THE IMPACTS OF PERMAFROST THAW ON NORTHERN INDIGENOUS COMMUNITIES

Firelight Research Inc. with the Canadian Climate Institute

The Impacts of Permafrost Thaw on Northern Indigenous Communities

FINAL REPORT / June 2022

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On behalf of:

The Canadian Climate Institute

Submitted to:

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Thanks and acknowledgments go to the Indigenous community members, Elders, knowledge holders, land users, staff, and leaders who contributed. This report could not have been completed without their support and expert knowledge.

Disclaimer:

The information contained in this report is based on research conducted by Firelight Research Inc., as well as published works and archival research. It reflects the understandings of the lead authors and is not intended to be a complete depiction of the dynamic and living systems of land use and knowledge maintained by the Indigenous community members interviewed, who spoke on their own behalf and not as representatives of their communities. It may be updated, refined, or changed as new information becomes available. All mapped information is based on interviews with Indigenous knowledge holders conducted within constraints of time, budget, and scope. Base map data originate from the National Topographic System and Natural Resources Canada. The information contained herein should not be construed as to define, limit, or otherwise constrain the treaty, land claim or Aboriginal rights of any Indigenous Peoples.

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EXECUTIVE SUMMARY

This report addresses the observed and anticipated impacts of permafrost thaw and degradation shared by Indigenous participants from communities across Northern Canada. It accompanies a study led by Canadian Climate Institute study on the impacts of permafrost thaw on Northern Indigenous communities *Due North: Facing the costs of climate change for Northern infrastructure*.

This research is responding to a gap identified in an initial scan of the literature. Thus far, the bulk of permafrost research has focused on monitoring and measuring subsurface temperatures and slumping. To date, there has been limited research—even with regard to impacts on infrastructure—focused on human experiences of permafrost thaw and the implications of thaw and related impacts for Northern and particularly for Indigenous communities.

Northern Indigenous observations, knowledge, oral history, adaptive behaviour, and opinion are largely absent from the Canadian permafrost literature. This data gap regarding the human impacts of permafrost thaw is mirrored by a policy gap. Policy responses to permafrost thaw have focused on acquiring or providing funding for technocentric approaches to shoring up unstable infrastructure. This approach fails to adequately recognize infrastructure as part of, and crucial to, the web of the community, resulting in inadequate support for the social structures and networks that provide critical capacity for climate adaptation.

In order to help address this gap, this report is based on interviews with Indigenous participants from communities across the North (defined as the Yukon, Northwest Territories, Nunavut, Nunavik, and Nunatsiavut). Regional differences both in permafrost impact and in adaptive response are central to this report. While adapting to permafrost thaw is a priority for Northern Indigenous communities, and should be a priority at a national level, any policy must acknowledge the regional differences that must inform a response to this challenge. Discussion of observed impacts includes mapped and qualitative information related to the impact of permafrost thaw on participants' communities and land use. Participant observations and concerns related to adaptive practices were also recorded.

This report is organized around five key themes that are crucial to Indigenous well-being in the North:

- Hunting, trapping, and fishing;
- Travel, trails, and access;
- Food sovereignty;
- Cultural continuity and knowledge transfer; and

- Household and community infrastructure.

The following key impacts on these themes were observed by interview participants.

Impacts for hunting, trapping, and fishing:

- Changes to the habitat of key species (e.g., impacts from permafrost thaw on caribou habitat or impacts from riverbank slumping and sedimentation on fish)
- Changes to the vegetation and forage of key species (e.g., caribou)
- Decreased harvests and/or increased effort required to successfully harvest country foods (food gathered and harvested from the land) as a result of the above changes

Impacts for travel, trails, and access:

- Thawed ground that slumps, slides, or becomes boggy and difficult to traverse
- Increased difficulty travelling on trails, increasing travel time and potentially leading to increased safety risks and increased cost of travel
- Increased costs and travel safety risks, potentially leading to decreased use of certain areas
- Slumping impacts on roads and airstrips, including reduced inter-community movement and increased costs (and decreased availability) for store-bought foods and goods

Impacts for food sovereignty:

- Difficulty harvesting and storing of a variety of country foods (e.g., thawing of permafrost lockers or underground cellars)
- Threats to building integrity in communities, creating repercussions for food storage and refrigeration

Impacts for cultural continuity and knowledge transfer:

- Increased difficulties and risks associated with travel and time spent on the land, leading to less time on the land; time spent on the land with Elders is essential to the transfer of many skills
- Decreased travel or use of areas where slumping or degradation of permafrost is occurring, reducing the transfer of Indigenous knowledge relevant to those areas

Impacts for household and community infrastructure:

- Damage to buildings, resulting in increased costs for construction, maintenance, and insurance incurred by both households and communities

- Increased (and potentially prohibitive) construction and maintenance costs, resulting in substandard housing conditions and exacerbating housing shortages

- Increased insurance costs, impacting households' financial stability and viability

This report concludes by offering the following recommendations for future research and monitoring:

- *Investigate regional differences.* The "Northern" experience is uniquely regional and highly localized, based on local ecologies and social, cultural, and economic systems. These have a profound impact on the ability of communities and individuals to effectively adapt.

