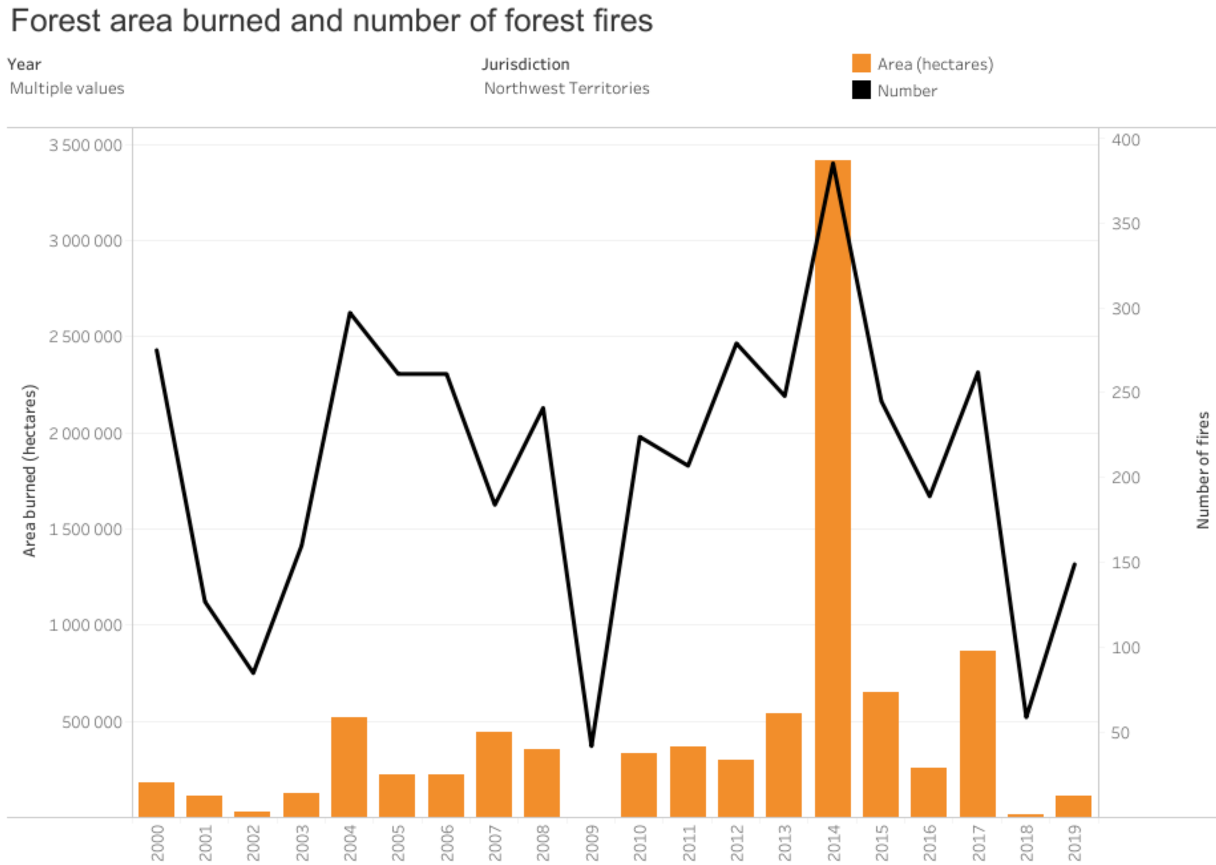

Figure 3 NWT Wildfires Within the Past 20 Years
Source: National Forestry Database, 2020

From studies by Environment and Natural Resources (ENR) of the NWT, although there are dramatic fluctuations in area burned and the number of annual fires, a linear regression shows a weak trend towards an increase in both the area burnt and the number of fires in recent 20 years (**Figure 3**). It is logically assumed that the frequency and intensity of fires will change as climate changes since a longer fire season associated with changes in precipitation and temperature coupled with additional stresses to forest and vegetation, such as drought, flooding, insects and disease, can enhance the potential for fires.

From regional perspective, the majority forest fires occur in **Region 3 – The Taiga Shield and Plains** as shown in **Figure 4**. (GNWT, 2018b)

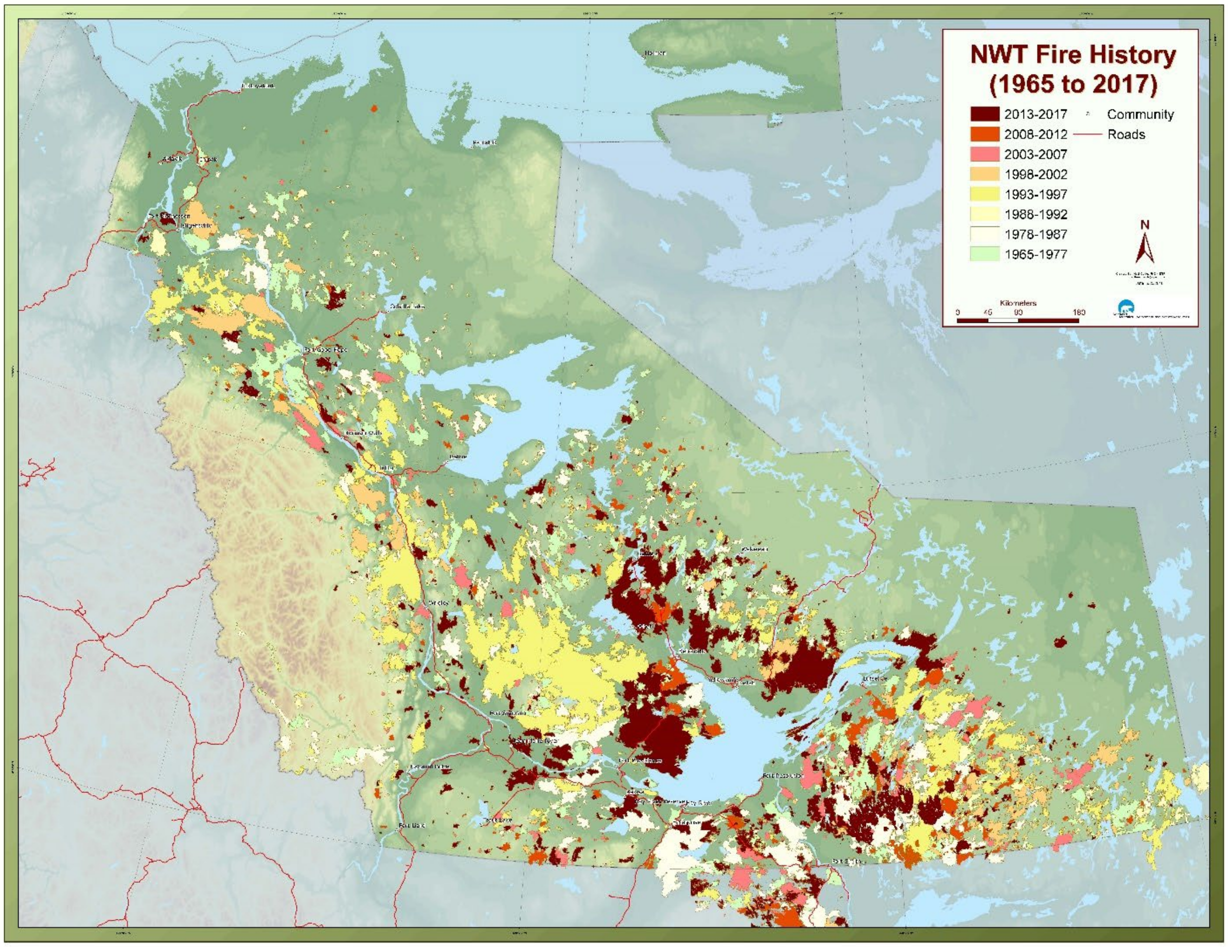

Figure 4 NWT Wildfire History by Geographic Distribution (1965-2017)
Source: NWT Centre for Geomatics, last accessed December 2020

4.1.2 Air Quality Trends

The NWT Ambient Air Quality Monitoring Network has been in operation for over a decade, and there is sufficient data to conduct longer term trend analyses. ENR's original four monitoring stations are small trailers holding highly specialized instruments that are continuously measuring particulate matter and chemicals in the air. All stations monitor levels of $PM_{2.5}$, PM_{10}, SO_2, NO_2 and O_3. At the Yellowknife (YK), Inuvik (IN) and Fort Smith stations (FS), ENR also monitors for CO, though this is not done at Norman Wells (NW). In recent years, more monitoring stations have been added. **Figure 5** shows the locations of NWT air quality monitoring stations. It is noticeable that the majority of air quality monitoring stations are located in **Region 3 – the Taiga Shield and Plains.**

Figure 5 **Air Quality Monitoring Stations in the NWT (ENR 2016)**
Source: ENR 2016

As mentioned above, air quality in the NWT is, in general, good compared to the rest of Canada. **Table 33** indicates NWT air quality standards and typical readings (ENR, 2016). Usual readings for the criteria air pollutants are much lower than the NWT's air quality standards (**Table 33**).

Table 33 GNWT Air Quality Standards & Typical Readings

Pollutant	Usual	Air Quality Standards		
		1-hr	8-hr	24-hr
SO_2	0 – 5 ppb	172 ppb		57 ppb
H_2S	0 – 2 ppb	10 ppb		3 ppb
O_3	10 – 40 ppb		63 ppb	
NO_2	0 – 10 ppb	213 ppb		106 ppb
CO	0 – 0.2 ppm	13 ppm	5 ppm	
$PM_{2.5}$	0 – 10 ug/m^3			28 ug/m^3
PM_{10}	0 - 15 ug/m^3			50 ug/m^3

Source: ENR, 2016

However, forest fires may spike air pollution readings during the fire season in the NWT which is usually from May to August. **Figure 6** compares the annual averaged $PM_{2.5}$ levels from the Yellowknife (YK), Norman Wells (NW), and Inuvik (IN) stations from 2005 to 2016. Fort Smith (FS) has only three years of data (ENR, 2016). **Figure 6** also demonstrates that the $PM_{2.5}$ levels in the NWT fluctuate annually, which is due to the major influence of forest fires, whose effects vary annually. The noticeable 2014 Yellowknife peak was directly caused by one of the worst forest fire events in the NWT history. The forest fire smoke that surrounded Yellowknife in 2014 caused the historically highest annual average $PM_{2.5}$ readings recorded at the Yellowknife station to date.

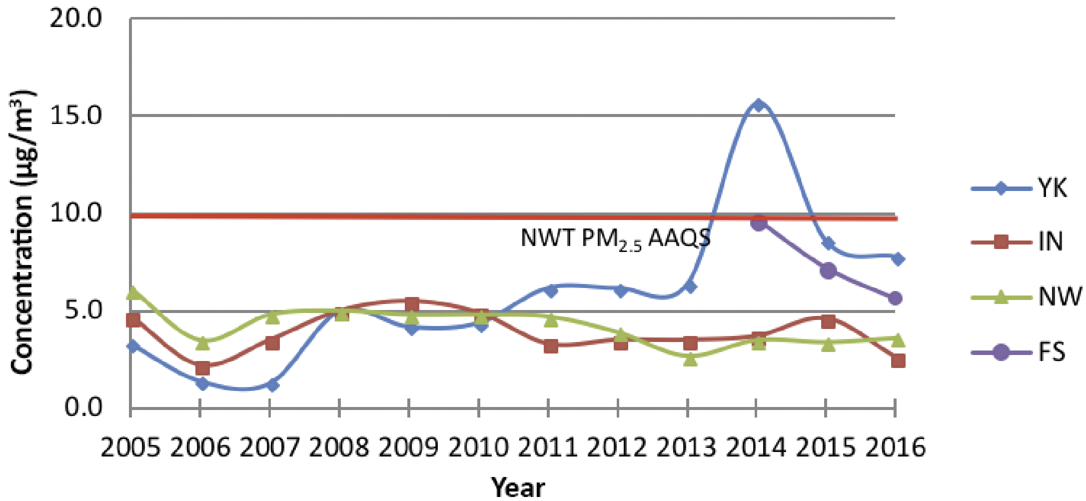

Figure 6 Annual Average PM2.5 Levels from 2005 to 2016
Source: ENR, 2016

It is difficult to identify long-term climate trends and the potential climate change impacts on air quality when air quality readings are largely dependent on forest fires. In order to assess the data without the natural and variable influences from fires, **Figure 7** presents the $PM_{2.5}$ averages for the years 2005 to 2016, excluding the May to August time frame when forest fires are normally most active. **Figure 7** demonstrates that when the seasonal influences from forest fire smoke are eliminated, the $PM_{2.5}$ levels in each of the NWT communities are generally consistent, with slight increases from year to year. Population growth with expansion of infrastructure in the NWT may also contribute to a slow increase in air pollution levels.

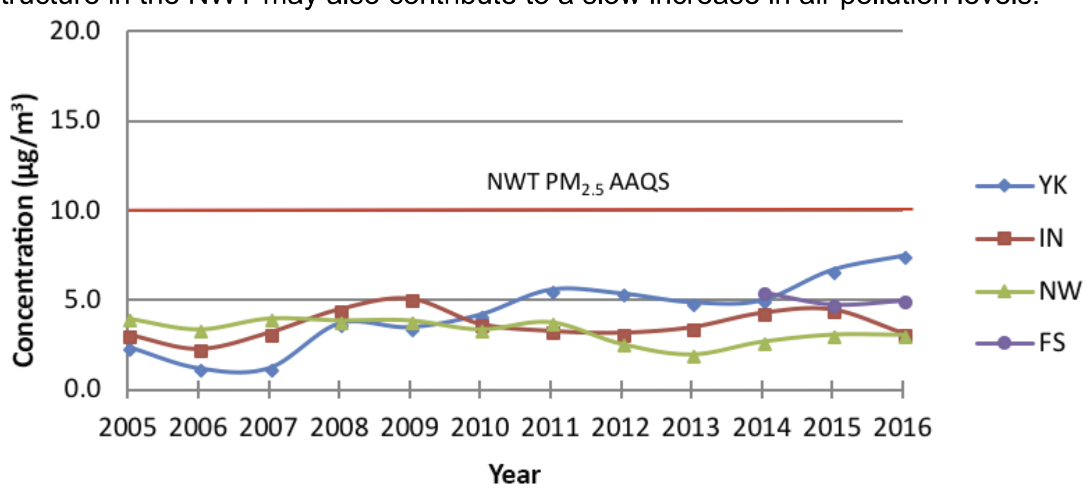

Figure 7 2005 to 2016 – PM2.5 Trends, Excluding May to August
Source: ENR, 2016

Other studies by ENR (2015, 2016) for other air pollutants such as NO_2, SO_2 and CO indicate a similar conclusion that air quality levels are generally consistent year by year in the NWT. However, a potential increase in forest fires due to climate change may result in decreased air quality in the long term, particularly in Region 3. Relatively, air quality is less impacted by forest fires and climate change in Regions 1 (Northern Arctic) and 2 (Southern Arctic), due to lack of forest coverage in colder climate zones.

4.1.3 Summary of Data Limitations and Trends

As stated throughout this section, the available air quality data for the NWT is largely dependent on a small number (four) of stations. Future air quality will depend on a combination of future forest fires, changes in population and land use, and human activities. At this moment, there are no accurate or available forecasts of either forest fires or air quality for the NWT, though it can be expected that current trends (a relatively weak increase) will continue.

One suggestion for future study is to use satellite remote sensing to provide data on air quality. The spatial gaps of ground monitoring resources are inevitable in the NWT, and satellite data are able to fill in air quality information in areas without ground monitoring. There are numerous satellite data that can indicate criteria air pollutants (e.g., $PM_{2.5}$ and NO_2) and greenhouse gases (e.g., CH_4 and CO_2). The selection of satellite data to address specific air quality issues depends on data accuracy and spatial and temporal resolution, among other factors. For example, ambient $PM_{2.5}$ concentrations can be estimated using NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) Aerosol Optical Depth (AOD, 10 km resolution) data and land use regression in the NWT. More satellite-based air quality data are available through the NASA's EarthData web portal[1].

4.2 Extreme Weather Events and Temperature

This section summarizes extreme weather and temperature projections for the NWT and the three Regions to 2100. The data are the summarized results from 24 different climate models used to simulate global climate change from the historical period (1850 – 2005) resulting from three climate emissions scenarios including a low, moderate, and high scenario up to 2100. These three scenarios result in a range of projections per parameter and in the case of the projections presented here, lower temperature and precipitation changes indicate lower range scenarios and higher changes indicate the high emissions scenarios. It is important to note that the high emissions scenario (RCP8.5) is widely used to characterize forecasts for the current and near terms and is most closely associated with a current "business as usual" trend in global climate emissions (Schwalm, Glendon, & Duffy, 2020)

4.2.1 Extreme Weather

Extreme weather events can include unexpected, unusual, severe, or unseasonal weather. It is often outside of the range of normal events that has been seen according to past meteorological records. Understanding and documenting extreme weather can include measuring the frequency, magnitude, and duration of such events as compared to the historical record for that location. This can include extreme precipitation, wind, drought, heat, and cold events. Most commonly, however, extreme weather includes references to increased severity and intensity of

[1] https://earthdata.nasa.gov/earth-observation-data/near-real-time/hazards-and-disasters/air-quality

precipitation events. These events can be highly disruptive and destructive to social and natural environments as well as increase the unpredictability within a given region.

In general, climate change has increased the probability of extreme events across Canada. With respect to precipitation, annual and winter precipitation is expected to increase in Canada within the next 100 years, with the largest changes anticipated for northern Canada. There is, however, little observational evidence of changes in extreme precipitation amounts.

Without a full review of the historical record of weather events in the NWT and in the absence of widely accepted parameters for “normal” events within the NWT, this review focuses on three precipitation related variables: average annual precipitation, maximum 1-day total precipitation, and the number of wet days greater than 20mm. These were identified based on our project team’s professional judgement and also on available data. Due to data limitations, only the high emissions scenario projections are shown for average annual precipitation, whereas low, medium, and high emissions scenario projections are shown as a range for maximum 1-day total precipitation and number of wet days greater than 20 mm.

In the Northwest Territories, from 1951 to 1980, average annual precipitation was 205 mm. Under a high emissions climate change scenario, this is projected to be 14% higher during the 2021-2050 period, 30% higher during the 2051-2080 period and 40% higher during last part of this century (ClimateData.ca, 2018-2020).

The following sections summarize precipitation projections for each of the regions in the NWT.

4.2.1.1 Region 1 – Northern Arctic

Average Annual Precipitation

For the Northern Region, which includes two communities with climate data, under a high emissions scenario, the average annual precipitation is projected to be 16% higher than current for the 2021-2050 period, 32% higher for the 2051-2080 period and 45% higher for the last 30 years of this century (ClimateData.ca, 2018-2020).

Table 34 Average Annual Precipitation (High Emissions Scenario) for Communities in Region 1 – Northern Arctic

	Average Annual Precipitation (High Emissions Scenario)			
	1951-1980	Increase to 2021-2050	Increase to 2051-2080	Increase to last 30 years of 21st C
Sachs Harbour	138 mm	17%	33%	47%
Ulukhaktok	168mm	14%	30%	42%

Source: climatedata.ca, 2018-2020

Average Maximum 1-Day Total Precipitation

For the Northern Region, maximum 1-day total precipitation is expected to increase in all emissions scenarios.

Table 35 Average Maximum 1-Day Total Precipitation for all Emissions Scenarios, for Communities in Region 1 – Northern Arctic

	Average Max 1-Day Total Precipitation		
	2020's	2050's	2080's
Sachs Harbour	8-11mm	10-14mm	13-15mm
Ulukhaktok	12-15mm	11-19mm	14-17mm

Source: climatedata.ca, 2018-2020

Average Wet Days

For the Northern Region, the average number of wet days with precipitation greater than 20mm is not expected to increase dramatically under any of the emissions scenarios. The highest emissions scenarios indicate a potential increase of up to two days per year by the 2080s for Ulukhaktok.

Table 36 Average Number of Wet Days Greater than 20mm for all Emissions Scenarios, for Communities in Region 1 – Northern Arctic

	Average Wet Days >20mm		
	2020's	2050's	2080's
Sachs Harbour	0-1 day	0-1 day	0-1 day
Ulukaktok	0-1 day	0-1 day	0-2 days

Source: climatedata.ca, 2018-2020

4.2.1.2 Region 2 – Southern Arctic

Average Annual Precipitation

For the Southern Region, which includes two communities with climate data, under a high emissions scenario, the average annual precipitation is projected to be 15% higher than current for the 2021-2050 period, 30% higher for the 2051-2080 period and 41% higher for the last 30 years of this century.

Table 37 Average Annual Precipitation (High Emissions Scenario) for Communities in Region 2 – Southern Arctic

	Average Annual Precipitation (High Emissions Scenario)			
	1951-1980	Increase to 2021-2050	Increase to 2051-2080	Increase to last 30 years of 21st Century
Paulatuk	173mm	15%	31%	41%
Tuktoyaktuk	161mm	15%	29%	41%

Source: climatedata.ca, 2018-2020

Average Maximum 1-Day Total Precipitation

For the Southern Region, maximum 1-day total precipitation is expected to increase in all emissions scenarios.

Table 38 Average Maximum 1-Day Total Precipitation for all Emissions Scenarios, for Communities in Region 2 – Southern Arctic

	Average Max 1-Day Total Precipitation		
	2020's	2050's	2080's
Paulatuk	11-13mm	11-15mm	10-18mm
Tuktoyaktuk	11-12mm	11-12mm	14-16mm

Source: climatedata.ca, 2018-2020

Average Wet Days

For the Southern Region, the average number of wet days with precipitation greater than 20mm is not expected to increase dramatically under any of the emissions scenarios. The highest emissions scenarios indicate a potential increase of up to two days per year by the 2080s for both communities.

Table 39 Average Number of Wet Days Greater than 20mm for all Emissions Scenarios, for Communities in Region 2 – Southern Arctic

	Average Wet Days >20mm

	2020's	2050's	2080's
Paulatuk	0-1 day	0-1 day	0-2 days
Tuktoyaktuk	0-1 day	0-1 day	0-2 days

Source: climatedata.ca, 2018-2020

4.2.1.3 Region 3 – Taiga Shield and Plains

For the Taiga Shield and Plains, which includes 26 communities with climate data, under a high emissions scenario, the average annual precipitation is projected to be 11% higher than current for the 2021-2050 period, 20% higher for the 2051-2080 period and 26% higher for the last 30 years of this century.

Average Annual Precipitation

Table 40 Average Annual Precipitation (High Emissions Scenario) for Communities in Region 3 – Taiga Shield and Plains

	Average Annual Precipitation (High Emissions Scenario)			
	1951-1980	Increase to 2021-2050	Increase to 2051-2080	Increase to last 30 years of 21st Century
Aklavik	251mm	12%	26%	32%
Behchokǫ̀	261mm	11%	19%	23%
Colville Lake	248mm	13%	23%	31%
Déline	274mm	11%	20%	27%
Detah	286mm	11%	19%	24%
Enterprise	335mm	12%	16%	24%
Fort Good Hope	276mm	12%	23%	32%
Fort Liard	384mm	9%	18%	22%
Fort McPherson	291mm	12%	24%	30%
Fort Providence	283mm	12%	18%	25%
Fort Resolution	307mm	11%	19%	23%
Fort Simpson	351mm	11%	19%	24%
Fort Smith	362mm	12%	17%	21%
Gamètì	238mm	12%	20%	27%
Hay River	335mm	12%	16%	24%
Inuvik	256mm	13%	26%	32%
Jean Marie River	327mm	10%	17%	23%
Kakisa	297mm	12%	17%	24%
Nahanni Butte	362mm	10%	18%	24%
Norman Wells	342mm	11%	20%	29%
Tsiigehtchic	266mm	12%	23%	29%
Tulita	314mm	11%	20%	27%
Wekweètì	258mm	12%	22%	29%
Whatì	259mm	12%	19%	25%
Wrigley	326mm	10%	18%	24%
Yellowknife	290mm	11%	19%	24%

Source: climatedata.ca, 2018-2020

Average Maximum 1-Day Total Precipitation

For the Taiga Shield and Plains, maximum 1-day total precipitation is expected to increase in all emissions scenarios.

Table 41 Average Maximum 1-Day Total Precipitation for all Emissions Scenarios, for Communities in Region 3 – Taiga Shield and Plains

	Average Max 1-Day Total Precipitation		
	2020's	2050's	2080's
Aklavik	13-16mm	14-16mm	13-18mm
Behchokǫ̀	13-17mm	17-20mm	17-20mm

Table 41 Average Maximum 1-Day Total Precipitation for all Emissions Scenarios, for Communities in Region 3 – Taiga Shield and Plains

	Average Max 1-Day Total Precipitation		
	2020's	2050's	2080's
Colville Lake	12-17mm	11-13mm	14-15mm
Déline	15-18mm	16-17mm	16-19mm
Detah	17-18mm	18-24mm	17-22mm
Enterprise	18-22mm	21-26mm	23-25mm
Fort Good Hope	15-19mm	15-21mm	19-20mm
Fort Liard	23-27mm	23-26mm	24-29mm
Fort McPherson	14-19mm	16-17mm	15-20mm
Fort Providence	15-21mm	17-20mm	18-21mm
Fort Resolution	16-21mm	19-22mm	18-25mm
Fort Simpson	23-26mm	24-26mm	19-30mm
Fort Smith	20-24mm	22-25mm	20-25mm
Gamètì	12-13mm	13-16mm	12-13mm
Hay River	19-30mm	20-28mm	21-28mm
Inuvik	13-17mm	14-15mm	16-19mm
Jean Marie River	20-22mm	19-23mm	19-25mm
Kakisa	15-19mm	16-19mm	19-20mm
Nahanni Butte	19-23mm	20-22mm	19-21mm
Norman Wells	19-20mm	21-23mm	22-26mm
Tsiigehtchic	12-15mm	12-14mm	12-15mm
Tulita	16-20mm	20-21mm	22-23mm
Wekweètì	13-15mm	12-16mm	14-17mm
Whatì	12-16mm	15-18mm	14-15mm
Wrigley	20-24mm	23-25mm	23-26mm
Yellowknife	17-19mm	19-25mm	19-24mm

Source: climatedata.ca, 2018-2020

Average Wet Days

For the Taiga Shield and Plains, the average number of wet days with precipitation greater than 20mm will vary by community. The highest emissions scenarios indicate a potential increase of up to six days per year by the 2080s in Fort Liard.

Table 42 Average Number of Wet Days Greater than 20mm for all Emissions Scenarios, for Communities in Region 3 – Taiga Shield and Plains

	Average Wet Days >20mm		
	2020's	2050's	2080's
Aklavik	0-1 day	0-1 day	0-2 days
Behchokǫ̀	0-1 day	0-1 day	0-2 days
Colville Lake	0-1 day	0-1 day	0-1 days
Déline	0-1 day	0-1 day	0-2 days
Detah	0-2 days	0-2 days	0-3 days
Enterprise	0-3 days	0-4 days	0-4 days
Fort Good Hope	0-1 day	0-2 days	0-3 days
Fort Liard	0-4 days	1-5 days	1-6 days
Fort McPherson	0-1 day	0-1 day	0-2 days
Fort Providence	0-2 days	0-2 days	0-2 days
Fort Resolution	0-2 days	0-2 days	0-3 days
Fort Simpson	0-4 days	0-3 days	0-5 days
Fort Smith	0-3 days	0-3 days	0-4 days
Gamètì	0-1 day	0-1 day	0-1 day
Hay River	0-3 days	0-3 days	0-3 days
Inuvik	0-1 day	0-1 day	0-2 days
Jean Marie River	0-3 days	0-3 days	0-4 days

Table 42	Average Number of Wet Days Greater than 20mm for all Emissions Scenarios, for Communities in Region 3 – Taiga Shield and Plains		
	Average Wet Days >20mm		
	2020's	2050's	2080's
Kakisa	0-2 days	0-2 days	0-2 days
Nahanni Butte	0-3 days	0-4 days	0-5 days
Norman Wells	0-2 days	0-3 days	0-3 days
Tsiigehtchic	0-1 day	0-1 day	0-2 days
Tulita	0-2 days	0-2 days	0-3 days
Wekweètì	0-1 day	0-1 day	0-1day
Whatì	0 days	0-1 day	0-1 day
Wrigley	0-1 day	0-2 days	1-3 days
Yellowknife	0-2 days	0-2 days	0-3 days

Source: climatedata.ca, 2018-2020

4.2.2 Temperature Extremes

Across Canada, annual and seasonal mean temperatures have increased in recent times, with the greatest of such increases happening in the winter months. Since 1948, it is estimated that annual temperatures in Canada have risen by 1.7ºC. This has been higher for northern Canada which has seen an increase of 2.3ºC for the same time period (Bush & Lemmen, 2019). Similarly, extreme temperatures (hot and cold) have increased over time and this is expected to continue over the coming Century.

In the NWT, for the 1951-1980 period, the annual average temperature was -13.1ºC; for 1981-2010 it was -11.1ºC. Under a high emissions scenario (see above regarding the likelihood of this scenario), annual average temperatures are projected to be -9.2ºC for the 2021-2050 period, -5.9ºC for the 2051-2080 period and -3.5ºC for the last 30 years of this century (ClimateData.ca, 2018-2020).

Temperature extremes can be measured by annual average temperatures, temperature for the hottest day of the year, and temperatures for the coldest day of the year. While average annual temperatures can indicate overall warming, both the extremes in hot and cold days can indicate a severity in annual temperature variances.

In Northern Communities, increases to extreme temperatures can have serious implications for permafrost stability, vector borne diseases, navigation, water quality, food security and many other facets of well-being. This section summarizes these trends using the high emissions scenario for average annual temperature (based on the best available data) and a range of scenarios for extreme hot and cold days to the 2080's.

4.2.2.1 Region 1 – Northern Arctic

Annual Average Temperature

For the Northern Region, which includes two communities with climate data, under a high emissions scenario, annual average temperatures are projected to be averaged -9.3ºC or the 2021-2050 period, -4.8ºC for the 2051-2080 period and -3.5ºC for the last 30 years of this century.

Table 43	Average Annual Temperature, Observed and Projected (High Emissions Scenario) for Region 1 – Northern Arctic Communities
	Average Annual Temperature, Observed and Projected (High Emissions Scenario), Degrees Celsius

	1951-1980	1981-2010	2021-2050	2051-2080	Last 30 Years of 21st Century
Sachs Harbour	-13.7	-12.4	-9.6	-6.5	-3.7
Ulukhaktok	-12.9	-11.3	-9.0	-5.9	-3.4

Source: climatedata.ca, 2018-2020

Median Hottest and Coldest Day Temperatures

In Region 1 communities, under a high emissions scenario, the hottest days are expected to increase in temperature and the coldest days are expected to become much milder.

Table 44 Median Range Temperatures, Hottest and Coldest Days, all Emissions Scenarios for Region 1 – Northern Arctic

	Median Range Temperature Projections			
		2020's	2050's	2080's
Sachs Harbour	*Median Range Hottest Day Temp*	16C to 21.9C	16C to 24C	15C to 25.2C
	Median Range Coldest Day Temp	-45.1C to -35.7C	- 44.9C to -31.1C	- 42.9C to -23.1C
Ulukhaktok	*Median Range Hottest Day Temp*	17.3C to 23.8C	17.0C to 28.2C	17.0C to 29.2C
	Median Range Coldest Day Temp	-44.1C to -37.5C	-43.3C to -33.5C	-42.3C to -25.8C

Source: climatedata.ca, 2018-2020

4.2.2.2 Region 2 – Southern Arctic

Annual Average Temperature

For the Southern Region, which includes two communities with climate data, under a high emissions scenario, annual average temperatures are projected to be averaged -7.0ºC for the 2021-2050 period, -3.8ºC for the 2051-2080 period and -1.5ºC for the last 30 years of this century.

Table 45 Average Annual Temperature, Observed and Projected (High Emissions Scenario) for Region 2 –Southern Arctic Communities

	Average Annual Temperature, Observed and Projected (High Emissions Scenario), Degrees Celsius				
	1951-1980	1981-2010	2021-2050	2051-2080	Last 30 Years of 21st C
Paulatuk	-10.8	-9.3	-7.1	-3.8	-1.7
Tuktoyaktuk	-10.8	-9.5	-6.9	-3.8	-1.3

Source: climatedata.ca, 2018-2020

Median Hottest and Coldest Day Temperatures

In Region 2 communities, under a high emissions scenario, the hottest days are expected to increase in temperature and the coldest days are expected to become much milder.

Table 46 Median Range Temperatures, Hottest and Coldest Days, all Emissions Scenarios for Region 2 – Southern Arctic

	Median Range Temperature Projections			
		2020's	2050's	2080's
Paulatuk	*Median Range Hottest Day Temp*	20.4C to 28.9C	20.4C to 31.0C	19.8C to 33.7C
	Median Range Coldest	-42.0C to -35.8C	-43.5C to -32.4C	-40.8C to -23.3C

	Day Temp			
Tuktoyaktuk	*Median Range Hottest Day Temp*	21.5C to 29.0C	22.0C to 31.1C	22.0C to 33.0C
	Median Range Coldest Day Temp	-44.6C to -36.4C	-44.7C to -32.4C	-42.1C to -22.1C

Source: climatedata.ca, 2018-2020

4.2.2.3 Region 3 – Taiga Shield and Plains

Annual Average Temperature

For the Taiga Shield and Plains, which include 26 communities with climate data, under a high emissions scenario, annual average temperatures are projected to be an average of -2.4ºC for the 2021-2050 period, 0.2ºC for the 2051-2080 period and 2ºC for the last 30 years of this century. Many communities in this region will expect to experience average annual temperatures above freezing.

Table 47 Average Annual Temperature, Observed and Projected (High Emissions Scenario) for Region 3 – Taiga Shield and Plains Communities

	Average Annual Temperature, Observed and Projected (High Emissions Scenario), Degrees Celsius				
	1951-1980	1981-2010	2021-2050	2051-2080	Last 30 Years of 21st Century
Aklavik	-9.3	-8.0	-5.8	-2.7	-0.6
Behchokǫ̀	-5.3	-4.4	-2.4	0.4	2.1
Colville Lake	-9.3	-7.9	-5.8	-3.0	-0.9
Déline	-7.0	-6.1	-3.9	-1.3	0.6
Detah	-5.2	-4.1	-2.2	0.5	2.3
Enterprise	-3.5	-2.5	-0.6	2.1	3.7
Fort Good Hope	-7.6	-6.1	-4.2	-1.6	0.4
Fort Liard	-2.1	-1.1	0.7	3.0	4.4
Fort McPherson	-8.3	-6.9	-5.0	-2.1	-0.1
Fort Providence	-3.8	-2.8	-0.9	1.8	3.5
Fort Resolution	-3.8	-3.0	-1.0	1.7	3.4
Fort Simpson	-3.8	-2.7	-0.8	1.7	3.4
Fort Smith	-3.0	-1.7	0.0	2.7	4.2
Gamètì	-6.6	-5.7	-3.5	-0.9	1.0
Hay River	-3.4	-2.4	-0.5	2.2	3.8
Inuvik	-9.6	-8.0	-5.9	-2.8	-0.6
Jean Marie River	-3.6	-2.5	-0.6	2.0	3.6
Kakisa	-3.7	-2.7	-0.8	1.9	3.5
Nahanni Butte	-3.4	-2.4	-0.5	1.8	3.3
Norman Wells	-5.8	-5.2	-2.9	-0.3	1.3
Tsiigehtchic	-8.5	-6.9	-5.0	-2.1	0.1
Tulita	-6.0	-5.0	-3.0	-0.4	1.3
Wekweètì	-8.3	-7.3	-5.3	-2.5	-0.7
Whatì	-5.9	-4.9	-2.8	-0.1	1.6
Wrigley	-4.9	-4.0	-2.0	0.5	2.1
Yellowknife	-5.3	-4.2	-2.3	0.4	2.2

Source: climatedata.ca, 2018-2020

Median Hottest and Coldest Day Temperatures

In Region 3 communities, under a high emissions scenario, the hottest days are expected to increase in temperature and the coldest days are expected to become much milder.