- *Connect infrastructure impacts to community use.* A holistic approach is recommended, one that situates infrastructure according to its use and purpose within the larger community. For example, what are the implications of poor building stability when the building in question is the warehouse in which the community stores food and supplies? In this case, research and policy must push beyond the immediate implications of building operational costs, maintenance, or insurance and into the role the building plays in community food supply and security.

- *Track costs and who pays them.* Effectively tracking the costs of permafrost thaw (including both operational and absence cost) should form a part of ongoing infrastructure assessment processes. A roadmap to understanding how these costs are met by Northern entities—federal agencies and departments; territorial, municipal, or Indigenous governments; or individual households—would be a valuable tool to assist in the effective deployment of subsidies or other supports.

- *Recognize that isolation magnifies climate impacts.* While food security/sovereignty research does tend to consider impacts of isolation such as road access or food travel times, the risks or costs posed by permafrost are magnified in remote communities in ways that are not always fully appreciated (for example, impacts to food storage like refrigeration capacity).

- *Fund Indigenous-led research on impacts to land use and culture.* Permafrost thaw poses a significant challenge to the traditional land uses, activities, and cultural continuity of Northern Indigenous communities. Appropriate mapping of these activities, both historical and contemporary, is necessary to fully understand and track the nature of such impacts. Funding community-led climate risk and

vulnerability assessments (including as part of broader climate adaptation planning processes) is a way for federal and territorial leaders to support and strengthen the agency of communities to gather and use data and maintain data sovereignty themselves, while also providing valuable outputs that can shape policy.

- *Recognize that climate impacts do not occur in isolation.* Permafrost thaw impacts must be considered as part of a constellation of climate-related impacts and within a broader context of cumulative effects on Indigenous communities. These cumulative effects include the long-term consequences of other processes in the North (whether ongoing or anticipated), including but not limited to the impacts of past Canadian colonial policy, infrastructure gaps, patterns of federal funding, the impacts of resource development and associated wealth transfers, and gaps in education and data.

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ACRONYMS AND ABBREVIATIONS

the Institute	Canadian Climate Institute
NWT	Northwest Territories
NL	Newfoundland and Labrador
NU	Nunavut
ISR	Inuvialuit Settlement Region
TASR	Tlicho All-Season Road

1. INTRODUCTION

1.1 OVERVIEW

Firelight Research Inc. (Firelight) is pleased to provide this report to the Canadian Climate Institute (the Institute). This report documents the background, methods, and findings of a study addressing the impact of permafrost thaw on Northern Indigenous communities.

This report provides a selection of observed and anticipated impacts of permafrost thaw and degradation shared by Indigenous participants from communities across Northern Canada. This report includes non-confidential, site-specific (i.e., mapped), and qualitative information related to the impact of permafrost thaw on participants' communities and land use.

This report is organized into five sections:

- Section 1 introduces the research project and process.
- Section 2 provides background and context to the study and situates permafrost thaw within the literature around climate change impacts on Northern Indigenous communities.
- Section 3 provides the results of both the literature scan and the interviews, organized according to key thematic clusters identified in the data and introduced by a discussion of permafrost thaw as one of a variety of participant-observed signals of climate change and other cumulative effects. This section also describes adaptations pursued by communities and individual participants.
- Section 4 describes key conclusions drawn by the authors regarding the impact of permafrost thaw on Northern Indigenous communities and identifies gaps and recommendations for future research.

1.2 SCOPE OF WORK

The Institute has retained Firelight to support a study on the impacts of permafrost thaw on Northern Indigenous communities. As detailed in the December 2020 work plan, this includes:

- Detailed budgeting, scoping, work planning, preliminary meetings with the Institute leadership and staff, and project management;
- Development and tailoring of interview and mapping methodologies for the study;

- Interview-based data collection (with a goal of 15–25 individual mapping interviews), followed by data verification and analysis; and

- Final reporting, including supporting the Institute staff on communications to decision makers and the public.

The primary goals of the study are to provide:

- Reliable and rigorous documentation, including mapping where possible, of Indigenous knowledge and key issues or concerns relating to the impacts of permafrost thaw on Northern Indigenous communities; and

- A public final report (this report) prepared for the Institute.

1.3 STUDY AREA AND INTERVIEWEES: NORTHERN INDIGENOUS COMMUNITIES AND REGIONS

The study area considered by this report is Northern Canada, defined as the Yukon, Northwest Territories, Nunavut, Nunavik, and Nunatsiavut (depicted in the map of the Study Area, Figure 1, on the following page). Where potential interviewees were outside of these areas, they were considered on a case-by-case basis depending on the relative proximity of their community to permafrost and the connectedness of their community to the Northern landscapes represented in these regions. These transboundary exceptions were made to acknowledge the arbitrary nature of bureaucratic boundaries when it comes to the patterns of traditional land use and occupancy of Indigenous communities. The breakdown of interviews by community can be found in Appendix 1.