Table 48	Median Range Temperatures, Hottest and Coldest Days, all Emissions Scenarios for Region 3 – Taiga Shield and Plains			
	Median Range Temperature Projections			
		2020's	2050's	2080's
Aklavik	*Median Range Hottest Day Temp*	26.0C to 33.5C	25.7C to 33.4C	25.6C to 33.5C
	Median Range Coldest Day Temp	-49.6C to -37.9C	-46.7C to -33.9C	-45.6C to -26.4C
Behchokǫ̀	*Median Range Hottest Day Temp*	26.2C to 34.3C	26.6C to 35.1C	28.2C to 37.2
	Median Range Coldest Day Temp	-45.1C to -38.0C	-43.1C to -34.5C	-43.5C to -28.9C
Colville Lake	*Median Range Hottest Day Temp*	24.3C to 30.8C	24.1C to 32.0C	24.4C to 33.7C
	Median Range Coldest Day Temp	-46.5C to -37.1C	-45.3C to -33.6C	-46.6C to -29.2C
Déline	*Median Range Hottest Day Temp*	26.2C to 32.3C	26.0C to 34.0C	26.4C to 35.4C
	Median Range Coldest Day Temp	-45.2C to -39.2C	-43.3C to -33.8C	-45.5C to -30.0C
Detah	*Median Range Hottest Day Temp*	24.9C to 32.8C	25.4C to 34.3C	27.5C to 34.6C
	Median Range Coldest Day Temp	-45.3C to -37.9C	-42.8C to -34.1C	-42.1C to -28.3C
Enterprise	*Median Range Hottest Day Temp*	27.3C to 34.8C	28.3C to 36.9C	29.4C to 37.3C
	Median Range Coldest Day Temp	-47.5C to -38.5C	-43.1C to -35.1C	-43.9C to -27.2C
Fort Good Hope	*Median Range Hottest Day Temp*	29.3C to 34.4C	28.6C to 35.9C	29.2C to 37.5C
	Median Range Coldest Day Temp	-49.6C to -40.7C	-47.1C to -37.3C	-50.7C to -33.1C
Fort Liard	*Median Range Hottest Day Temp*	28.9C to 35.8C	29.3C to 36.4C	29.9C to 39.5C
	Median Range Coldest Day Temp	-45.2C to -36.1C	-43.5C to -32.2C	-41.9C to -25.2C
Fort McPherson	*Median Range Hottest Day Temp*	27.4C to 34.7C	27.5C to 34.2C	26.7C to 35.1C
	Median Range Coldest Day Temp	-50.4C to -39.2C	-47.0C to -34.9C	-47.3C to -27.8C
Fort Providence	*Median Range Hottest Day Temp*	27.6C to 35.6C	29.2C to 36.6C	30.0C to 37.8C
	Median Range Coldest Day Temp	-46.7C to -38.4C	-42.6C to -34.6C	-44.4C to -27.0C
Fort Resolution	*Median Range Hottest Day Temp*	26.1C to 33.7C	28.2C to 35.6C	28.7C to 36.1C
	Median Range Coldest Day Temp	-45.4C to -36.7C	-42.7C to -32.8C	-42.1C to -25.2C
Fort Simpson	*Median Range Hottest Day Temp*	29.4C to 36.2C	29.9C to 37.9C	30.4C to 39.1C
	Median Range Coldest Day Temp	-46.0C to -37.5C	-44.6C to -33.7C	-48.4C to -27.6C
Fort Smith	*Median Range Hottest Day Temp*	28.1C to 35.0C	28.9C to 37.4C	28.8C to 37.2C
	Median Range Coldest Day Temp	-45.5C to -38.0	-42.1C to -34.1C	-43.2C to -26.5C
Gamètì	*Median Range Hottest Day Temp*	25.6C to 33.0C	26.0C to 34.9C	27.4C to 35.8C
	Median Range Coldest Day Temp	-45.0C to -37.4C	-43.5C to -35.1C	-45.6C to -28.7C

Table 48	Median Range Temperatures, Hottest and Coldest Days, all Emissions Scenarios for Region 3 – Taiga Shield and Plains			
		Median Range Temperature Projections		
		2020's	2050's	2080's
Hay River	*Median Range Hottest Day Temp*	28.8C to 34.7C	28.2C to 37.6C	29.8C to 37.4C
	Median Range Coldest Day Temp	-45.6C to -37.4C	-41.5C to -33.7C	-42.5C to -25.3C
Inuvik	*Median Range Hottest Day Temp*	26.2C to 32.9C	26.2C to 34.2C	24.9C to 34.4C
	Median Range Coldest Day Temp	-49.2C to -38.7C	-48.0C to -34.8C	-46.4C to -26.9C
Jean Marie River	*Median Range Hottest Day Temp*	28.7C to 36.2C	29.6C to 37.8C	29.8C to 38.4C
	Median Range Coldest Day Temp	-48.1C to -37.7C	-45.2C to -33.3C	-46.3C to -27.6C
Kakisa	*Median Range Hottest Day Temp*	27.2C to 35.8C	28.9C to 36.2C	29.6C to 37.6C
	Median Range Coldest Day Temp	-46.3C to -38.0C	-42.8C to -34.8C	-44.3C to -27.0
Nahanni Butte	*Median Range Hottest Day Temp*	28.5C to 35.2C	28.7C to 36.3C	28.7C to 37.5C
	Median Range Coldest Day Temp	-48.2C to -36.6C	-46.0C to -33.9C	-43.4C to -27.4C
Norman Wells	*Median Range Hottest Day Temp*	29.2C to 34.0C	28.4C to 35.6C	29.4C to 37.3C
	Median Range Coldest Day Temp	-47.7C to -37.9C	-46.2C to -35.7C	-48.0C to -30.3C
Tsiigehtchic	*Median Range Hottest Day Temp*	27.6C to 34.6C	28.0C to 34.7C	26.5C to 35.7C
	Median Range Coldest Day Temp	-50.6C to -38.5C	-45.8C to -34.9	-47.6C to -28.6C
Tulita	*Median Range Hottest Day Temp*	28.6C to 34.0C	28.1C to 35.4C	28.8C to 37.8C
	Median Range Coldest Day Temp	-47.5C to -37.8C	-45.8C to -35.0C	-46.4C to -29.8C
Wekweètì	*Median Range Hottest Day Temp*	23.6C to 30.5C	23.5C to 32.6C	25.4C to 33.6C
	Median Range Coldest Day Temp	-45.9C to -38.8C	-45.1C to -36.1C	-43.6C to -29.5
Whatì	*Median Range Hottest Day Temp*	26.0C to 33.8C	26.7C to 35.5C	27.9C to 37.4C
	Median Range Coldest Day Temp	-45.5C to -38.0C	-43.7C to -34.9C	-45.6C to -28.8C
Wrigley	*Median Range Hottest Day Temp*	29.2C to 35.3C	29.3C to 37.4C	30.4C to 38.0C
	Median Range Coldest Day Temp	-48.2C to -38.4C	-45.4C to -35.6C	-47.4C to -29.4C
Yellowknife	*Median Range Hottest Day Temp*	26.5C to 32.8C	25.4C to 34.3C	27.4C to 34.7C
	Median Range Coldest Day Temp	-45.3C to -38.1C	-42.9C to -34.2C	-42.2C to -28.6C

Source: climatedata.ca, 2018-2020

4.2.3 Summary of Data Limitations and Gaps

The climate records and projections for temperature and extreme weather (precipitation) are relatively complete and comprehensive, compared to the other climate data for the NWT. Further study and models could look at the likelihood of specific types of storms with varying intensity, duration, wind speeds and other factors. However, at the time of this writing, those studies were not readily available. Meanwhile, applying satellite-based remote sensing data to analyze NWT temperature, moisture, cloud and other climatic variables could help understand climate change trends.

4.3 Exposure to Ultraviolet (UV) Radiation

Atmospheric ozone is vital to life on earth. The stratosphere contains the majority of atmospheric ozone, which shields the biosphere by absorbing Ultraviolet (UV) radiation from the sun. Anthropogenic chlorofluorocarbons are primarily responsible for the depletion of ozone in the stratosphere, particularly over the poles. Atmospheric dynamics and circulation strongly influence ozone amounts over the poles, which in normal conditions tend to be higher than over other regions on earth. During conditions of ozone depletion, however, ozone over the polar regions can be substantially reduced. This depletion is most severe in the late winter and early spring, when unperturbed ozone amounts are typically high. Ozone losses over the Arctic are also strongly influenced by meteorological variability and large-scale dynamical processes. Winter temperatures in the polar stratosphere tend to be near the threshold temperature for forming polar stratospheric clouds, which can accelerate ozone destruction, leading to significant and long-lasting depletion events. Because climate change due to increased GHGs is likely to lead to a cooling of the stratosphere, polar stratospheric cloud formation is likely to become more frequent in future years, causing episodes of severe ozone depletion to continue to occur over the Arctic regions, including the NWT.

The Arctic Climate Impact Assessment (ACIA) is a four-year project of the Arctic Council that started in 2000 and was completed in 2004 (Weller et al., 2005). The study used combined satellite and ground-based observations and found that mean spring and annual atmospheric ozone levels over the Arctic declined by 11% and 7%, respectively, between 1979 and 2000. These losses allowed more UV radiation to reach the surface of the earth. Individual measurements suggest localized increases in surface UV radiation levels, although high natural variability made it difficult to identify a conclusive trend.

Ozone levels over the Arctic are still difficult to project into the future, partly owing to the link with climate change. Current projections suggest that ozone over the Arctic is likely to remain depleted for several decades. This depletion would allow UV radiation levels to remain elevated for this time period. The elevated levels are likely to be most pronounced in spring, when many ecosystems are most sensitive to UV radiation exposure.

Within the NWT, it is likely that Region 1 (Northern Arctic) may experience the highest exposure to UV radiation, followed by Region 2 (Southern Arctic) and then Region 3 (Taiga Shield and Plains) due to relative latitude. Nevertheless, variations in UV radiation are also affected by other meteorological/climatic conditions. Cloud cover typically attenuates the amount of UV radiation reaching the surface of the earth. When the ground is snow-covered, this attenuation is diminished and UV radiation levels reaching the surface may increase due to multiple scattering between the surface and cloud base. Future changes in cloud cover are currently difficult to project but are likely to be highly regional.

Albedo is another key factor affecting UV radiation. Changes in snow and ice extent in the NWT affect the amount of UV radiation reflected by the surface. Reflection off snow can increase biologically effective UV irradiance by over 50% (Weller, et al, 2005). Regional terrain can also influence UV radiation. For example, snow-covered terrain can substantially enhance UV radiation exposure to the face or eyes, increasing cases of snow blindness and causing potential long-term skin or eye damage. Climate change is likely to alter snow cover and extent in the NWT. Reduced snow and ice cover may result in less reflection of UV radiation, decreasing the UV radiation levels affecting organisms above the snow.

4.3.1 Summary of Data Limitations and Gaps

As mentioned above, the factors affecting UV radiation within the NWT are varied and at this time, it is not possible to determine the exact magnitude and direction of these changes over time, based on available desktop data. Further and specialized studies to model these complex interactions at the site-specific scale could help to understand future changes, though these studies would be time and resource intensive.

4.4 Permafrost

Rapid warming in the NWT is resulting in the degradation and thawing of permafrost. Permafrost thawing will likely threaten buildings, roads, and other infrastructure. This includes increases in the settling and breaking of underground pipes and other installations used for water supply, heating systems, and waste disposal, and threats to the integrity of containment structures such as tailing ponds and sewage lagoons.

Figure 8 shows permafrost across Canada (ENR, 2014). In the NWT, extensive continuous permafrost is present in Regions 1 (Northern Arctic) and 2 (Southern Arctic), as described earlier. While Region 3 (Taiga Shield and Plains) is dominated by extensive discontinuous permafrost. Only the southern part of Region 3 has sporadic discontinuous permafrost. Tracking ground temperatures and active-layer monitoring in the NWT can give early-warning information on the degradation of permafrost.

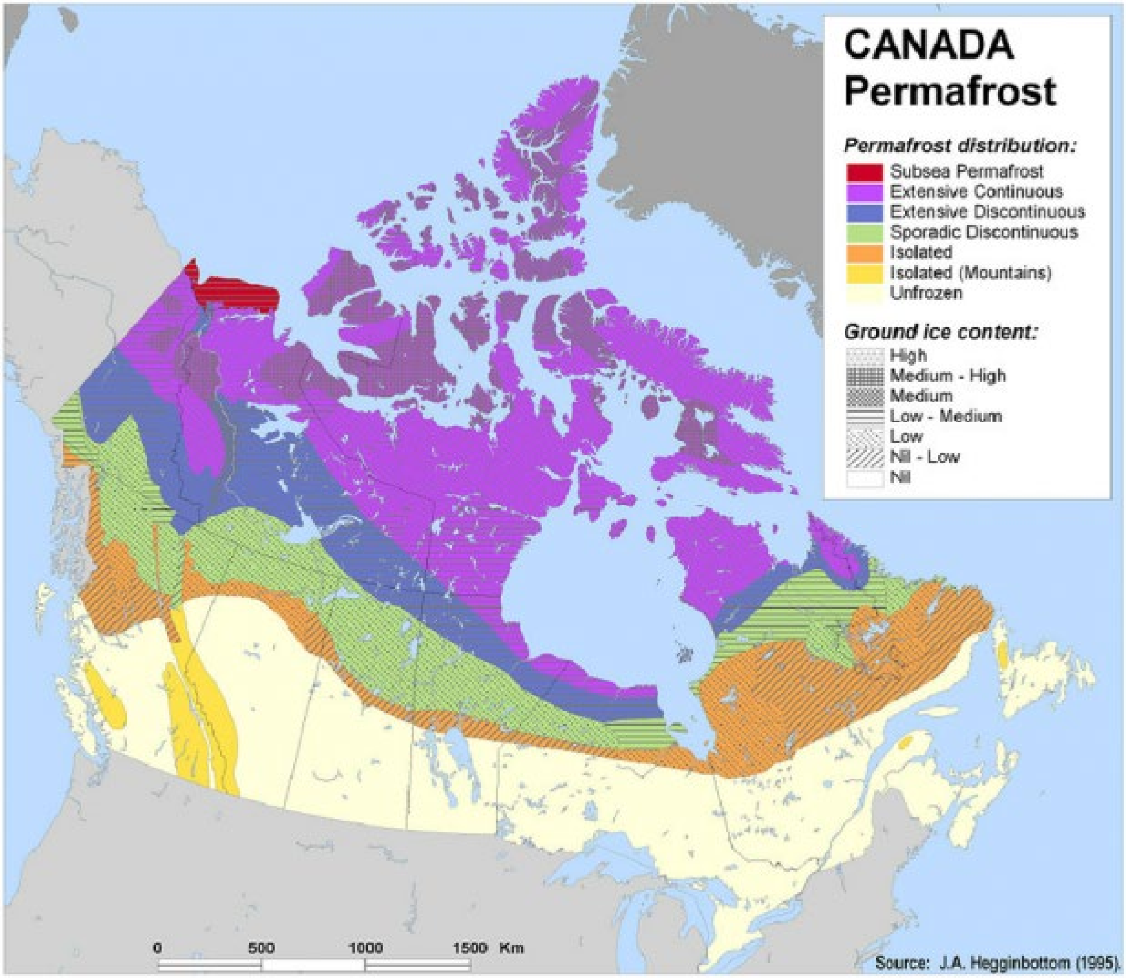

Figure 8 Permafrost in Canada
Source: ENR, 2014

Current research (Burn et al., 2006; 2009) indicates that the cumulative impacts of disturbance or ecological change will increase the effects of climate warming on permafrost.

Thermal modelling has shown that the majority of permafrost warming at abandoned oil and gas infrastructure in the western Arctic can be attributed to the increase in tall shrubs and snow accumulation, rather than due to rising air temperatures (Short et al., 2011). This study also illustrates that shrubbier tundra and enhanced snow cover will likely accelerate the warming of permafrost anticipated with climate change.

Duchesne and others (2020) in the *Report on 2018 field activities and collection of ground-thermal and active-layer data in the Mackenzie corridor, Northwest Territories*, indicate that ground temperature records for the 2007–2018 period indicate that permafrost is generally warming throughout the corridor. For a majority of sites, permafrost is currently warmer than the baseline established during the International Polar Year (2007–2009).

Although data records are not sufficient to assess long-term trends in ground temperatures, they can be used to characterize recent 10-year temperature fluctuations and the range of changes. For example, **Figure 9** demonstrates annual mean ground temperature (AMGT) at the measurement depth at or closest to depth of zero annual amplitude (ZAA) for selected permafrost sites in the discontinuous permafrost zone, in Region 3 (Taiga Shield and Plains). An obvious conclusion from **Figure 9** is that the ground is warming up over time. These changes in AMGT correspond with those acquired from longer records for the central Mackenzie Valley (Smith, Duchesne, & Lewkowicz, 2011) (Romanovsky et al., 2018) which indicate permafrost has been warming since the mid-1980s. Similar to sites in continuous permafrost in Regions 2 (Southern Arctic) and 1 (Northern Arctic), the increase in AMGT since 2010 at some sites may be the result of higher air temperatures in the last 9 years compared to those between 2007 and 2009 (**Figure 10**).

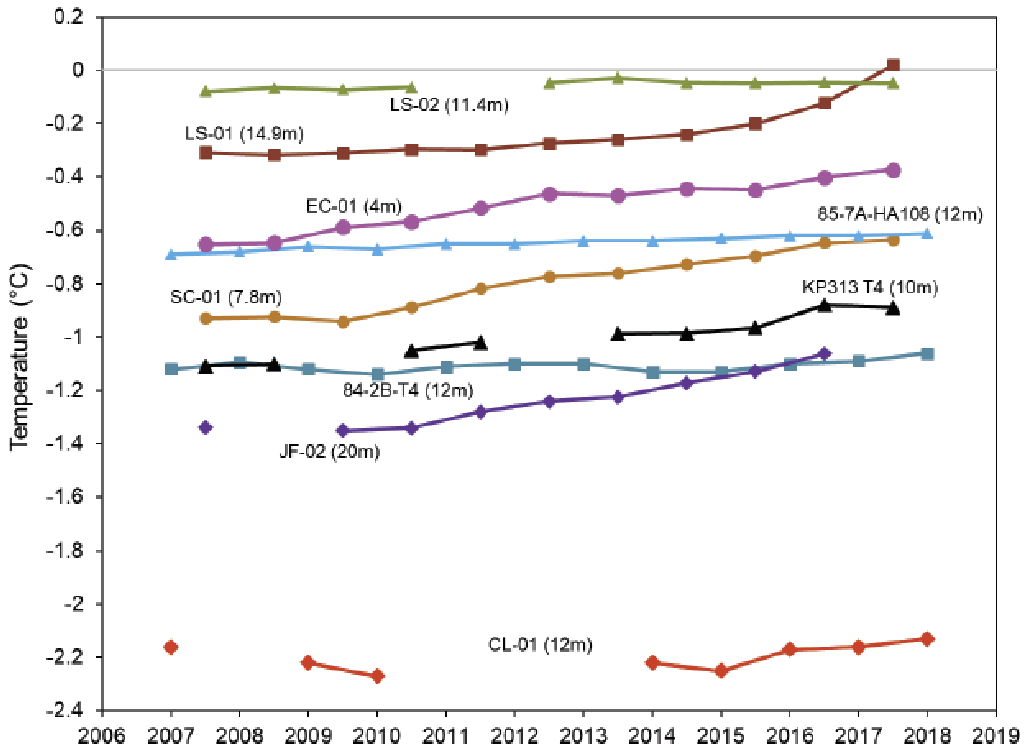

Figure 9 Annual Mean Ground Temperature (AMGT) at the Measurement Depth at or Closest to Depth of Zero Annual Amplitude (ZAA) for Selected Permafrost Sites in the Discontinuous Permafrost Zone

Source: Duchesne et al., (2020)

In general, it is anticipated that ground temperatures will continue to increase with future warming, but regional changes in vegetation or snow cover, or proximity of sites to water, may either enhance or slow the ground warming. Consequently, permafrost thawing will be expected along with the increase in ground temperature in the NWT.

Planning and managing development of northern infrastructure in the NWT and understanding environmental responses to climate warming require information on permafrost temperatures. Ongoing monitoring of permafrost by the GNWT is underway, and sharing of that information to help inform planning will help advance adaptation activities. At the time of this writing, however, this information was not readily available to the Project Team.

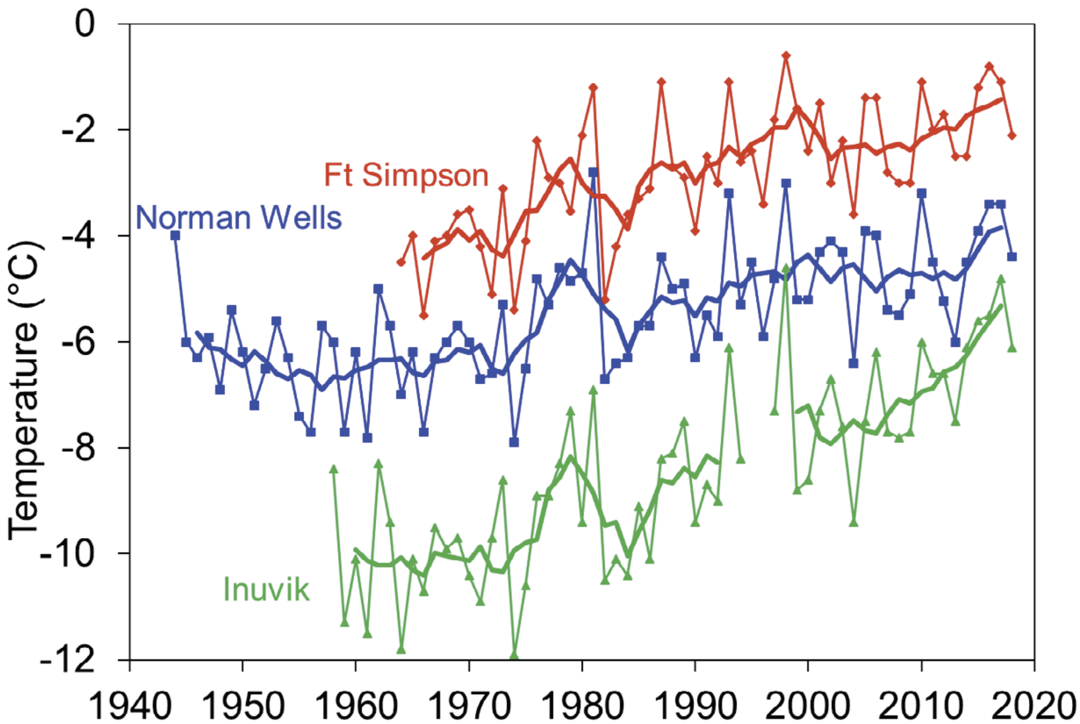

Figure 10 Annual Air Temperature for Weather Stations in the Mackenzie Valley
Source: Data from Environment Canada (Government of Canada, 2020)
Note: Thick lines represent the 5-year running mean

4.4.1 Summary of Data Gaps and Limitations

Permafrost monitoring is intensive and involves ground truthing and field study. While it can be expected that changes to permafrost will be strongly related to changes in air temperatures, site specific modeling and study can indicate with any certainty, permafrost projections over time. It is also possible to apply advanced global climate models to simulate and predict the changes in permafrost. For example, Yokohata and others (2020) conducted a series of studies to improve the modeling of permafrost processes in a state-of-the-art climate model by taking into account some of the relevant physical properties of soil such as changes in the thermophysical properties due to soil freezing. As a result, the improved version of the global land surface model was able to reproduce a more realistic permafrost model. The improved sharing of permafrost data will help to advance adaptation and impact studies.

4.5 Ice Infrastructure – thickness and extent

Overall, arctic sea ice extent has reduced in recent decades. On an annual basis arctic sea ice usually reaches its minimum each September. NASA satellite observations indicate that September Arctic sea ice is now declining at a rate of 13.1% per decade, relative to the 1981 to 2010 average.

Figure 11 shows the average monthly Arctic sea ice extent each September since 1979, derived from satellite observations.

Figure 11 Average September Arctic Sea Ice Minimum
(Source: Satellite observations - https://climate.nasa.gov/vital-signs/arctic-sea-ice/)

Information regarding change in sea ice in the NWT, however, has not been updated recently. Data provided by Environment Canada's Sea Ice Service, and the Fourth Assessment Report of the International Panel on Climate Change 2013 only reflect sea ice information in 2012 and earlier (https://www.enr.gov.nt.ca/en/state-environment/14-trends-arctic-sea-ice). Additional research and projections would be required to better understand sea ice conditions and future projections in the NWT.

5.0 CURRENT AND FUTURE HEALTH IMPACTS DUE TO CLIMATE CHANGE IN THE NWT

The potential health impacts of climate change are wide-ranging (**Figure 12**). This section discusses health impacts due to climate change and related issues identified in **Section 3** at a territorial level. The Ontario Climate Change and Health Toolkit was used to assist in the preparation of this section. The NWT Health Status Chartbook (GNWT, 2019b) was also used as a guide to identify current health status and morbidities in the NWT. In addition, a literature search was conducted on each major topic discussed in this section, including studies from the NWT and other northern and territorial jurisdictions. Where possible, effort was made to identify information related to how climate change is expected to affect human health, within an NWT context (e.g., Furgal and Seguin, 2006; Seguin, 2008; Furgal et al., 2008; Berry et al., 2014; Health Canada, 2019; Akearok et al., 2019; Bush and Lemmen, 2019; Elman et al., 2019). The subject matter experts consulted for this Project also provided valuable insight in identifying literature and information related to the potential health impacts due to climate change in the NWT.

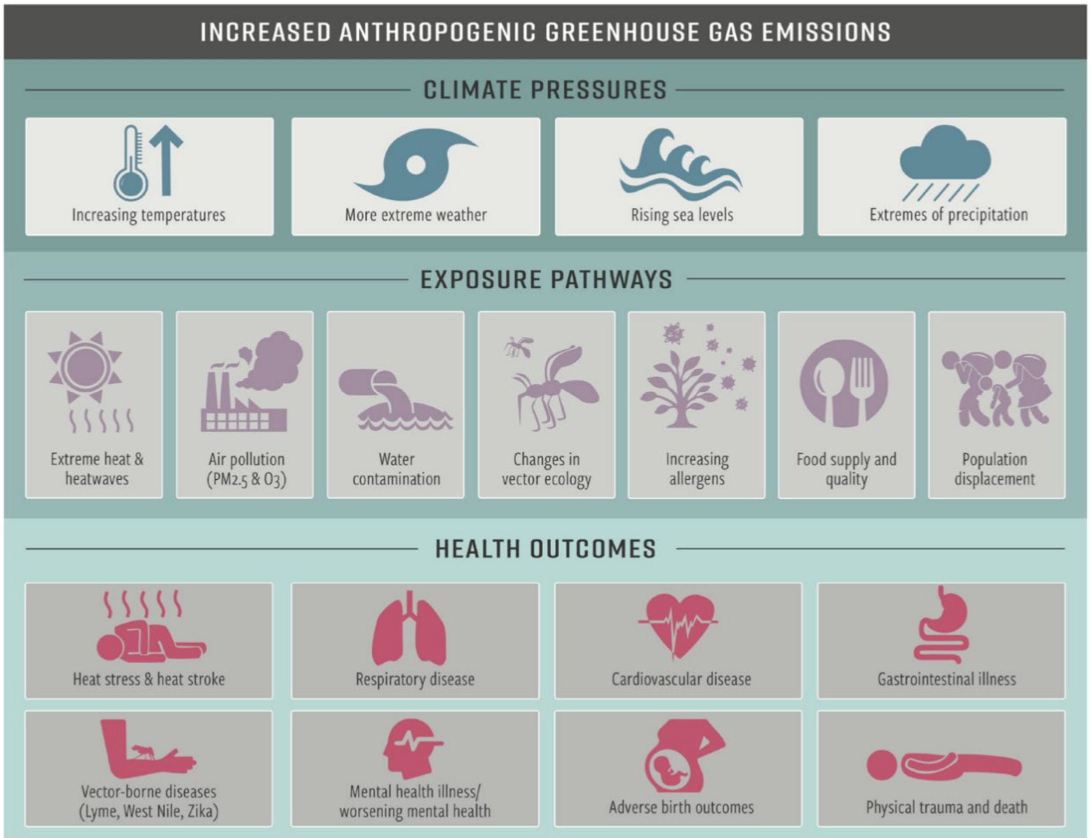

Figure 12 The Potential Health Impacts of Climate Change

(Source: Lancet Countdown, 2018. Figure created for Brief by M. Lee (Climate Nexus))

A limitation of this section, and this assessment as a whole, is the lack of meaningful engagement and consultation with communities, both Indigenous and non-Indigenous, in the NWT who experience the health impacts due to climate change. It is acknowledged that much of what is missing in this report can be gained by engaging local communities that experience the burden of climate change impacts and by listening to their lived experience realities related to health outcomes. Traditional and community knowledge from Indigenous communities has been included in this report only to the extent available in published reports and peer-reviewed literature. It is important to note that consultation with subject matter experts and inclusion of academic resources in this report should be followed up by engaging with communities across the NWT and ground-truthing the information presented in this report. Nevertheless, this assessment serves as an important first step in identifying key areas of climate change-related health impacts in the NWT, the populations most vulnerable to these impacts and potential adaptation strategies to embed resilience within communities in the territory.

In the following **Sections 5.1** to **5.9**, the potential health impacts due to climate change have been outlined, with reference to the NWT-specific context where possible.

5.1 Extreme Weather Events

As seen in **Section 4.1.1**, there is an increasing trend in the number of wildfires in the NWT and the forest area burned as a result. Flannigan and others (2013) found that the frequency and intensity of Canadian wildfires is increasing due to a changing global climate, which also impacts long-standing forest management practices. The NWT experienced its worst wildfire season since the 1990s in 2014, leading to the burning of three million hectares (40,000 square kilometres) of land in just one summer. **Section 4.2** provided a discussion not only on the criteria of extreme weather events such as frequency, magnitude, duration of events, increased severity, and intensity, but also how these extreme weather events can disrupt everyday lives due to their unpredictable nature. Although extreme weather events observed in the NWT can include storms, hurricanes, heatwaves and drought, it was wildland fires and floods that were deemed the top hazards in the territory (GWNT, 2018c).

The increasing unpredictability in the frequency and severity of extreme weather events indicates that there is potential for a simultaneous increase in injuries, illness and deaths experienced by communities as a result of extreme weather events (Berry et al., 2014; **Figure 13**). **Section 5.7** provides additional details on accidents and/or injuries in northern populations.

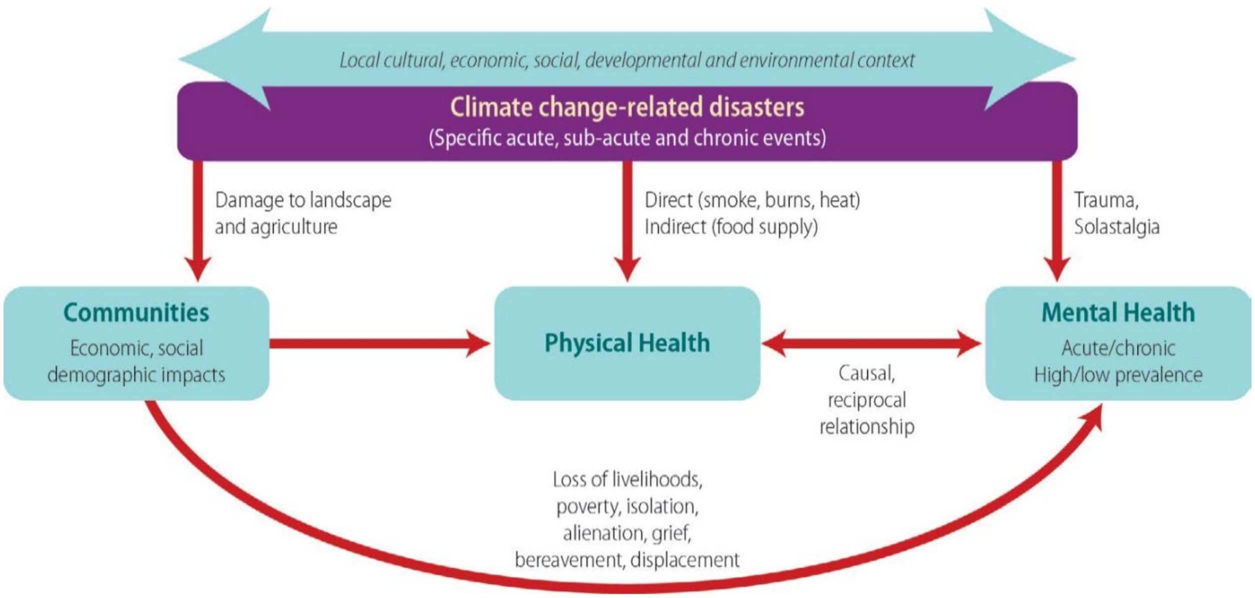

Figure 13 Possible direct and indirect impacts of extreme weather events on health and well-being
(Source: Berry et al., 2009)

The unpredictability of extreme weather events can further stress pre-existing health and social issues. While wildfires have been increasing, the need for clean air shelters during these extreme events is also increasing. Wildfires produce increasing amounts of heat that most homes in the NWT are not built for. Most homes in the territory have been designed and built to provide insulation against the cold. As such, even if temperatures in the NWT are not relatively high, people still feel the consequences (Subject Matter Expert Interview, February 2021). This heat from wildfires can lead to sickness in the community due to lack of proper ventilation. These housing issues may vary region to region, but if houses are not built for extreme weather events on opposite ends of the spectrum, i.e., from extreme cold, to relatively high temperatures due to wildfires, then people living in such housing conditions experience additional stressors (Subject Matter Expert Interview, February 2021). Extreme weather events due to climate change are compounding current problems in the NWT, which then impact people's mental and physical health.

The increase and unpredictability in extreme weather events can also have adverse impacts on traditional hunting and trapping grounds which could lead to a decrease in traditional economies

(GWNT, 2018c). The potential increase in severity and frequency of unpredictable weather and ice conditions may cause physical injury when travelling for hunting, fishing or trapping. Travel safety, access, and participation in traditional land-based and subsistence activities are at risk in the NWT due to unpredictable weather patterns (Furgal et al., 2008). Therefore, traditional and cultural activities, such as the sale of wild furs, have been negatively impacted (GNWT, 2018c). For Indigenous populations, mental health and other stress-related issues may also arise when participation in traditional land-based and subsistence activities are put at risk (Berry et al., 2014). Transportation infrastructure such as roads, bridges and airstrips are being affected as well as changes to navigable waters and air spaces (GWNT, 2018c). With these unpredictable extreme weather events occurring more frequently there is a heightened risk of injury and death on both land and sea (Furgal et al., 2008). Changes to transportation infrastructure as a result of extreme weather events may also interrupt health services or impact food security (**Section 5.8**). Extreme weather events such as floods, wildland fires, erosion, rapid permafrost thaw, critical infrastructure failure and transportation accidents can result in physical injuries, illnesses, and in some cases death (GWNT, 2018c).

Another extreme weather event experienced in the NWT is increased precipitation (**Section 4.2**). The 2008 NWT Climate Change Impacts and Adaptation Report outlines the effects that groundwater from increased precipitation has on building infrastructure (GNWT, 2008). Changes to infrastructure may result in damages and interruptions in health services leading to psychological health effects including mental health and stress-related illnesses (Seguin, 2008). These changing precipitation patterns are leading to significant flooding events in some areas, and extreme low water levels in others, causing restricted barge traffic (GNWT, 2008). Extreme weather events such as increased precipitation may also displace populations and create crowding in emergency shelters (Berry et al., 2014). Crowding and displacement can further worsen mental health impacts.

5.2 Air Quality

Climate change impacts not only temperature but air quality as well. **Section 4.1** discusses the by-products of wildfires, including particulate matter and nitrogen dioxide (NO_2). Wildfires, discussed further in **Section 5.1**, adversely impact the quality of ambient air as a result of the accompanying emissions. Smog formation, wildfires, pollen production and greater emissions of air contaminants are a number of events affecting the quality of air in Canadian communities (Berry et al., 2014).

Although the discussion in **Section 4.1.2** demonstrated that air quality in the NWT is generally good compared to the rest of Canada, wildfires create major spikes in air pollution readings during the fire season. This increase in smoke and particulates from wildfires due to climate change may result in decreased air quality in the long term (Seguin, 2008).

In general, air quality is a serious public health issue due to the impacts of air pollution on both the lungs and the respiratory tract. Individuals who suffer from respiratory illnesses are more vulnerable to adverse health impacts due to decreasing air quality. Other human health effects due to negative impacts of wildfires on air quality are increases in eye, nose and throat irritation, shortness of breath, exacerbation of respiratory conditions and allergies, chronic obstructive pulmonary disease, asthma, increased risks of cancer, and increased risk of cardiovascular diseases (Seguin, 2008; GWNT, 2018c). In Canada, typical climate risks and related health effects due to increased exposure to environmental contaminants from the changing air quality include an increased incidence of respiratory and cardiovascular diseases (Furgal & Seguin, 2006). There has also been an increase in air pollution in Canada due to increased production of pollens and spores by plants (Seguin, 2008).

As previously mentioned, greater emissions of air contaminants affect the quality of air in Canadian communities. From the Waste Resource Management Strategy and Implementation Plan (2019), landfills generate approximately 20% of Canada's methane emissions. This report acts as a road map for improving waste resource management throughout the territory since the waste disposed of in the NWT is nearly 1.3 times the Canadian average according to 2014 data (ENR, 2019). These goals include preventing and reducing waste at the source, diverting waste from disposal, improving waste management facilities and practices, and leading by example by greening the GNWT (ENR, 2019). Methane is a greenhouse gas that has approximately 25 times the warming potential of carbon dioxide, therefore, improving waste management and reducing greenhouse gas emissions are a necessity (ENR, 2019). The only communities where waste is weighed is Yellowknife and Inuvik, meaning waste is not well monitored or understood in the NWT (ENR, 2019). In order to reduce emissions from disposal of municipal solid wastes, landfills will need to meet higher environmental standards. The limited financial resources, human capacity and transportation logistics make this challenging. These challenges can be overcome with solutions specific to the north including building on existing infrastructure, developing supportive legislation, increasing collaborations within the NWT and with neighbouring jurisdictions, and through investment in new technology (ENR, 2019). Currently, the GNWT is focusing on using less fossil fuels, thereby reducing greenhouse gas emission by 30% below 2005 levels by 2030 (GNWT, 2019a).

5.3 Temperature Extremes

The Canadian Arctic is one of the most rapidly-warming areas on the planet. Temperatures in the NWT have been rapidly increasing over the recent years, and temperature extremes are occurring more frequently (see **Section 4.2.2**). Temperature extremes, both hot and cold, are leading to health impacts ranging from frostbite, hypothermia, and an increased risk of injury from accidents in extreme cold, to respiratory distress, dehydration, heat-related illnesses, physical and mental stress, or worsening existing medical conditions such as asthma or allergies during extreme heat (Seguin, 2008). In either temperature extreme, there can be exacerbated conditions and a changed pattern of illness resulting from an increased risk of food- and water-borne infections discussed further in **Section 5.8**. The possible health effects from temperature extremes include respiratory and cardiovascular disorders as well as death due to cold (Berry et al., 2014). Overall, in Canada, warmer weather is seen more frequently and severely, with colder conditions occurring in some places (Berry et al., 2014). More frequent and severe heat waves can also have negative health impacts due to impacts on food security (**Section 5.8**) and vector-borne diseases (**Section 5.9**) (Seguin, 2008).