This report covers a range of regions, representing diverse geographies, ethno-linguistic regions, and polities. Acknowledging these regional differences both in permafrost impact and in adaptive response is central to this report.

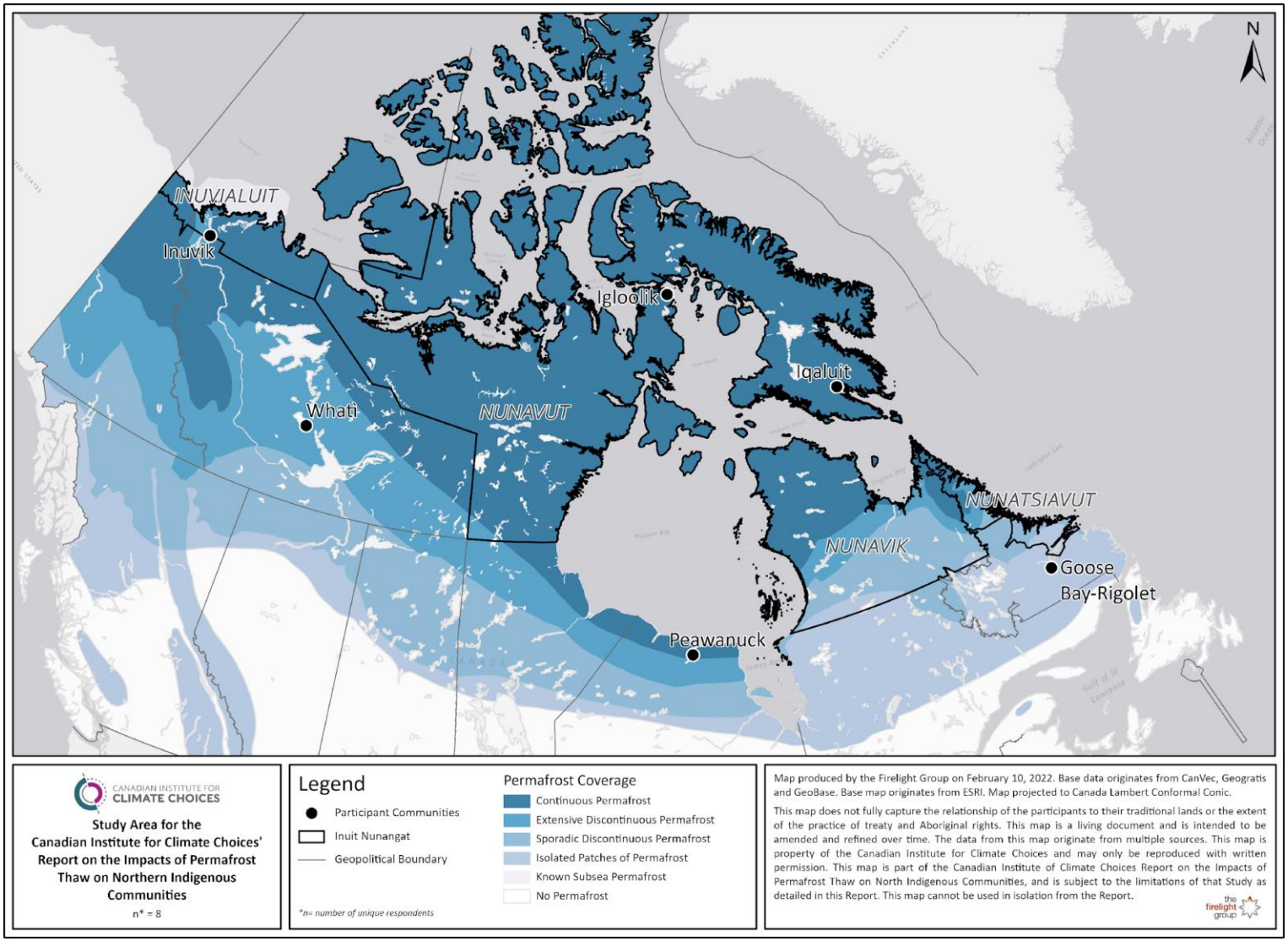
N
INUVIALUIT
Inuvik
Igloolik
Iqaluit
Whati
NUNAVUT
NUNATSIAVUT
NUNAVIK
Goose Bay-Rigolet
Peawanuck
CANADIAN INSTITUTE FOR CLIMATE CHOICES
Study Area for the Canadian Institute for Climate Choices' Report on the Impacts of Permafrost Thaw on Northern Indigenous Communities
n* = 8
Legend
Participant Communities
Inuit Nunangat
Geopolitical Boundary
*n= number of unique respondents
Permafrost Coverage
Continuous Permafrost
Extensive Discontinuous Permafrost
Sporadic Discontinuous Permafrost
Isolated Patches of Permafrost
Known Subsea Permafrost
No Permafrost
Map produced by the Firelight Group on February 10, 2022. Base data originates from CanVec, Geogratis and GeoBase. Base map originates from ESRI. Map projected to Canada Lambert Conformal Conic.
This map does not fully capture the relationship of the participants to their traditional lands or the extent of the practice of treaty and Aboriginal rights. This map is a living document and is intended to be amended and refined over time. The data from this map originate from multiple sources. This map is property of the Canadian Institute for Climate Choices and may only be reproduced with written permission. This map is part of the Canadian Institute of Climate Choices Report on the Impacts of Permafrost Thaw on North Indigenous Communities, and is subject to the limitations of that Study as detailed in this Report. This map cannot be used in isolation from the Report.
the firelight group