Increasing temperatures in the North can promote the spread of infectious diseases transmitted by insects, ticks, or rodents that could otherwise not survive. For example, tropical diseases such as malaria and West Nile virus are projected to move northward due to increasing temperature from climate change (GNWT, 2008). This would lead to the spread of diseases to communities and populations where little to no pre-existing immunity to these diseases (GWNT, 2008). Individuals with pre-existing health conditions may be disproportionately affected. It is worth noting that different levels of exposures to diseases will exist in different communities and changes are likely to occur from one ecoregion to the next.

Changing temperatures also cause a longer transition between seasons, which means freeze and thaw cycles in the NWT have become more common, leading to concerns surrounding road safety and air transport (GWNT, 2008). Spring and fall in the NWT have traditionally been short seasons, but due to climate change these transition seasons have lengthened. Increasing temperatures are suggesting warmer winters which compromises the long-term viability of winter roads and increases the risk for those travelling (GWNT, 2018c). The viability of winter roads is decreasing and can possibly lead to a greater risk of accidents and injuries (**Section 5.7**).

Smaller communities can be different in their adaptive capacities and may be much more sensitive to variations in temperatures, leading to health impacts. With the effects of climate change being seen much more rapidly in the North and in the NWT, this can lead to combined events or multiple stressors. For example, extreme weather events combined with temperature extremes could occur more frequently. The increased frequency of these events in turn applies additional pressure and adversely affects people's mental and physical health. Although this is not quantifiable, the potential pressure/stress from such combination events should be noted.

5.4 Exposure to Ultraviolet (UV) Radiation

Increased exposure to Ultraviolet (UV) radiation is an indirect impact of climate change due to changes in stratospheric temperatures and enhanced ozone depletion (Furgal et al., 2008). **Section 4.3** discussed several factors which contribute to increased exposure to UV radiation. Increased UV exposure is of special concern for individuals living in the north who are exposed to the sun for long periods of time, such as Indigenous populations and residents of northern and remote communities spending time on the land hunting, fishing and travelling.

Increased UV exposures have been associated with negative health impacts such as skin damage and cancers, cataracts and immune system damage (Furgal et al., 2008; Furgal & Séguin, 2006; WHO, n.d.). Based on perceptions of increased sun intensity, increased sun burns and rashes have been reported in several northern regions (Furgal et al., 2008). Additionally, increased incidence of snow-blindness has been reported in northern populations (Furgal et al., 2008). The chances of being injured while out on the land may also potentially increase when experiencing snow-blindness.

From workshops in the Inuvialuit Settlement Region of the NWT, behavioural modifications have been reported by community residents to minimize negative health impacts from increased exposure to UV radiation (Furgal et al., 2008). These include increased use of protective creams and staying out of the sun and indoors (Berry et al., 2014; Furgal et al., 2008).

5.5 Permafrost

Permafrost maintains the structural integrity of the ground and, as such, the degradation of permafrost can result in ground subsidence, landslides, and thaw slumps where large amounts of sediments are displaced (GWNT, 2018c). As discussed in Section 4.4, permafrost thawing in the NWT can have significant effects on existing infrastructure, including health infrastructure, and can change the physical landscape in the NWT through coastal and shoreline erosion (GNWT, 2018c).

The cost of maintaining infrastructure, such as roads and buildings, and mitigating impacts can be expected to significantly increase in the NWT with the changing climate accelerating permafrost thaw (GWNT, 2018c). Thawing of permafrost will reduce the stability of homes, public health and transportation infrastructure in the NWT as foundations of the buildings, for instance, often rely on the ground being solid due to the permafrost. Damage to health and transportation infrastructure can impact various factors important to overall health and wellbeing such as the availability and quality of health care that individuals and communities have, access to emergency health and other services, connectivity to other communities, and infrastructure related to drinking water sources and water treatment facilities. Several of the subject matter expert interviews identified that impacts to public health infrastructure due to permafrost are an important concern in the NWT. For instance, changes to winter roads and air service runways associated with healthcare services can impact accessibility to health care. Infrastructure in communities in the coastal and/or high permafrost risk thaw zones are considered to be the most vulnerable to the impacts of climate change on permafrost (Subject Matter Expert, February 2021; Furgal et al., 2008).

Water quality can be greatly impacted by thawing permafrost as sediment, soluble materials (including metals) and organic carbon are released into nearby water bodies, potentially affecting the surrounding ecosystem and traditional uses (GNWT, 2018c). Infrastructure for water distribution and wastewater management within communities may face higher risks of damage and stresses through thawing of permafrost (Furgal et al., 2008).

The 2030 NWT Climate Change Strategic Framework also identifies that contaminated sites in the NWT may also be at risk from the thawing of permafrost. Contaminated sites with tailings ponds and other impoundment structures can pose a risk to the environment and human health, especially if they rely on permafrost as a containment medium (GNWT, 2018c).

5.6 Ice infrastructure – Thickness and Cover/Extent

Ice is an environmental factor which is an important concern to communities in the NWT. The unpredictability associated with land, sea and fresh-water ice formation, changes in the timing of ice freeze-ups and break-ups throughout the year, and changes in the structural integrity of ice are linked to the changing climate. Based on *Canada's Changing Climate Report* (Bush & Lemmen, 2019), over the recent decades, the Canadian arctic is exhibiting thinner seasonal ice rather than the perennial sea ice which would otherwise survive the summer melt. Over the past five decades, a delay in ice formation in the fall and earlier spring ice break-ups across Canada have driven a decline in the duration of seasonal lake ice cover (Derksen et al., 2019).

The phenomenon of changes in the timing of sea ice freeze-ups and break-ups is experienced by several members of communities in the NWT, such as those from Aklavik (Friendship and Community of Aklavik, 2011), Paulatuk (Pearce, 2010), and Ulukhaktok (Pearce et al., 2010). These changes to sea ice affect northern communities' livelihoods due to impacts on transportation and safety, food security and the ability to hunt and fish, economic activities, and cultural practices (Derksen et al., 2019). As discussed in Section 3.1, all three Level II eco-regions in the NWT are identified to have large networks of waterbodies (e.g., lakes, rivers, creeks, etc.) and as such, many communities have a dependence on fresh-water ice and land ice, rather than sea ice, for travel and subsistence activities.

Ice infrastructure is an area of concern as ice roads, ice bridges and winter roads are essential for many communities and project operations in the North. Although the GNWT has increased maintenance of winter roads due to changes in ice characteristics (e.g., thinner ice), there have been increasing number of earlier closures of winter roads, and restrictions on weight limits (Government of Canada, 2017). Winter road closures and restrictions can disrupt the transportation of goods and services for communities and various industries which can in turn impact the availability of food, fuel, and other essential materials (Government of Canada, 2017). For those living traditional lifestyles and communities which rely on subsistence activities, the alterations to travel can have a substantial impact on safety, food security, mental health, and overall health and well-being.

Characteristics of sea ice, such as its thickness, extent or coverage, duration and location are important indicators for injury and mortality (Akearok et al., 2019). Although accidents and injuries are further discussed in **Section 5.7**, it is important to emphasize that the inherent hazards associated with travelling, hunting and harvesting on ice are amplified due to the unpredictable conditions of ice. Poor ice formation and uncharacteristic sea ice has been linked to reports of drownings and accidents due to skidoos breaking through the ice. The 2030 NWT Climate Change Strategic Framework (GNWT, 2018c) has identified the risk of accidents and injuries from falling through thin ice. Risks associated with ice use are not only physical in nature (e.g., injury and potentially death) but also monetary where individuals can have financial costs associated with damaged or lost equipment (Ford et al., 2008).

Ice use impacts food security (**Section 5.8**) because hunting on ice requires stable ice conditions. Previously, community members, especially those with traditional knowledge, could predict when weather conditions were unsafe. However, now, increasingly, due to a changing climate and unpredictable weather conditions, gauging the safety of weather and ice conditions has become more challenging. Due to changes in ice characteristics, increased hazardous conditions and uncharacteristic weather patterns (Furgal & Séguin, 2006), acquisition of traditional foods may be delayed or more difficult (Ford et al., 2008). In some communities where there is limited access to traditional foods, there may be an increased reliance for market food as a result of climate change (Ford et al., 2008). A potential shift in diet, from nutritious traditional foods to market foods, may increase the risk of chronic health diseases, such as diabetes, within communities (Indigenous Services Canada, 2019). An inability to practice subsistence activities, due to a lack of proper ice conditions, can lead to stress and a fear of cultural loss for individuals and communities as a whole. Mental health can be negatively impacted by a loss of traditional ways of life; a loss of travel along traditional routes to access wildlife, loss of traditional foods and a loss of time spent on the land due to the changing climate (GNWT, 2018; Indigenous Services Canada, 2019). Changes in ice patterns are noted to not only impact individuals' ability to travel and hunt on ice but impact wildlife. Changes in ice patterns can have implications on the wildlife vital for traditional foods, such as caribou (Indigenous Services Canada, 2019). For instance, oral narratives from Behchokǫ̀ identify concerns associated with the changes in the migratory patterns of caribou, where caribou are unable to cross ice (Indigenous Services Canada, 2019).

Ice use is linked to various factors contributing to overall health, such as safety (Akearok et al., 2019; Derksen et al., 2019), food security (Akearok et al., 2019; Derksen et al., 2019), accessing wildlife (Derksen et al., 2019; Furgal & Séguin, 2006), cultural practices (Akearok et al., 2019; Derksen et al., 2019), and connectivity between communities (Furgal & Séguin, 2006). Every community in the NWT is unique and there are complex interplays between the factors contributing to overall health of individuals and communities. As such, ice use may be an important indicator for some communities for monitoring potential human health impacts of climate change.

5.7 Accidents and Injuries

Climate change may indirectly contribute to increases in the number of accidents and injuries within Indigenous populations and residents of northern and remote communities. Morbidity and mortality were discussed as health indicators of climate change in Nunavut in the work completed by Akearok et al. (2019) as these indicators can highlight causes of illness or death due to factors related to climate change.

As discussed in the Sections above, extreme weather events (**Section 5.1**), drastic changes in temperature (**Section 5.3**), snow-blindness and sun burns through exposure to UV radiation (**Section 5.4**), and unstable ice infrastructure (**Section 5.6**) can impact the frequency of accidents and/or injuries in northern populations, including in the NWT.

With increasing unpredictability in the frequency and severity of extreme weather events, such as storms, wildfires and flooding, communities could see an increase in injuries, illness and deaths (Berry et al., 2014). As an adaptation strategy to the unpredictability of extreme weather, there has been an increased focus on travel safety noted for communities in Nunavik which include reliance on cabins on the land and increased communication via radio on weather conditions between hunters (Communities of Nunavik et al., 2005, as cited in Furgal et al., 2008).

As discussed in **Section 5.6**, unstable ice, unusually thin ice, and unstable snow can increase the risk of injury or mortality (Indigenous Services Canada, 2019). Rates of unintentional injuries from accidents associated with motor vehicle accidents and drowning in Northern populations are higher than national rates (Furgal et al., 2008), which may be associated with the breadth of modes of transportation utilized such as skidoos, all-terrain vehicles, boats, etc. In the NWT, between 2004 and 2013, ice and water conditions were the most frequently reported contributing factor for search and rescue events in the work conducted by Young et al. (2016). The most common mode of transportation involved in an incident was boating (35%), followed by snowmobiles (24%), other vehicles (17%), and on foot (14%), with 11% unknown (Young et al., 2016). Gender and age are important risk factors associated with ice use (Durkalec et al., 2014). The distribution of the risks of injury and death associated with travelling on ice within communities is often seen in young men (Young et al., 2016) as they are most likely to hunt on the land (Durkalec et al., 2014). The study completed by Durkalec et al. (2014), also identified that male travellers, when compared to female travellers, were six times more likely to require search and rescue assistance. It is important to identify that there would be differences for the rates and types of accidents across communities in the NWT. Furthermore, young Indigenous males are likely to be disproportionately impacted by the changes in ice and weather conditions due to gender roles in communities and reliance on subsistence activities such as hunting and fishing on ice.

5.8 Food security – including food and water-borne illnesses

Food security is one of the top concerns in the NWT. Availability of good quality nutritious food and regular access to it, both play a role in food security, an important determinant of health. Food security impacts several health outcomes, including malnutrition, infections, chronic diseases, obesity, stress, social exclusion and mental health. A background paper from the Library of Parliament on food insecurity in Northern Canada notes that in 2017–2018, the rate of household food insecurity in the NWT was 21.6% (Leblanc-Laurendeau, 2019). The average cost of a healthy diet for a family of four in Northern Canada was estimated to be $422.07 per week (Leblanc-Laurendeau, 2019), and within the Northern context, the populations most vulnerable to food insecurity are women, children and Indigenous peoples. Specifically, a study of community food programs in Inuvik, NWT, found that the primary users of these food programs tended to be housing insecure, female, unemployed and Indigenous (Ford et al., 2013). In the NWT, almost one-third of the children are estimated to live in food insecure households (Leblanc-Laurendeau, 2019). Socio-economic status is an important contributing factor to food insecurity in the North, where Indigenous populations face a greater burden of health inequity due to having a lower socio-economic status than non-Indigenous Canadians (Leblanc-Laurendeau, 2019). Increasingly, vulnerable groups, such as the elderly, lower socioeconomic groups, women, etc., face challenges in having regular access to traditional foods.

Climate change has impacted the accessibility, quality and availability of traditional foods in several areas in the NWT. Moreover, the partial discontinuance of traditional knowledge used in harvesting country food, especially in the context of a changing climate, also has impacts on traditional food security. Climate change, along with other factors, has led to changes in animal behaviour and availability. Current responses to this changing food security have included changing the times of hunting activities to match the availability of both marine and terrestrial prey, as well as using various transportation vehicles (Furgal et al., 2008; Ford et al., 2006; Guyot et al., 2006).

In a report on wellness initiatives in the NWT, eating nutritious store-bought and traditional foods was identified as a priority for the territory (GNWT, 2016). Of the 33 communities supported under the 2014-2015 Community Wellness Initiatives funding, all communities prioritized healthy eating in their wellness programming. Several communities also identified access to healthy food (store-bought and traditional) and lack of food storage (i.e., freezers) to store traditional foods as challenges. Lack of year-round ice and snow to store wild foods now makes freezers a requirement in the North.

Climate-related impacts on the upper Mackenzie River Basin is an example of how climate change has impacted traditional food security (Wesche et al., 2016). Among the changes local residents have observed are lower water levels, instability and a high degree of variability in ice formation and cover, and increased sediment in river and lake water. Together, these changes potentially impact access to harvesting/fishing/hunting areas as well as the quality of wildlife (Wesche et al., 2016). Another example is from the Ross River First Nations in the Yukon Territory, where a combination of an earlier spring thaw, warmer and lengthier summers, and increasing number of wildfires are affecting the number, feeding grounds and distribution of caribou populations (Health Canada, 2012).

Overall, more research and knowledge are needed to understand and evaluate the impacts of climate change on food security, especially, traditional food security in the NWT, and to understand the potential worsening health implications of a warming and unpredictable climate on Indigenous land use and reliance on the land and water for traditional foods (Halseth, 2015).

Although few in number, a potential positive impact of climate change could be an increase in a few food sources, such as crops cultivated in community gardens (GNWT, 2019a). This potential opportunity for the agricultural sector and farmers in the territory to boost food security is largely a result of longer crop-growing seasons due to a shift in the regular climate cycle.

Variable climate conditions in the NWT have also resulted in increased exposure to food- and water-borne pathogens, the most common of these being *Giardia* (in contaminated water) and *Salmonella* and *Campylobacter* (in contaminated foods that are unpasteurized or eaten poorly cooked) (GNWT, 2005; Furgal et al., 2008; Pardhan-Ali et al., 2013). Further research found that *Giardia* was a common cause of gastrointestinal illness in the NWT (Pardhan-Ali et al. 2012). Moreover, Pardhan-Ali and others (2013) also highlighted a potential link between socioeconomic status, poor housing conditions, lack of adequate food storage facilities and exposure and spread of these pathogens. This further demonstrates that potential health impacts due to climate change are not necessarily the result of one issue, but could be representative of cumulative effects converging on a given population or community at a particularly vulnerable time.

5.9 Vector-borne Diseases

Although a review of the literature indicates that current levels of exposure to vector-borne diseases in the North are not well documented, a changing climate, including rapidly increasing temperatures, have shifted the range of vector-borne diseases, such as tick-borne encephalitis towards the north (Rogers and Randolph, 2006). Human diseases or reservoir species that may not have previously survived cold temperatures, are potentially now more viable due to warming temperatures in the North, including in the NWT. These diseases may be food or waterborne, and potentially transmitted by vectors such as insects, ticks and rodents. Similarly, increasing temperatures may continue the northward spread of the distribution of the *Ixodes scapularis*, the tick vector that causes Lyme disease. Climate predictions indicate that by the 2080s, the NWT will have temperature conditions suitable for this tick (Ogden et al., 2006). In the Communities of the Inuvialuit Settlement Region of the NWT, where fast-increasing temperatures have been observed in recent decades, residents have reported higher numbers and new species of insects, including biting flies and bees (Furgal et al., 2008; Barrow et al., 2004).

Culex tarsalis, a species of mosquito, is the main vector of West Nile Virus in western Canada, and was found as far north as Yellowknife in 2010 (Waeckerlin et al., 2012). While West Nile Virus is currently primarily restricted to southern latitudes, the presence of vector mosquitoes as far north as Yellowknife indicates the need for systematic surveillance of arthropod vectors, because a warming climate has the potential to favor the spread of competent vectors and pathogens further north (Waeckerlin et al., 2012). Other zoonotic diseases that could potentially spread northward as result of warming temperatures include Hantavirus and Rocky Mountain spotted fever, including a re-emergence of diseases currently uncommon in the NWT, such as brucellosis and anthrax (GNWT, 2018c).

Anthrax is an infectious disease caused by the bacteria *Bacillus anthracis.* This bacterium affects wild bison and livestock and can be found naturally in alkaline and calcium rich soil (Elkin et al., 2013). These spores, once in contaminated soil, can remain dormant for many years. The first outbreak of anthrax in Northern Canada was confirmed in 1962 and has killed at least 2,196 bison since then (Elkin et al., 2013). The last outbreak of anthrax in the NWT occurred in 2012 in the Mackenzie bison population (New et al., 2017). Anthrax outbreaks in bison in Northern Canada are potentially linked to climate conditions, especially when periods of drought follow periods of heavy rainfall (MOHLTC, 2019). Although not well understood or easily predicted, outbreaks have occurred in the summer that follows a wet spring. Infection with anthrax, although not common, is possible through open skin contact with infected animals, other animal products or contaminated soil (MOHLTC, 2019). Transmission may also occur from the ingestion of undercooked, contaminated, or raw meat. The GNWT Department of Environment and Natural Resources conducts regular surveillance flights every summer over the Slave River Lowlands and the Mackenzie Bison Sanctuary to monitor bison populations for signs of anthrax; there have been no confirmed cases in the NWT since 2012 (ENR, 2018).

5.10 Mental health and well-being

The potential impacts of climate change on mental health are an increasing focus of studies assessing the overall health implications of climate change, associated weather events and a changing environment (Hayes and Poland, 2018). Climate change and related events have been linked to increased mental health impacts, including increasing rates of depression, anxiety, and pre-and-post-traumatic stress; increased drug and alcohol usage; and increased suicidal ideation, suicide attempts and death by suicide (Cunsolo and Ellis, 2018; Howard et al., 2018; also see **Figure 14**). The concepts of ecological grief and eco-anxiety have emerged as a result of Canadian research on the mental health impacts of climate change (Cunsolo and Ellis, 2018).

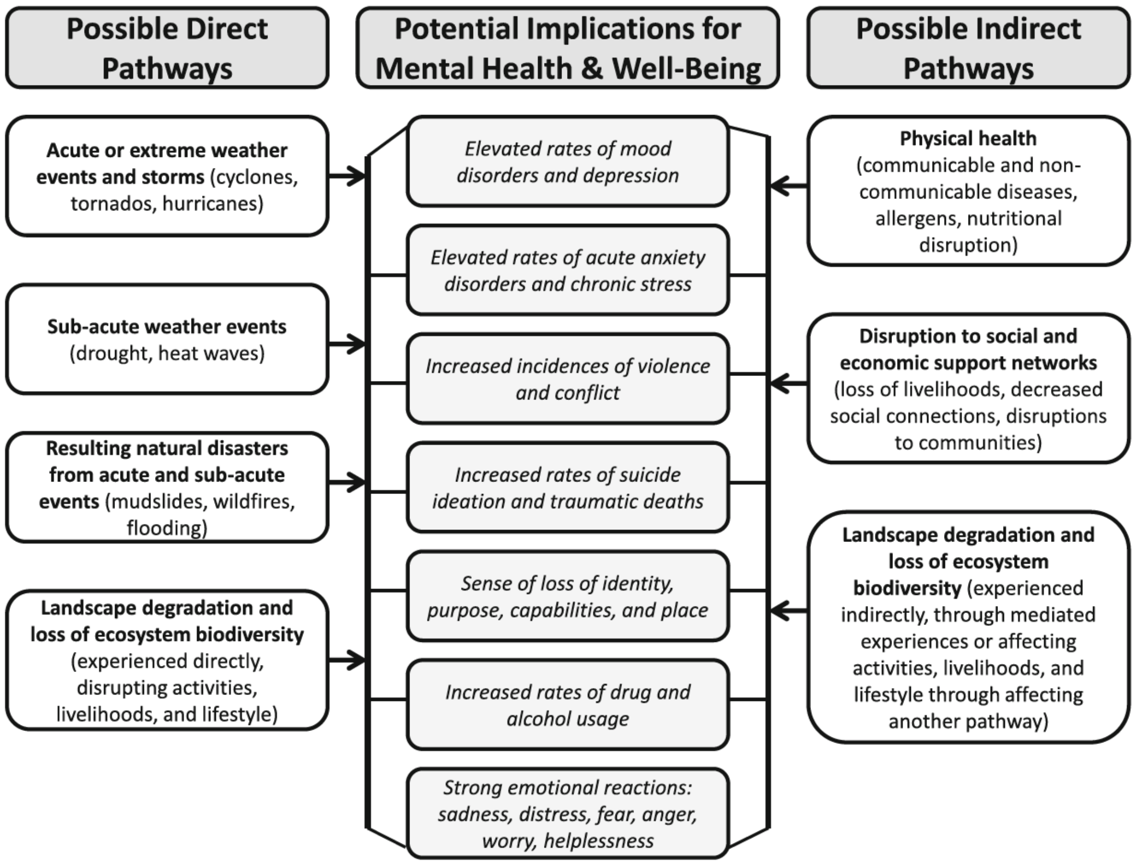

Figure 14 Possible direct and indirect impacts of climate change on mental health and well-being
(Source: Cunsolo Willox et al., 2013)

Throughout a discussion of potential health impacts in the Canadian North or in the NWT specifically, **Sections 4.1 to 4.7** have acknowledged how each of these areas also has potential impacts on mental health. Food insecurity in the North is a crucial link between climate change impacts and mental health. Rapid change in the Arctic has been contributing to decreased access to traditional foods (Furgal et al., 2008; Berry et al., 2014) as well as an increasing unpredictability of safe travel on ice. Both of these, together with changing landscapes, impact mental health, especially for Indigenous peoples, who have inhabited the Canadian Arctic for millennia and have an intimate connection to and knowledge of the land (Howard et al., 2018).

Indigenous communities in all northern regions have also reported that changing ice conditions have negative implications for social cohesion, and eventually mental health, due to the increasing interruption of the regular cycle of traditional land-based activities and disruption of sharing of traditional foods (Huntington et al., 2005).

The Department of Health and Social Services at the GNWT, in its annual Health Status Chartbook, provides information on the current health status of the residents of the territory, including information and statistics on mental health, hospitalizations related to mental health issues and substance use (GNWT, 2019b). As per the 2019 Health Status Chartbook, compared to national statistics, the NWT has a lower proportion of individuals who rate their mental health status as being good or excellent (56% in NWT compared to 72% in Canada). Within the NWT, Indigenous populations rate their mental health lower (46%) than non-Indigenous populations (66%) (GNWT, 2019b). An important context for the discussion of mental health impacts in Indigenous populations in Canada is the acknowledgement of the "*century-long policy of state-sponsored, forced assimilation and systematic oppression"* to erase the cultures of Indigenous peoples (reviewed in Elman et al., 2019; Boksa et al., 2015), and the wide-ranging disastrous impacts this has had, and continues to have, on the collective Indigenous psyche. Forced colonization, displacement and the catastrophic residential school system, have together led to lasting intergenerational impacts and harmed the mental health and well-being of Indigenous peoples across the country (reviewed in Elman et al., 2019).

These mental health impacts are more severe in the North when compared to southern Canada due to a higher number of residential schools (Boksa et al., 2015; Restoule et al., 2015; reviewed in Elman et al., 2019). This has led to challenges throughout the region, including forced displacement, reduced autonomy and systemic racism that continue to impact the social determinants of health and wellness of Indigenous peoples (Kirmayer et al., 2011; reviewed in Elman et al., 2019). It is in the context of these deep and underlying injustices that we observe high rates of mental health-related hospitalizations and substance use issues, suicides, cultural degradation, poverty and homelessness, disproportionately impacting Indigenous people (Restoule et al., 2015; reviewed in Elman et al., 2019). For example, the NWT has over twice the rate of mental health hospitalizations when compared to Western Canada, and the main driver for these hospitalizations is increased substance use (GNWT, 2019b). Since the mid-2000s, there has been an increasing trend of mental health hospitalizations in the NWT, with Indigenous residents having a rate of mental health hospitalizations three times higher than non-Indigenous residents (GNWT, 2019b). Rates of suicide are also significantly higher in northern regions that have a higher proportion of Indigenous population, and these numbers are being influenced by suicide rates among Indigenous youth, which have continued to rise in some regions (Government of Canada, 2006). Suicide rates among the Inuit population in Canada, are up to 10 times higher than the overall rate for Canada (Kral, 2016). Such severe mental health impacts do not exist in isolation, and are often symptomatic of deep underlying and ongoing systemic issues that act as multiple stressors and upset the balance of the determinants of health that maintain health and wellbeing. In this environment of converging multiple stressors on Indigenous populations in the NWT, a rapidly changing climate is a further risk magnifier.

As such, it is vital to understand and appreciate that despite these lasting and ongoing impacts of colonization and systemic racism against Indigenous peoples, there is tremendous individual and collective resilience, which is tethered in Indigenous cultural values and in the deep and meaningful connection Indigenous peoples have with the land and nature.

A recent study on socioeconomic inequalities and mental health impacts on off-reserve Indigenous populations in Canada identified food insecurity as being a contributor "*to the concentration of psychological distress and suicidal behaviours among low-income Indigenous peoples in Canada*" (Hajizadeh et al., 2019). This study also found that women and poorer individuals had a higher prevalence of suicidal thoughts and attempts. In Inuit children, hunger caused by food insecurity has been found to have a negative impact on the ability to learn, thus contributing to poor educational outcomes (Inuit Tapiriit Kanatami, 2017).

As discussed previously, a common running theme through several of the subject matter expert interviews that were conducted for this assessment was that mental health impacts due to climate change were a major concern in the NWT, and especially within Indigenous communities. Statistics from the NWT specifically, and from the national perspective, shine light on the disproportionate burden related to adverse health conditions in general, and adverse mental health conditions, specifically, that Indigenous communities within the NWT continue to face. It was also pointed out to the Project Team that climate change acts as a magnifier of existing socioeconomic and health inequities in the territory, and further stresses already stressed Indigenous communities. As such, strategies for addressing mental health impacts of climate change in the NWT should take into account these existing disparities, identify their root causes and eliminate them.

6.0 VULNERABLE POPULATIONS ASSESSMENT, INCLUDING A GENDER-BASED ANALYSIS

Vulnerable communities and peoples are disproportionately affected by climate change impacts, whether this vulnerability is related to age, gender, low income, poor health, education, ethnicity and/or location. Vulnerable communities can also have more challenges in recovering from climate impacts, especially extreme weather events, as they may already face a disproportionate burden of health and socioeconomic inequities. In addition, gender may amplify or affect how climate change impacts health. Socio-cultural and socioeconomic differences, including Indigenous identity may also affect how health is impacted by climate change and how information and services to mitigate these effects are accessed.

Indigenous populations in the NWT experience much worse socioeconomic indicators than non-Indigenous populations (**Table 49**).

Table 49 Select Socioeconomic Indicators in the NWT (2011 census)

Indicator	First Nations	Métis	Inuit	Non-Aboriginal
Employment rate	57.2%	78.6%	57.0%	88.7%
Education • No high school • Bachelor's degree	 43.5% 5.4%	 22.9% 11.9%	 47.0% 2.8%	 7.9% 34.7%
Average employment income (2016 census)**	$42,891	$63,949	$40,800	$77,586
Housing conditions • Crowding • Home in need of major repairs	 22.5% 29%	 5.4% 17.7%	 15.3% 26.1%	 3.2% 11.1%

Source: Statistics Canada, National Household Survey, 2011 (https://www150.statcan.gc.ca/n1/pub/89-656-x/89-656-x2016013-eng.htm)
** Statistics Canada, 2016 Census of Population, Statistics Canada Catalogue no. 98-400-X2016268.

Table 50 collates information presented throughout **Section 4** re: climate change-related potential health impacts to vulnerable population groups. It provides examples of some of the ways in which vulnerable population groups may experience disproportionate health impacts as a result of climate change and related effects. When there are interconnections between vulnerable population groups, for example, elderly Indigenous women, the health inequities experienced may be potentially more severe. However, more work needs to be done to understand the full breadth and extent of vulnerabilities of population groups, and how climate change magnifies existing health and socioeconomic equities in these groups. A gender-based analysis has also been provided to characterize vulnerable population groups, including women, Indigenous populations and youth.

Table 50 Examples of Vulnerable Populations and Potential Overall Health Impacts

Population Group	Potential Overall Health Impacts
Indigenous	• Suffer a greater burden of health inequity and poor housing conditions, which are likely to be exacerbated as a result of extreme weather events. • More reliant on traditional foods which are healthier and more culturally appropriate than store bought foods. Climate change is likely to adversely affect access to traditional foods, thereby increasing reliance on unhealthier and more expensive store-bought items and affecting food security. • Loss of culture and negative impacts on mental health are possible when travel between communities is restricted or unsafe, if environmental factors prevent traditional activities and if skills and knowledge are unable to be passed down to younger generations due reduced time spend on the land. • Younger men often have higher rates of injury and incidents while on the land for travelling and/or traditional activities as they may be inexperienced and could potentially take more risks while hunting and fishing. • Due to a deeper connection to the land and waters, suffer a greater loss when environmental conditions are irreparably changed as a result of climate change-related effects.
Elderly	• Elders in Indigenous communities may have a harder time relying on unhealthier store-bought foods when access to healthier and culturally appropriate traditional foods are impacted because of climate change. • Increased unpredictability with weather and ice conditions often prevent older and more mature hunters to go on the land and ice. Mature hunters may be unwilling to take risks associated with unstable ice conditions and as such could potentially consume less traditional foods. This can have implications on mental health and cultural identity. • Loss of cultural and spiritual connection to the land due to climate change impacts, and partial obsolescence of traditional knowledge in an environment increasingly transformed by climate change has rippling implications on health and well-being.
Children and youth	• Suffer a greater burden of food insecurity with wide-ranging potential health impacts including malnutrition, chronic illnesses, developmental disorders and mental health issues. • Youth in Indigenous communities in Canada, due to a myriad of reasons, including those related to climate change, face a higher burden of mental health issues and higher than average rates of suicide when compared to non-Indigenous youth in Canada.
Women	• Suffer a greater burden of health inequity, income and poor housing conditions, and are more likely to be adversely affected by extreme weather events and extreme temperatures. • Tend to be the primary care givers within their families and bear the health responsibilities for themselves as well as their immediate and extended families. • Suffer a greater burden of food insecurity and related cascading impacts in the NWT.
Individuals with lower income and people experiencing homelessness	• Families may be unable to afford safety equipment such as life jackets required for activities on water and ice which can contribute to higher risks for injury and death. • Suffer a greater burden of health inequities, lower incomes, poorer overall health status, and poor housing conditions, with potential to be much more affected due to extreme weather events, including temperature extremes. • Suffer a greater burden of food insecurity, leading to chronic poor nutrition,

Table 50 Examples of Vulnerable Populations and Potential Overall Health Impacts

Population Group	Potential Overall Health Impacts
	increased prevalence of chronic illnesses, such as diabetes, and mental health issues.
Lesbian, Gay, Bisexual, Transgender, Queer, and Two-Spirited (LGBTQ2+) Individuals	• Individuals and groups are more susceptible to discrimination, hatred, and isolation, which can affect their access to health resources, their mental health, and overall well-being. • These individuals may be at higher risk for other factors including lower incomes and homelessness.
Refugees	• Climate change and other socio-economic factors will lead to an increased number of refugees across Canada, including in the NWT. These individuals have a heightened vulnerability to a number of socio-economic factors that will affect their health, including lower incomes, challenges in navigating new health care systems, language barriers and others. In many cases climate change may have contributed to push factors causing them to leave their homeland.

Gender-Based Analysis Plus (GBA+)

Every individual has multiple identifying factors that combine to create their identity and influence their lives. For example, identity factors can include sex, gender, religion, ability and age, as shown in **Figure 15** below. GBA+ is an intersectional process to assess the potential impacts of policies, projects, and initiatives on diverse groups of people (Status of Women Canada, 2020). Sex, a biological factor, and gender, a social construct, are important identity factors considered in GBA+ analysis; however, identity factors contributing to diversity are also part of the analysis. GBA+ aims to identify challenges and inequalities faced by diverse groups.

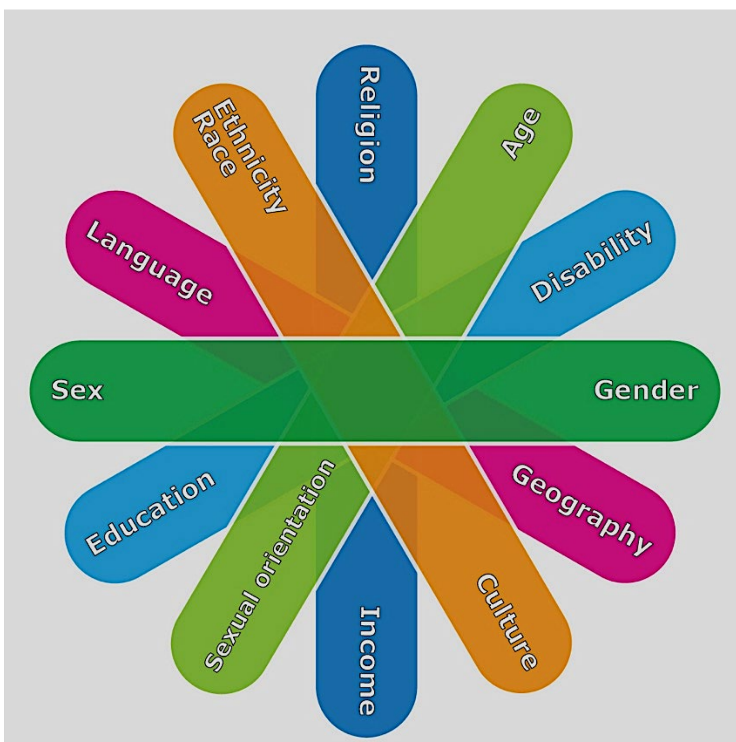

Figure 15 Intersectionality in GBA+
(Status of Women Canada, 2020)

As mentioned above, each of the vulnerable populations described in **Table 50** have intersections that amplify health vulnerabilities due to climate change. For example, Indigenous men may be more likely to experience a loss of identity as they move from reliance on traditional lifestyles as providers for their families and communities, which can also increase pressure on Indigenous women to take on roles as economic providers in their families. These women may also experience greater barriers to quality and reliable child care, which can lead to increased stress, depression, anxiety and poverty. Due to colonial history and ongoing racial bias, Indigenous children are more likely to be involved in government care systems or care giver environments outside of immediate family. Care from underqualified individuals or crowded care giver environments within these systems can place Indigenous children at a greater risk to experience neglect, abuse, abandonment, and other negative outcomes.

Members of one vulnerable group likely belong to other vulnerable groups and it is this intersection of vulnerabilities that must be considered through a GBA+ lens. The health impacts of climate change will not affect all individuals equally and some will be more adversely affected than others. Strategies should be developed that seek to better understand the influences of GBA+ on health vulnerability to climate change, so that adaptations, programs and funding can be better directed to alleviate these inequitable impacts.

7.0 ADAPTATION ASSESSMENT AND NEXT STEPS

Individuals and communities in the NWT, particularly Indigenous peoples and communities, have a strong connection to the natural environment and are concerned about impacts due to a rapidly changing climate. Indigenous people in the NWT, who have been sustained by the land, wildlife and water in the territory for millennia are especially vulnerable to climate change impacts. A changing climate, in this context, not only implies a reduced supply of traditional food and clean drinking water, but also threatens traditional ways of life, and of inter-generational cultural and spiritual practices. As discussed in **Sections 5.0 and 6.0**, vulnerable populations, especially within Indigenous communities, are faced with climate change impacts that worsen existing health and social inequities. However, even faced with the daunting challenges brought forward by a fast-changing climate, Indigenous peoples' cultural identity, their language and traditions, their fundamental connection to the land and nature, their history of adversity, and overall self-determination, are critical factors that play a significant role in establishing and maintaining the potential to adapt to the health impacts of climate change.