Figure 1. Study area, including participants' communities

1.4 LIMITATIONS

The report itself has a number of limitations and should be considered a first step in identifying Indigenous uses and values that may be impacted by permafrost thaw. Report limitations include the following:

- Not all knowledge holders and not every community impacted by permafrost thaw was able to participate in this study. Efforts were made to include key knowledge holders active in and knowledgeable about permafrost thaw and its impacts on their communities, but many Indigenous community members with important knowledge of the study subject may have been unable to participate due to time and budget restrictions.

- The COVID-19 pandemic has resulted in community restrictions across the North since March of 2020, which have at times led to delays and likely impacted research participation.

- Data collected for each participant is limited by what the participant is able and willing to report.

- Because little detail on the location and nature of permafrost thaw is available, the analysis in this report should be considered conservative, with actual effects likely to be greater than predicted.

Given the above limitations, this report cannot be used as a representative spatial account of Indigenous land use in Northern Canada. It is important to note that the study does not reflect all current Indigenous use in those areas and that *an absence of data does not signify an absence of use or value.* This report is not intended as a complete depiction of the dynamic way of life and living system of use and knowledge maintained by Indigenous Peoples of Northern Canada.

2. BACKGROUND

This section summarizes the key findings of the literature scan (see Appendix 1 for study methods), which focused on the impacts of permafrost thaw on Northern Canadian Indigenous communities. These findings provide important background and context for the interviews with community members presented in later sections. This summary situates permafrost literature within the broader study of the human dimensions of climate change, describes documented permafrost impacts, and identifies key gaps in the literature and their implications for the interview process and results described in Sections 3 and 4 in this report.

2.1 PERMAFROST AND CLIMATE CHANGE

The permafrost layer is becoming a well-studied subject in environmental science (Wallace 2019). Up to 50 per cent of Canada's landmass is situated on permafrost, and scientists estimate that the Northern Hemisphere's permafrost may hold up to 1.7 trillion tonnes of organic carbon (Bush and Lemmen 2019). The release of carbon dioxide and methane from thawing permafrost is among the most researched aspects of permafrost thaw, along with thaw rate, impact on microbial communities, and landscape change.

Global warming is the main factor driving the deterioration and thaw of permafrost. Between 1948 and 2016, the annual mean temperature in Canada's North increased by 2.3 degrees Celsius (Bush and Lemmen 2019). Warmer temperatures and seasonal changes cause snow and ice to melt quickly, resulting in larger spring run-off events. Water can permeate the ground and accelerate the thaw of permafrost because water is a good conductor of temperature, unlike ice or frozen soil (Vincent et al. 2017).

Thawing permafrost creates an unstable layer that can cause landslides, further exposing deeper layers of permafrost to the atmosphere. In this way, permafrost thaw is a process that cannot easily be reversed: while the upper surface, or active layer, may refreeze seasonally, current trajectories of global warming are such that it is unlikely that thawed ground will fully refreeze and become permafrost again during this geological epoch (Vincent et al. 2017).

Like sea ice, permafrost has been extensively monitored. This is largely due to the implications for built infrastructure in the North. Ground movement (from thawing permafrost) can cause shifting and settling of foundations, slumping, and associated damage to a range of surfaces including roads, railways, pipelines, transmission lines, and airstrips. Infrastructure such as houses and utilities, however, also require constant maintenance and repair due to the seasonal freeze/thaw cycle of the active layer (Allard et al. 2012, Baird and Podlasly 2020, Fortier et al. 2011). These structures are designed around their permafrost base in order to avoid heat transfer, and many have built-in monitoring systems to detect instability caused by thawing. This maintenance cost or burden is already increasing rapidly across Canada as the active layer deepens (Vincent et al. 2017). The Canadian Climate

Institute's quantitative analysis of the cost of permafrost thaw captures key aspects of this challenge and its expected cost for Northern communities.

2.2 DOCUMENTED PERMAFROST IMPACTS ON INDIGENOUS COMMUNITIES

With respect to direct effects of permafrost thaw on Indigenous communities, literature describing the experiences of Northern communities has largely focused on the built environment. There is, a dearth of permafrost policy and studies—in the grey and academic literature—focused on "soft" (unbuilt) aspects of community life.

Research and policy from across the North, including from Nunavut (Government of Nunavut 2010) and Nunavik (Fortier et al. 2011), is evidence of this trend. While policy and studies continue to identify infrastructure as being impacted by permafrost thaw, there remain few studies that identify the impacts of this on inhabitants, beyond potential impacts on housing or the cost of infrastructure maintenance or replacement. The literature associating housing quality (as an example) with mental and physical health had yet to be effectively or meaningfully united with infrastructure-focused literature to identify the many direct and indirect pathways by which permafrost thaw may have implications for human health and well-being.

The literature gap identified above—a mismatch between data-driven measurements of permafrost impact and human-experienced changes—is even more pronounced when considering the impacts of permafrost on Indigenous communities. There are few academic or government studies, programs, or policies engaged in assessing the impacts of permafrost on Indigenous communities. Instead, the emphasis is on climate change (Downing and Cuerrier 2011) and climate change adaptations (Nunavut Government 2010, Cochran et al. 2014) across all signals (including climate change but often overshadowed by more visible changes like snowfall or the melting of sea ice). The available literature on how permafrost thaw affects Indigenous communities is centred on journalistic work and grey literature, including interviews, videos, and pictures with Indigenous community members, addressing how Indigenous lifestyles and hunter-gatherer lifeways are affected (Wallace 2019, Shah 2019, Schreiber 2018, Mercer 2019, Kintisch 2015). This report draws from these aforementioned sources (see Appendix 4), as well as interviews conducted for this study—the results of which are presented in the section that follows.

3. RESULTS

3.1 PLACING PERMAFROST-THAW IMPACTS IN CONTEXT: CLIMATE CHANGE AND CUMULATIVE EFFECTS

Permafrost thaw is one of many measurable signals of climate change. Community experiences of permafrost thaw cannot be considered in isolation from other climate-related changes. These changes, as well as other social, economic, and cultural changes impacting Northern Indigenous communities over the past several generations should be considered as cumulative effects. As such, changes unrelated to permafrost may shape or even magnifying the impacts of permafrost thaw.

To effectively understand permafrost thaw, it is essential to place it in the context of adverse effects from other sources (past, present, and likely future). The data presented below serve to underscore the fact that impacts from permafrost thaw would be adding to, and compounding, damage already incurred on Indigenous culture and cultural continuity.

In Indigenous communities across the North, a wide range of changes are being observed, many of which were acknowledged by participants of this study to be associated with a shifting climate. Changes in weather patterns, and in particular the seasonal timing of weather, were often noted in this regard, as the quotes below describe.

> *I would say [the road] freezes like exactly a month later.... All these changes is affecting the precipitation. I noticed that in the fall we get more water now—more than before … people are, got accustomed to the same temperature. (C02, September 28, 2021)*

> *Well, I can remember one time, like in September … it gets really windy and then also that it's—gets colder there around September. ... And today, like October the 5th—plus one. ... There's rain off and on steady—kind of wet. I can remember one time around October the 10th, the lake was frozen … And springtime is different again, like no, you know, like you see patches of snow on the ground, but it's just some time it goes away, you know … And some time it's too hot at times. And makes you wonder where it's coming from. ... So, I kind of notice all that. ... You know, all these years living here. (C05, October 5, 2021)*

> *… right now, here we are in October 14th and normally we have snow here, but now it's just sunshine and plus eight right now. We haven't had any snow here at all, and normally it freeze up here on the lake. We have a big lake here—freezes up around, around the bay here the middle of October, but it seems to be really just like summer here. So, yes, it's changed quite a bit. The weather have changed … we're really getting warmer…. (C06, October 14, 2021)*

Changes in seasonal timing have significant implications for community life, altering patterns of knowledge and use and demanding adaptive behaviours like relying on certain trails or transport networks and limiting use of others. With changing weather comes increased safety risks for land users as it becomes difficult to gauge how long journeys may take, or even if they will be possible.

> *Yeah, there's impact everywhere. I mean, if you go out on the land, either trapping or harvesting, the snow is kind of not the same. […] and then also after it freeze up too and there's always a slush, so people are very cautious of going out. It's not like before. It's quite a bit of change. (C06, October 14, 2021)*

Several participants expressed observations and concerns around species shifts associated with climate change, including the timing (arrivals and departures) of migratory species, as well as what species are present (i.e., species composition). The implications of these ecological changes are profound, as participants noted, and deeply rooted in changes to weather and climate, as well as the terrestrial environment (including permafrost) and vegetation communities.

> *Often, I think of the changes I have seen and it [climate change] really alters everything, not only the environment, it changes the landscape, it changes the habitat … changes everything—caribou, geese, and we also have a species of trees that we haven't seen before.… I think there's all of the changing landscape—it's changing everything. The environment and the melting permafrost has to do with a lot of it. (C02, September 28, 2021)*

> *We've got new birds coming in we've never seen before. It's a lot of moose. We never had moose here. I think a hundred years ago we started getting moose and maybe there'll be more in a hundred years, but my great-grandfather was saying … pelican and muskrat are disappearing. There's so many eagles.… Now we're getting bald eagles and ... The geese—the geese, they migrate in—I'm talking about the snow geese—they used to migrate in October.… Now they migrate at the end of August, like almost two months difference. (C02, September 28, 2021)*

Changes in vegetation associated with climate change are altering landscapes such that memories are no longer accurate portrayals of the landscape. With these transformations come necessary changes to land use, such as the creation of new landmarks or routes for navigation. These changes may also be accompanied by a feeling of dislocation, with a range of emotional and functional impacts. In the quote below, one participant describes the rapidity of changes he has observed in vegetation at one site.