A key point in this context made by subject matter experts consulted for this project is related to the fact that over the years, Indigenous peoples in Canada have had no choice but to be resilient and strong in the face of adversities, including the challenges posed by climate change. However, this burden of resiliency should not be the status quo. Indigenous and Northern communities should be active participants in the growing body of knowledge and information on current and future climate change impacts, how they could potentially affect health, as well as the resources and assistance to overcome these challenges. In addition, when considering adaptation strategies, there should be an emphasis on first alleviating the persistent disparities and current inequities in health, housing, water, food and income security, to which climate change acts as a risk magnifier.

Adaptation strategies identified in this section are referenced from the following main sources:

- The 2030 NWT Climate Change Strategic Framework (GNWT, 2018c), the 2030 NWT Climate Change Strategic Framework - 2019-2023 Action Plan (GNWT, 2019a), the 2030 NWT Energy Strategy (GNWT, 2018d), and other relevant GNWT planning documents that identify how NWT communities, and in particular, vulnerable populations, can be strengthened to adapt to the impacts of climate change.
- Climate Change Adaptation Plans from communities in the NWT, including the communities of Aklavik, Paulatuk, Ulukhaktok, Tsiigehtchic, the Yellowknives Dene First Nation youth, and Fort McPherson.
- Adaptation strategies from other parts of the Canada that are relevant to the NWT context have been proposed (for example, Indigenous Services Canada, 2019; MOHLTC, 2016; Furgal et al., 2008; Ford et al., 2014; and Berry et al., 2014).
- Subject matter experts consulted for this report have provided invaluable insights on current resiliencies and potential adaptation strategies to mitigate health impacts due to climate change.

Table 51 below provides examples of several key adaptation strategies to address climate change-related health impacts in the NWT.

Table 51 Examples of Proposed Adaptation Strategies to Address Potential Health Impacts of Climate Change in the NWT

Climate Change Impacts	Proposed Adaptation Strategies	References
Extreme Weather Events	Extreme weather events, such as wildfires, put additional stress on current infrastructure not necessarily built to handle the heat stress from wildfires. To mitigate these issues, the following adaptation strategies are recommended: • Update building designs to require better ventilation during wildfire events so that buildings are better equipped to handle an increase in temperature. • Provide access to better equipped housing and clean air shelters for these kinds of extreme weather events. • Complete fire risk mapping for vulnerable communities. • Alert communities using weather warnings for extreme conditions, including for poor air quality. Increased rainfall and floods also negatively affect infrastructure in the NWT. Community infrastructure, including critical healthcare infrastructure, may suffer damage to foundations caused by permafrost degradation, and roads may suffer damage from municipal drainage issues resulting from flooding and road erosion. To mitigate these issues, the following adaptation strategies are recommended: • A municipal drainage plan should be completed, and bigger culverts should be installed. • Extreme weather events will need to be taken into consideration during planning, design, construction, and operations of future and existing infrastructure, especially roads, homes, and health care infrastructure. • If possible, new infrastructure should be located on higher ground that is less prone to flooding and coastal erosion. • Enable the stress testing of health systems, such as hospitals, that are impacted by extreme weather events. • Existing infrastructure not built to a particular design code to withstand changing climate conditions may need to be upgraded. An improved knowledge of climate change impacts may help inform development. Remote communities should be included in the development and implementation of upgraded design codes meant to withstand climate change impacts. • Flood zone mapping for vulnerable communities should be completed. • Science-based tools can also be used to assist in project planning or infrastructure development in permafrost regions.	Berry et al., 2014 GNWT, 2018c Subject Matter Expert Interview, February 2021 Dodd et al., 2018

Table 51 Examples of Proposed Adaptation Strategies to Address Potential Health Impacts of Climate Change in the NWT

Climate Change Impacts	Proposed Adaptation Strategies	References
Air Quality	• Build new infrastructure with proper ventilation so that air contaminants during wildfires are filtered out. • Retrofit existing buildings with proper ventilation systems to allow for clean air to be filtered in during wildfires and for buildings to be cooled even without air conditioning. • Plan for wildfire suppression and adopt Fire Smart principles such as strategies and planning measures to help reduce the risk and minimize the unwanted effects of wildland fires in communities to help adapt to negative impacts of wildland fires, such as poor air quality. • Implement fire prevention practices wherever possible and create wildfire education training and awareness sessions for first responders and the public. • To improve air quality impacted by contaminants from waste disposal practices, and other waste-related health concerns, implement strategies to prevent and reduce waste at the source, divert waste from disposal, and improve waste management facilities and practices. • Build tall litter fences to prevent waste from blowing off-site or build electric fences to reduce instances of wildlife habituation to landfills and to reduce risks to both wildlife and humans. • Equip landfills in the NWT to current environmental standards, including use of engineered lined cells which prevent the migration of leachate into underlying aquifers or surrounding environments. Raising NWT landfill design and operation to current environmental standards will also reduce the use of fossil fuels and improve air quality. • Consider unique challenges faced by small remote communities to waste management solutions, such as the northern climate and transportation requirements, and implement local-made strategies that work for each community. • Encourage composting organic waste and recycling as well as preventing waste through regulated or voluntary programs and initiatives. Partnerships among GNWT departments, stakeholders and community governments should also be developed as they can produce efficiencies through shared infrastructure and logistical costs.	ENR, 2019 GNWT, 2018c GNWT, 2019a Subject Matter Expert Interview, February 2021
Temperature Extremes	• Due to country foods spoiling quicker than they can be consumed, recommend that hunters return to the community more frequently while hunting during the warmer months to store food safely in cool temperatures. • Invest more funds for hunting activities as well as a re-investment in the government-supported community freezer program to increase the amount of meat that could be stored during and after hunting. • Alter the construction of smoke houses to accommodate being able to prepare dried/smoked	Furgal & Seguin, 2006 GNWT, 2018c

Table 51	Examples of Proposed Adaptation Strategies to Address Potential Health Impacts of Climate Change in the NWT	
Climate Change Impacts	**Proposed Adaptation Strategies**	**References**
	fish during warmer temperatures; changes could include having thicker roofs to regulate temperature. • Higher than average temperatures result in lower water levels in some areas, leading to drying up of brooks and creeks and reducing the sources of clean natural drinking water. Ensure communities have access to bottled water or a means to filter water for safe consumption on trips to reduce the risk of waterborne illnesses. • Lengthening of growing seasons due to temperature extremes may allow for new opportunities in the agricultural and forestry sectors. Apart from producing food locally (discussed below), longer growing seasons may also result in taller and faster growing trees with the potential for greater biomass for wood production industry. The harvesting, storage and distribution of biomass (cordwood and pellets) has the potential to provide local business and employment opportunities.	
Exposure to UV	Elevated UV radiation exposure can lead to increased health risks such as skin and eye damage. The following adaptation strategies are recommended: • Promote behavioural modifications such as wearing protective clothing, wearing a hat and sunglasses, applying sunscreen, reducing time spent in the sun. • Encourage use of UV monitoring tools such as the UV Index developed by the Government of Canada to help individuals protect themselves from UV rays. • Support further research on the effects of climate change on behaviour and UV exposure in the NWT. • Support education and knowledge sharing on the health risks of UV radiation, especially among youth. • Promote shade creation in public spaces for preventative measures.	ACIA, 2004 Berry et al., 2014 Furgal et al., 2008 GNWT, 2018c Séguin, 2008
Permafrost	Thawing of permafrost can significantly impact built infrastructures, such as houses, health centres, hospitals, roads (winter and all season), and airport runways. The following adaptation strategies are recommended: • Improve the built environment to withstand the thawing of permafrost; for example, the NWT Housing Corporation utilizes foundation systems that absorb the stress from ground movement due to permafrost thawing. • Install thermosyphons in all new buildings to help keep the ground frozen under new buildings. • Develop research and projects that map the permafrost for future buildings and build this	ACIA, 2004 GNWT, 2008 Huntington et al., 2005 Subject Matter Expert Interview, February 2021

Table 51 Examples of Proposed Adaptation Strategies to Address Potential Health Impacts of Climate Change in the NWT

Climate Change Impacts	Proposed Adaptation Strategies	References
	information into health infrastructure planning, to be used regularly. • Apply the best current practices in engineering to the built environment as an adaptation strategy to reduce the costs associated with future effects from the degradation of permafrost. • Modify shorelines with stone break walls and gravel to reduce the impacts of waves. • Monitor conditions of shorelines within communities as it provides an understanding of long-term trends and if adaptation strategies are effective. • To mitigate the migration of potential contaminants due to thawing of the permafrost, appropriate protective liners should be in place for containment structures (e.g., tailings ponds). • For containment structures currently reliant on permafrost as the containment medium, monitoring can be conducted, and risk management measures can be applied if necessary.	
Changes in Ice Infrastructure	Changes in ice can impact transportation of goods and services, access to communities, wildlife migration routes, and traditional uses. The following adaptation strategies are recommended: • Improve community food programs and community freezers to support community members unable to hunt for themselves is a possible adaptation strategy to support the reliance on traditional foods. • Support, financially and institutionally, for community food programs would be needed based on communities' needs. • Support community-based monitoring of migration routes for wildlife due to changes in ice characteristics. • To reduce disruption to the transportation of goods and services, technology can be used to improve winter road conditions. For instance, ice spray technology has been utilized on the Mackenzie River crossing to create thick, load-bearing ice. • Consider adding more all-season roads with the acknowledgement that there are potential human health and environmental impacts to creating new all-season roads that should first be addressed. Having permanent, reliable, all-season roads reduces the time needed to construct and maintain winter roads and allows for continued transportation of goods and services in the NWT throughout the winter. With increased permanent transportation infrastructure, communities could reliably travel to health care appointments, other communities and access hunting grounds. For instance, shorter winter road seasons have initiated the construction of bridges along winter roads, such as the Mackenzie Valley Winter Road. • Explore opportunities in new shipping routes and in the predicted increase in the navigation season in the North. This can have significant implications on transportation and access to	Furgal & Seguin, 2006 Huntington et al., 2005 Séguin, 2008

Table 51 Examples of Proposed Adaptation Strategies to Address Potential Health Impacts of Climate Change in the NWT

Climate Change Impacts	Proposed Adaptation Strategies	References
	resources. • Further research into this effect of climate change can be conducted to determine the potential challenges and benefits increased marine transport can have for the NWT, especially through the Northwest Passage. • Promote the use of Personal Floatation Devices (life jackets), especially among youth and use of SPOT devices (GPS) when going on the land.	
Accidents and Injuries	Public safety is a concern when assessing potential impacts of climate change through extreme weather events, permafrost thaw, changes in ice infrastructure, etc. Injuries and death are associated with various climate change effects and to mitigate these issues, the following adaptations are recommended: • Support continued sharing of traditional knowledge and survival skills while hunting or travelling on the land. • Increase knowledge by communicating risks and understanding of dangers associated with trails and/or weather patterns. • Establish capacity and/or support existing local search and rescue. • Decrease the urgency to hunt or fish during unsafe and risky conditions by establishing and supporting food sharing within communities through community food programs and community freezers. • Encourage taking of extra precautions and increasing travel safety by reading environmental signs and weather forecasts before travelling, travelling with extra gas, fuel, food, and supplies, travelling closer to the community when there is the potential for an early spring melt, travelling in groups, leaving travel itineraries behind, and travelling with a VHF radio, satellite phone and/or GPS. • Increase travel safety by relying on communication between the individuals on the land and by having additional cabins on the land for shelter.	Communities of Nunavik et al., 2005, as cited in Furgal et al., 2008 Ford et al., 2014
Food Security	Food security, in general, and especially in the context of climate change is a major concern in the NWT. Based on the discussion provided in Section 5.8, the following adaptation strategies are recommended: • Establish improved programs to eliminate food insecurity, especially in remote communities in the NWT where dependence on traditional foods is high. Where needed, make access to store-bought healthy food more affordable. • Establish accessible food programs and food sharing networks that target vulnerable	GNWT, 2018c Ford et al., 2014 Friendship and Community of Aklavik, 2011 Pearce et al., 2010 Subject Matter Expert

Table 51 Examples of Proposed Adaptation Strategies to Address Potential Health Impacts of Climate Change in the NWT

Climate Change Impacts	Proposed Adaptation Strategies	References
	populations, such as the elderly, women and children. For example, hold community harvests and include Elders, single mothers and families in need. • Explore opportunities for communities to increase local food production and take advantage of longer growing seasons due to rising temperatures. The longer growing season would also allow for vegetables and could result in an increased prevalence of community gardens and cold storage. • Improve geo-mapping to identify and communicate trends in potential contaminants to better support public health authorities on advisories on the consumption of traditional foods with potentially high concentrations of contaminants. • Support access to country foods where this has become difficult due to climate change, for example, access to transportation vehicles that allow hunters to safely extend their hunting grounds. • Support the implementation of cooking courses on traditional foods and healthy diet cooking. • Provide more opportunities to learn and improve gardening skills and implement gardening programs for communities to potentially be able to start growing their own food; also revise land-use plans to allow for larger gardening spaces. • Gather more information on whether invasive species, such as Whitetail deer, may also serve as a potential new food source.	Interview, February 2021
Vector-Borne Diseases	• Improve access to community freezers and food storage facilities, especially in the summer months. • Recommend use of insect repellant, lotion, or sprays, and having netting and screens placed on windows and entrances of houses to deter the increasing number of mosquitoes and other (new) biting insects as a result of rising temperatures. • To address the perception, fear and increasing concern surrounding new biting insects, provide information and education to communities to protect themselves and develop community-based programs to monitor incidence and travel patterns of new biting insects. • Increase community-accessible information and education relating to public health implications associated with environmental causes of disease to allow community members to make healthy and informed decisions related to perceived risks of new insects, biting flies, as well as organisms in animal meat that cause illnesses, such as Trichinellosis.	GNWT, 2018c Friendship and Community of Aklavik, 2011 Pearce et al., 2010

Table 51 Examples of Proposed Adaptation Strategies to Address Potential Health Impacts of Climate Change in the NWT

Climate Change Impacts	Proposed Adaptation Strategies	References
Mental Health and Well-being	• Increase collaboration and communication between federal, territorial, regional and Indigenous governments to support and optimize access to mental health services in the NWT. • Build local capacity, including within members of a community, in mental health care delivery, in order to improve uptake of services, deescalate potential crises, and reduce wait times for mental health counsellors. • In conjunction with Indigenous governments, create and implement Crisis Response plans for designated medical detoxification programs or residential treatment facilities in the NWT. • Adapt mental health services in the NWT to specific needs within different communities in the territory. • As a follow-up to building local capacity, increase the number of local mental health workers/counsellors. • Focus on supporting mental health and resilience in communities through carefully planned policies and local programs, and incorporate traditional knowledge and healing methodologies into mental health programs. • Presence of local mental support/services ensures that even during extreme weather events, mental health services and programs are available to communities in case of crises. • Provide support for programming that promotes sharing of knowledge between Elders and younger generations to limit and prevent obsolescence of Indigenous Knowledge.	Boksa et al., 2015 Kirmayer et al., 2011 Elman et al., 2019 Ford et al., 2014 Health Canada and Assembly of First Nations, 2015 Friendship and Community of Aklavik, 2011 Pearce et al., 2010 Subject Matter Expert Interview, February 2021

7.1 Important Next Steps

Based on the information provided in the report so far, several broad areas of focus for the next steps were identified by the project team and several subject matter experts consulted for this assessment:

- Ground-truthing of the information related to the potential health impacts of climate change identified in this report with local Indigenous and non-Indigenous communities, and adding traditional knowledge to this climate change and health vulnerability assessment of the NWT;
- Identifying and reducing inequities across the NWT, and especially in Indigenous communities, in access to:
    - Health care services;
    - Clean and affordable housing;
    - Healthy and affordable food, including traditional food;
    - Clean drinking water;
    - Mental health services; and
    - Livable household income
- Promoting the sharing of traditional knowledge between Elders and Indigenous youth, especially as related to safety while being on the land, harvesting and hunting skills, and cultural values;
- Identifying ways to stress-test health systems, such as hospitals, to withstand extreme weather events and extreme temperatures;
- Identifying and acknowledging the potential health impacts of ‘combination events’ and ‘multiple stressors’ (e.g., extreme heat wave in addition to wildfires) on individuals and communities;
- Strengthening relationships between communities and promoting the sharing of knowledge and information with regards to climate change adaptation strategies;
- Promoting food sharing within communities, especially for traditional foods and with vulnerable populations, such as Elders, women, children and single-parent families;
- Identifying and taking advantage of new opportunities for growth and diversification; especially as related to advancing food security in the NWT by expanding local growing of crops;
- Establishing monitoring programs for climate change impacts on communities;
- Planning and implementing ways to mitigate future impacts of climate on human health, infrastructure, and the traditional way of life; and
- Maintaining this climate change and health vulnerability assessment of the NWT as a living document that needs to be updated every few years.

8.0 REFERENCES

ACIA (Arctic Climate Impact Assessment). (2004). *Impacts of a warming arctic: Arctic Climate Impact Assessment (ACIA).*Available at: https://www.amap.no/documents/doc/impacts-of-a-warming-arctic-2004/786

Akearok, G. H., Holzman, S., Kunnuk, J., Kuppaq, N., Martos, Z., et al. (2019) Identifying and Achieving Consensus on Health-Related Indicators of Climate Change in Nunavut. Arctic; Vol. 72, Iss. 3: 289-299. DOI:10.14430/arctic68719

Barrow, E., Maxwell, B., and Gachon, P. (2004). Climate variability and change in Canada: Past, present and future. Ottawa: Environment Canada.

Berry, H. L., Bowen, K., and Kjellstrom, T. (2009): Climate change and mental health: a causal pathways framework; International Journal of Public Health, v. 55, no. 2, p.123-132.

Berry, P., Clarke, K., Fleury, M.D. and Parker, S. (2014): Human Health; in Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, (ed.) F.J. Warren and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 191-232.

Boksa, P., Joober, R., Kirmayer, L.J. (2015). Mental wellness in Canada's aboriginal communities: striving toward reconciliation. J Psychiatry Neurosci. Nov;40(6):363–365. PubMed PMID: 26513541; PubMed Central PMCID: PMCPMC4622632.

Bush, E. and Lemmen, D.S., editors (2019): Canada's Changing Climate Report; Government of Canada, Ottawa, ON. 444 p.

Canadian Council of Forest Ministers. (2020). Forest Fires. Retrieved from National Forestry Database: http://nfdp.ccfm.org/en/data/fires.php

ClimateData.ca. (2018-2020). Location Profiles. Retrieved from Climate Data for a Resilient Canada: https://climatedata.ca/

Communities of Nunavik, Furgal, C., Nickels, S., and Kativik Regional Government, Environment department. (2005). *Unikkaaqatigiit—Putting the human face on climate change: Perspectives from Nunavik.* Ottawa: Joint publication of Inuit Tapiriit Kanatimi, Nasivvik Centre for Inuit Health and Changing Environments at Université Laval and the Ajunnginiq Centre at the National Aboriginal Health Organization. [As cited in Furgal et al., 2008]

Cunsolo, A., Ellis, N. (2018) Ecological grief as a mental health response to climate change-related loss. Nature Climate Change; 8:275-81.