> *I only started going back hunting again when in my late twenties.… So, it's really over 16 years that I've observed this particular change where the land is green. Like it's insanely green, like we never had that before. And in the early years, it*

> *was never—like, it was never that green.… And so, having gone there year after year and even right now, especially having my own boat now, this is an area that I'm familiar with, that I'm comfortable with, do I visit it often. And my son got pulled for a caribou tag, so we went, actually, to the mainland here to do some hunting. And just in the last, I don't know, in the last five years, it looks like Scotland, for Christ's sake. (C01, September 27, 2021)*

Alongside changes in climate and weather (or seasonal cycles) come changes in other seasonal phenomena like flooding. As one participant from Ontario observed, the scale and frequency of flooding have dramatically increased.

> *And we got more floods at the mouth of the river.… But I noticed that Elders would say there would be a flood every 30 years in Winisk, but now I think since we moved, there's been about four floods in Winisk now, and all these things that are happening now. (C02, September 28, 2021)*

Permafrost thaw was discussed by one participant as a possible magnifying effect for other geological processes or events, with the potential to cause increased earth tremors.

> *One thing that worries me is that with the Canadian Shield, with the permafrost, would have had an effect with earthquakes. That's another concern that I have. And earth tremors, now we're starting to feel a bit more. And whether there'll be more earthquakes occurring. (C03, September 28, 2021)*

Analyses of changes to Northern Indigenous communities as a result of permafrost thaw should be understood in the context of other climate effects, as well as the transformative changes caused by colonial Canadian society and government. In the quote below, one participant describes their experience of these wide-ranging social changes and what they have meant for their community's health and the well-being of their environment in Igloolik.

> *Well, my biggest worry is social issues. There's so much mental illness and also the social issues is one thing that's brand new. And as you know, in oral history, that our ancestors, especially our—my parents were nomadic people, and they were relocated to a community—and one of the biggest worries that our ancestors had was never, ever stay in one spot for more than a period of three years. And after three years, if it's not affected by the humans, the dogs will be the first to go, because you're actually killing the land that you're occupying because you're staying in one area for too long.… since they're relocated to the community of Igloolik Island, they actually said, "We actually killed the Island of Igloolik."… And those are the concerns that they have, and because they were nomadic and also relocated to one area, the life and the social issues change so rapidly. (C03, September 28, 2021)*

3.2 IMPACTS OF PERMAFROST THAW ON NORTHERN INDIGENOUS COMMUNITIES

Study participants from different regions described both regionally unique and broadly similar impacts of permafrost thaw and degradation. While the relative depth or continuity of this permafrost may vary (as well as its rate of thaw), producing some thaw effects that are more pronounced in some localities than others, there are also marked similarities in terms of the impacts felt by Indigenous communities and land users. Observations from participants of existing impacts of permafrost thaw, as well as anticipated future impacts, are described and addressed in this section. Impacts are organized by the key themes of:

- Hunting, trapping, and fishing;
- Travel, trails, and access;
- Food sovereignty;
- Cultural continuity and knowledge transfer; and
- Household and community infrastructure.

3.2.1 Hunting, trapping, and fishing: Observed and anticipated permafrost impacts

In the Qikiqtaaluk region of the eastern Arctic, permafrost is discontinuous atop shallow bedrock. Patterns of land use in this region emphasize marine travel during the months of permafrost thaw. While these patterns might suggest the reduced visibility of inland thaw, there are other notable similarities with experiences elsewhere. Respondents from both Iqaluit and Inuvik noted a pattern of pond and small-lake drainage. This pattern, also documented by scientists (Marsh et al. 2020, Marsh and Neumann 2001), was considered by participants to have the potential for significant impacts on the breeding and nesting habitat of wildfowl (and therefore related impacts on subsistence). In the quotes presented further below, participants describe how permafrost thaw increases the ability of the land to absorb water and thus remove the standing water that is vital habitat for waterfowl.

Permafrost thaw also has a major impact on changing plant communities, which in turn impacts important species harvested by Indigenous communities across the North. As one participant from Peawanuck explained, the loss of permafrost and increasing saturation and bogginess of the ground leads to a corresponding loss of lichen, which needs drier conditions. They consider this to be a highly significant impact, and one that risks a further decline in caribou numbers in their area, as lichen is one of the most important sources of forage for caribou.

Lichen insulates the permafrost and reflects light energy (because it is typically white). As permafrost thaws, trees have been recorded as growing bigger, and the resulting shade inhibits lichen growth (Downing and Cuerrier 2011; Shah 2019). Seasonal vegetation growth and animal movements are also affected by changing permafrost conditions (Cochran et al. 2013).

Alongside observing changes in terrestrial harvesting, participants also commented on the impact of permafrost thaw on rivers and lakes and the fish within them (see Figure 2). As one participant, quoted below, observes, permafrost degradation and associated slumping likely has an impact on reducing the quality of fish habitat. In this example from the Foxe Basin area, thawing of land has had a direct impact on reducing fish habitat, but in other contexts like the Mackenzie Delta, impacts may be more subtle. Sediments introduced into the river through slumping may reshape streambeds, altering the spawning habitat of fish such as char.

Permafrost thaw or degradation therefore has an array of direct and indirect impacts on important harvested species traditionally used by Northern Indigenous communities. Changes to species habitats and food sources may have profound impacts on the ecologies on which Northern Indigenous communities rely, potentially reshaping the harvesting culture of these communities.

In addition to noting changes that have taken place, participants also anticipated a number of possible future changes. In particular, participants expected that the scale and intensity of changes would likely require constant adaptation. Impacts to animal and bird habitats were broadly expected to continue, which some participants speculate will likely lead to decreases in game species.

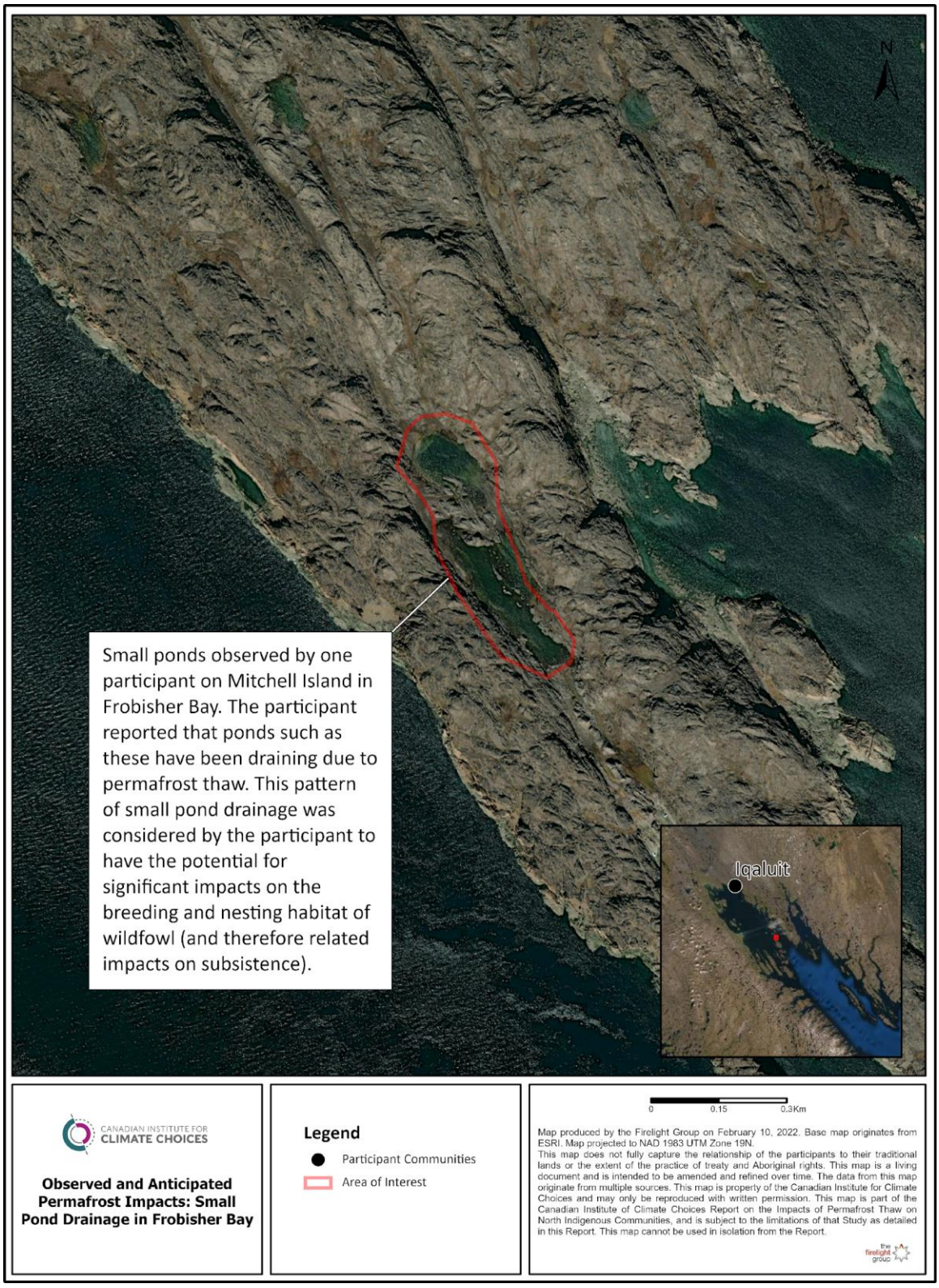
N
Small ponds observed by one participant on Mitchell Island in Frobisher Bay. The participant reported that ponds such as these have been draining due to permafrost thaw. This pattern of small pond drainage was considered by the participant to have the potential for significant impacts on the breeding and nesting habitat of wildfowl (and therefore related impacts on subsistence).
Iqaluit
CANADIAN INSTITUTE FOR CLIMATE CHOICES
Observed and Anticipated Permafrost Impacts: Small Pond Drainage in Frobisher Bay
Legend
Participant Communities
Area of Interest
0
0.15
0.3Km
Map produced by the Firelight Group on February 10, 2022. Base map originates from ESRI. Map projected to NAD 1983 UTM Zone 19N.
This map does not fully capture the relationship of the participants to their traditional lands or the extent of the practice of treaty and Aboriginal rights. This map is a living document and is intended to be amended and refined over time. The data from this map originate from multiple sources. This map is property of the Canadian Institute for Climate Choices and may only be reproduced with written permission. This map is part of the Canadian Institute of Climate Choices Report on the Impacts of Permafrost Thaw on North Indigenous Communities, and is subject to the limitations of that Study as detailed in this Report. This map cannot be used in isolation from the Report.
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Figure 2. Islands in Frobisher Bay with small ponds and tarns observed by one participant to be draining, with implications for the viability of waterfowl breeding (and hunting) in the area.