Cunsolo Willox, A.C.; Harper, S.L.; Ford, J.D.; Edge, V.L.; Landman, K.; Houle, K.; Blake, S.; Wolfrey, C. (2013). Climate change and mental health: An exploratory case study from Rigolet, Nunatsiavut, Canada. Clim. Chang. 2013, 121, 255–270. DOI 10.1007/s10584-013-0875-4.

Derksen, C., Burgess, D., Duguay, C., Howell, S., Mudryk, L., Smith, S., Thackeray, C. and Kirchmeier-Young, M. (2019): Changes in snow, ice, and permafrost across Canada;

Chapter 5 in Canada's Changing Climate Report, (ed.) E. Bush and D.S. Lemmen; Government of Canada, Ottawa, Ontario, p.194–260.

Dodd, W., Scott, P., Howard, C., Rose, C., Scott, C., Cunsolo, A., et al. (2018) Lived experience of a record wildfire season in the Northwest Territories, Canada. Canadian Journal of Public Health 109:327–337.

Duchesne, C., Chartrand, J., & Smith, S. L. (2020). Report on 2018 field activities and collection of ground-thermal and active-layer in the Mackenzie corridor; Northwest Territories. Geological Survey of Canada, Open File 8707, 84p.

Durkalec, A., Furgal, C., Skinner, M. W., & Sheldon, T. (2014). Investigating environmental determinants of injury and trauma in the Canadian north. *International Journal of Environmental Research and Public Health*, *11*(2), 1536–1548. https://doi.org/10.3390/ijerph110201536

Elkin, B., Armstrong, T., & Ellsworth, T. (2013). Anthrax Emergency Response Plan (AERP). Department of Environment and Natural Resources. Government of the Northwest Territories. Available: https://www.enr.gov.nt.ca/sites/enr/files/file_reports/139_file.pdf

Elman, A., Etter, M., Fairman, K., & Chatwood, S. (2019). Mental health services in the Northwest Territories: a scoping review. International journal of circumpolar health, 78(1), 1629783. https://doi.org/10.1080/22423982.2019.1629783

ENR. (2016). Northwest Territories Air Quality Report. Environment and Natural Resources. Available: https://www.enr.gov.nt.ca/sites/enr/files/resources/128-air_quality_report_2016_press.pdf

ENR. (2018). 2018 NWT bison survey shows no signs of anthrax. Environment and Natural Resources. Available: https://www.enr.gov.nt.ca/en/newsroom/2018-nwt-bison-survey-shows-no-signs-anthrax

ENR. (2019). Northwest Territories: Waste Resource Management Strategy and Implementation Plan. Available at: https://www.enr.gov.nt.ca/sites/enr/files/resources/waste_strategy_plan.pdf

EPSKFS (2014). Expert Panel on the State of Knowledge of Food Security in Northern Canada. Aboriginal Food Security in Northern Canada: An Assessment of the State of Knowledge, Council of Canadian Academies, Ottawa, 2014, p. 193. Available: https://foodsecurecanada.org/sites/foodsecurecanada.org/files/foodsecurity_fullreporten.pdf

Flannigan et al. (2013). Global wildland fire season severity in the 21st Century. Forest Ecology and Management, 54-61. vol. 294.

Ford, J.D., Smit, B., and Wandel, J. (2006). Vulnerability to climate change in the Arctic: A case study from Arctic Bay, Nunavut. Global Environmental Change, 16(2), 145–160.

Ford, J. D., Pearce, T., Gilligan, J., Smit, B., & Oakes, J. (2008). Climate Change and Hazards Associated with Ice Use in Northern Canada. *Arctic, Antarctic, and Alpine Research*, *40*(4), 647–659. https://doi.org/10.1657/1523-0430(07-040)[FORD]2.0.CO;2

Ford, J. D., Lardeau, M.-P., Blackett, H., Chatwood, S., & Kurszewski, D. (2013). Community food program use in Inuvik, Northwest Territories. BMC Public Health, 13(1), 970. https://doi.org/10.1186/1471-2458-13-970

Ford, J. D., Willox, A. C., Chatwood, S., Furgal, C., Harper, S., Mauro, I., & Pearce, T. (2014). Adapting to the effects of climate change on Inuit health. American journal of public health, 104 Suppl 3(Suppl 3), e9–e17. https://doi.org/10.2105/AJPH.2013.301724

Friendship, K. and Community of Aklavik (2011). Climate Change Adaptation Action Plan. Community of Aklavik, Northwest Territories. Compiled by Katelyn Friendship and Community of Aklavik, in collaboration with ArcticNorth and RavenQuest. March 2011. Available at: https://arctichealth.org/media/pubs/301005/Aklavik_Adaptation_Plan.pdf

Furgal, C., Buell, M., Chan, L., Martin, D., and Ogden, N. (2008). Health Impacts of Climate Change in Canada's North. Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity. Available: https://www.researchgate.net/publication/242306913_Health_Impacts_of_Climate_Change_in_Canada's_North

Furgal, C., and Séguin, J. (2006). Climate change, health and community adaptive capacity: Lessons from the Canadian North. Environmental Health Perspectives, 114(12), 1964–1970.

GNWT. (n.d.). Ecological Regions of the Northwest Territories – Northern Arctic. Retrieved from Department of Environment and Natural Resources: https://www.enr.gov.nt.ca/sites/enr/files/reports/poster.pdf

GNWT. (n.d.). Ecological Regions of the Northwest Territories – Taiga Plains. Retrieved from Department of Environment and Natural Resources: https://www.enr.gov.nt.ca/sites/enr/files/reports/taigaplains_poster.pdf

GNWT. (n.d.). Ecological Regions of the Northwest Territories Southern Arctic. Retrieved from Department of Environment and Natural Resources: https://www.enr.gov.nt.ca/sites/enr/files/reports/128-southernarcticposter_press.pdf

GNWT. (n.d.). Ecological Regions of the Taiga Shield. Retrieved from Department of Environment and Natural Resources: https://www.enr.gov.nt.ca/sites/enr/files/reports/taiga_shield_poster.pdf

GNWT. (n.d.). Ecosystem Classification. Retrieved from Environment and Natural Resources: https://www.enr.gov.nt.ca/en/services/ecosystem-classification

GNWT. (2005). Government of Northwest Territories. The NWT health status report: 2005. Yellowknife: Department of Health and Social Services.

GNWT. (2008). Government of Northwest Territories – The Department of Environment and Natural Resources. NWT Climate Change Impacts and Adaptation Report. Available: https://www.enr.gov.nt.ca/sites/enr/files/reports/nwt_climate_change_impacts_and_adaptation_report.pdf

GNWT. (2011). Northwest Territories Health Status Report. Yellowknife, NT: Department of Health and Social Services. Available:

GNWT. (2013). Community Infrastructure Profiles. Retrieved from GNWT Bureau of Statistics: https://www.statsnwt.ca/community-data/

GNWT. (2014). NWT Community Survey Results. Retrieved from GNWT Bureau of Statistics: https://www.statsnwt.ca/community-data/

GNWT. (2016). Northwest Territories Community Wellness Initiatives. Annual Report 2014-2015. Available: https://www.hss.gov.nt.ca/sites/hss/files/resources/community-wellness-initiatives-report-2014-2015.pdf

GNWT. (2018a). Community Data. Retrieved from NWT Bureau of Statistics: https://www.statsnwt.ca/community-data/

GNWT. (2018b). Maps Available - Environment and Natural Resources. Retrieved from Northwest Territories Centre for Geomatics: https://www.geomatics.gov.nt.ca/en/maps-available-environment-and-natural-resources

GNWT. (2018c). Government of Northwest Territories. The 2030 NWT Climate Change Strategic Framework. Available: https://www.enr.gov.nt.ca/sites/enr/files/resources/128-climate_change_strategic_framework_web.pdf

GNWT. (2018d). Government of Northwest Territories. The 2030 NWT Energy Strategy. Available: https://www.inf.gov.nt.ca/sites/inf/files/resources/gnwt_inf_7272_energy_strategy_web-eng.pdf

GNWT. (2019a). Government of Northwest Territories. The 2030 NWT Climate Change Strategic Framework - 2019-2023 Action Plan Available: https://www.enr.gov.nt.ca/sites/enr/files/resources/128-climate_change_ap_proof.pdf

GNWT. (2019b). Government of Northwest Territories. NWT Health Status Chartbook: Transition and Strategic Planning. Available: https://www.hss.gov.nt.ca/sites/hss/files/resources/health-status-chartbook.pdf

Government of Canada (2017). October 2017 Report of the Auditor General of Canada to the Northwest Territories Legislative Assembly -Climate Change in the Northwest Territories. Available: https://www.oag-bvg.gc.ca/internet/English/nwt_201710_e_42609.html

Government of Canada. (2020). Historical Climate Data. Retrieved from Environment and Natural Resources: https://climate.weather.gc.ca/

Guyot, M., Dickson, C., Macguire, K., Paci, C., Furgal, C., et al. (2006). Local observations of climate change and impacts on traditional food security in two northern Aboriginal communities. International Journal of Circumpolar Health, 65(5), 403–415.

Hajizadeh, M., Bombay, A., and Asada, Y. (2019) “Socioeconomic inequalities in psychological distress and suicidal behaviours among Indigenous peoples living off-reserve in

Canada". Canadian Medical Association Journal, Vol. 191, No. 12, 25 March 2019, p. E334.

Health Canada (2012): Ross River First Nation Yukon: caribou culture and climate change. Available: http://climatetelling.ca/community/ross-river-caribou

Health Canada & Assembly of First Nations. (2015). First Nations Mental Wellness Continuum Framework. Available: https://thunderbirdpf.org/wp-content/uploads/2015/01/24-14-1273-FN-Mental-Wellness-Framework-EN05_low.pdf

Halseth, R. (2015). The nutritional health of the First Nations and Métis of the Northwest Territories: A review of current knowledge and gaps. Prince George, BC. Available: http://www.nccah-ccnsa.ca/Publications/Lists/Publications/Attachments/141/2015_04_21_RPT_DietNutritionNWT_EN_Web.pdf

Hayes, K., Poland, B. (2018). Addressing Mental Health in a Changing Climate: Incorporating Mental Health Indicators into Climate Change and Health Vulnerability and Adaptation Assessments. Int J Environ Res Public Health;15(9).

Howard, C., N, Rose, C., and Rivers, N. (2018). Lancet Countdown 2018 Report: Briefing for Canadian Policymakers. November 2018. The Lancet 2018. Available: https://www.cma.ca/sites/default/files/pdf/Tools%20%26%20resources/2018-lancet-countdown-policy-brief-canada.pdf

Huntington, H., Fox, S., Berkes, F., Krupnik, I., Whiting, A., et al. (2005). The changing Arctic: Indigenous perspectives. In Arctic Climate Impact Assessment (ACIA) (pp. 61–98). Cambridge, U.K.: Cambridge University Press.

Indigenous Services Canada. (2019). Community Voices on Climate Change and Health Adaptation in Northern Canada: Research and Action and the Stories Behind Them 2012-2016. Ottawa, ON. Available: http://www.climatetelling.info/uploads/2/5/6/1/25611440/19-012-climate-change-c2-ang.pdf

Inuit Tapiriit Kanatami (2017). An Inuit-Specific Approach for the Canadian Food Policy. Available: https://www.itk.ca/wp-content/uploads/2019/01/ITK_Food-Policy-Report.pdf

Kirmayer, L.J., Dandeneau, S., Marshall, E., et al. (2011). Rethinking resilience from indigenous perspectives. Can J Psychiatry. Feb;56(2):84–91. PubMed PMID: 21333035; eng.

Kral, M.J. (2016) Suicide and suicide prevention among Inuit in Canada. Can J Psychiatry; 61:688-95.

Lancet Countdown, 2018: 2018 Lancet Countdown on Health and Climate Change Brief for the United State of America. Salas RN, Knappenberger P, Hess JJ. Lancet Countdown U.S. Brief, London, United Kingdom, 32 pp. Available: https://storage.googleapis.com/lancet-countdown-preprod/2019/10/2018-lancet-countdown-policy-brief-usa.pdf

Leblanc-Laurendeau, O. Food Insecurity in Northern Canada: An Overview, Publication no. 2019-18-E, Parliamentary Information and Research Service, Library of Parliament, Ottawa, 5 July 2019. Available: https://lop.parl.ca/sites/PublicWebsite/default/en_CA/ResearchPublications/202047E

Minister of Health and Long-term Care (MOHLTC) (2016) Ministry of Health and Long-Term Care. Ontario Climate Change and Health Toolkit. Available: http://www.health.gov.on.ca/en/common/ministry/publications/reports/climate_change_toolkit/climate_change_toolkit.pdf

Ministry of Health and Long-Term Care (MOHLTC) (2019). Infectious Diseases Protocol Appendix A: Disease-Specific Chapters-Chapter Anthrax. Available: http://www.health.gov.on.ca/en/pro/programs/publichealth/oph_standards/docs/anthrax_chapter.pdf

New, D., Elkin, B., Armstrong, T., & Epp, T. (2017). Anthrax in the Mackenzie Wood bison (*Bison bison athabascae*) population: 2012 anthrax outbreak and historical exposure in non outbreak years. *Journal of Wildlife Diseases*, *53*(4), 769–780. https://doi.org/10.7589/2016-11-257

Ogden, N.H., Maarouf, A., Barker, I.K., Bigras-Poulin, M., Lindsay, L.R., et al. (2006). Climate change and the potential for range expansion of the Lyme disease vector *Ixodes scapularis* in Canada. International Journal for Parasitology, 36(1), 63–70.

Pardhan-Ali A., Wilson J., Edge V. L., Furgal C., Reid-Smith R., Santos M. & McEwen S. A. (2012). A descriptive analysis of notifiable gastrointestinal illness in the Northwest Territories, Canada, 1991-2008. BMJ Open 2 (4), e000732.

Pardhan-Ali, A., Wilson, J., Edge, V. L., Furgal, C., Reid-Smith, R., Santos, M., & McEwen, S. A. (2013). Community-level risk factors for notifiable gastrointestinal illness in the Northwest Territories, Canada, 1991-2008. BMC Public Health, 13(1), 63. https://doi.org/10.1186/1471-2458-13-63

Pearce, T., Ford, F., Caron, A., Prno, J., and Smith T. (2010). Climate Change Adaptation Action Plan, Paulatuk, Northwest Territories. Guelph, Ontario. Joint publication of the Community of Paulatuk and ArcticNorth Consulting. ISBN 0-9865908-0-8. March 2010. Available: https://www.cakex.org/sites/default/files/documents/Paulatuk-Adaptation-Action-Plan-20102.pdf

Pearce, T., Smit, B., Duerden, F., Ford, J. D., Goose, A., & Kataoyak, F. (2010). Inuit vulnerability and adaptive capacity to climate change in Ulukhaktok, Northwest Territories, Canada. *Polar Record*, *46*(2), 157–177. https://doi.org/10.1017/S0032247409008602

Restoule, B.M., Hopkins, C., Robinson, J., et al. (2015). First nations mental wellness: mobilizing change through partnership and collaboration. Can J Community Mental Health;34(4):89–109.

Rogers, D.J., and Randolph, S.E. (2006). Climate change and vector-borne diseases. Advances in Parasitology, 62, 345–381.

Romanovsky, V. E., Smith, S. L., Isaksen, K., Shiklomanov, N. I., Streletskiy, D. A., Kholodov, A. L., . . . Marchenko, S. S. (2018). Terrestrial Permafrost. Bulletin of the American

Meteorological Society, v. 100, no. 9, p. S153-S156, doi: 10.1175/2019BAMSStateoftheClimate.1

Schwalm, C., Glendon, S., & Duffy, P. (2020). RCP8.5 tracks cumulative CO2 emissions. Proceeding of the National Academy of Sciences of the United States of America, 117 (33) 19656-19657.

Séguin, J. (ed.) (2008): Human Health in a Changing Climate: a Canadian Assessment of Vulnerabilities and Adaptive Capacity; Health Canada, Ottawa, Ontario, 484 p.

Short, N., Brisco, B., Couture, N., Pollard, W., Murnaghan, K., & Budkewitsch, P. (2011). A comparison of TerraSAR-X, RADARSAT-2 and ALOS-PALSAR interfermetry for monitoring permafrost environments, case study from Herschel Island. Canada Remote Sens. Environ., 115 3491-506.

Smith, S. L., Duchesne, C., & Lewkowicz, A. G. (2011). Tracking changes in permafrost thermal state in Northern Canada; In Cold Regions Engineering 2019 (Proceedings of the 18th International Conference on Cold Regions Engineering and the 8th Canadian Conference on Permafrost. (J. Bilodeau, D. F. Nadeau, D. Fortier, & D. Conciatori, Eds.) American Society of Civil Engineers, 670-677.

Statistics Canada (2011). National Household Survey, 2011. Aboriginal Peoples: Fact Sheet for Northwest Territories. Available: https://www150.statcan.gc.ca/n1/pub/89-656-x/89-656-x2016013-eng.htm

Statistics Canada (2016). 2016 Census of Population, Statistics Canada Catalogue no. 98-400-X2016268. Available: https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/dt-td/Rp-eng.cfm?TABID=2&LANG=E&A=R&APATH=3&DETAIL=0&DIM=0&FL=A&FREE=0&GC=61&GL=-1&GID=1334865&GK=1&GRP=1&O=D&PID=110682&PRID=10&PTYPE=109445&S=0&SHOWALL=0&SUB=0&Temporal=2017&THEME=123&VID=0&VNAMEE=&VNAMEF=&D1=0&D2=0&D3=0&D4=0&D5=0&D6=0

Status of Women Canada (2020). Government of Canada's Approach. Government of Canada. Retrieved March 15, 2021, from https://cfc-swc.gc.ca/gba-acs/approach-approche-en.html

Waeckerlin, R., Swann, J., Elkin, B., Zuliani, A., Cork, S. (2012) Flavi and Bunyavirus mosquito vector distribution in North Western Canada. Int J Infect Dis; 16: e449.

Weller, et al. (2005). Summary and synthesis of the Arctic Climate Impact Assessment, Chapter 18. ACIA.

Wesche, S. D., O'Hare-Gordon, M. A. F., Robidoux, M. A., & Mason, C. W. (2016). Land-based programs in the Northwest Territories: Building Indigenous food security and well-being from the ground up. Canadian Food Studies/La Revue Canadienne Des Études Sur l'alimentation, 3(2), 23–48. https://doi.org/10.15353/cfs-rcea.v3i2.161

WHO (World Health Organization). (n.d.). Ultraviolet radiation. Retrieved January 27, 2021, from https://www.who.int/westernpacific/health-topics/ultraviolet-radiation

Young, S. K., Tabish, T. B., Pollock, N. J., & Young, T. K. (2016). Backcountry Travel Emergencies in Arctic Canada: A Pilot Study in Public Health Surveillance. *International Journal of Environmental Research and Public Health*, *13*(3). https://doi.org/10.3390/ijerph13030276