Selected Quotes

The quotes below outline participants' experiences and observations of how permafrost thaw impacts their hunting and trapping activities, as well as anticipated changes or impacts that they are concerned may occur in the future.

Permafrost thaw causes ponds to drain on the tundra:

> *We just have ponds dotting the landscape, because there's permafrost under the ground [that] contain the water on top of the land and that gave us a lot [of] duck wildlife. And the ducks, I don't know if their population is going down in the area … we used to have thousands and thousands of ponds that dotted the landscape. And suddenly … you got ice gone from under the ground. Rain comes for us … just sinks, it'll get absorbed—absorbed to the ground. But all these things are happening up here at an alarming rate, faster than—faster than what used to take thousands of years is happening in decades up here. (C02, September 28, 2021)*

> *So, this is a general observation on pretty much every place that I've hiked … over the last, say, 20 years: all the little ponds have dried up. And my thinking was that they had just drained.… So, I always notice those, because as you're walking you can tell where it was because it just looks like a dry lake.… So, my idea, my thinking, is that the permafrost is just a little bit deeper now and that this stuff has literally drained out. And you see it absolutely everywhere. I mean, it can be attributed to maybe warmer temperatures and the water evaporating, but … it would just have to be so warm, you know, that that happened. (C01, September 27, 2021)*

The draining of small lakes and ponds affects waterfowl populations:

> *Ducks love these islands, and seems like the ones with the most ducks have these little ponds all over the place. And I've noticed as well that these ponds on the islands are drying up, becoming a lot more shallow.… It's very rare that eider ducks will nest on the mainland or an island too big, as they like to be away from predators.… Any time that I'm hiking, I'll go hiking to one of many islands just like this, and I always look for the little ponds because you get the most eggs around those little ponds.… Geese also like that … because I found*

> *Canada goose nests kind of all over the place. But whenever you find a little pond, you tend to see higher concentrations. (C01, September 27, 2021)*

Permafrost thaw affects caribou forage:

> *… the permafrost really is—gives the area lichen for caribou. You know, with caribou, we used to get hundreds of thousands of caribou from the high Arctic.… Now they're gone. All we have is the caribou that will migrate with the big herds … but now, it's really different, and I think that it is sad that we are losing this permafrost. (C02, September 28, 2021)*

Climate changes and weather affect hunting patterns and safety:

> *The changes, the climate change is really affecting our hunting, you know. In the summertime, we go out hunting in the bay there, in that area where it's nice and calm and we usually idle the boat like this, hit the shore and shut the motor off and sit there most of the day just having coffee and waiting for … woodland caribou or a moose. But now it's not like that. But you know, all of a sudden a storm come up, and also there's always changes happening like the wind … a lot of time when I go hunting I go to this areas and I try to—land in a calm spot, but I have to wait for ten, fifteen minutes and a big wind come up and you have to move again. So, it's really affecting our hunting now with this climate change. So, it's a big concern.… What's going to happen in the future, right? It might affect our moose, their migration, right? We haven't seen caribou in this area for the last ten years. We used to have caribou right up here, and nothing anymore. (C08, October 19, 2021)*

Changes to the land may make hunting more difficult as key habitat is altered:

> *… Between my great-grandfather's time and my generation, I would say 50 per cent of the permafrost is kind of gone, and when it's gone, all the wild tea, all the berries, all of the lichen, it turns into a swampland and there's a lot of water, and it's a lot of—everything gets sick. Trees died, including the vegetation. They're all dying … the birds are disappearing. (C02, September 28, 2021)*

> *It's hard, it's hard to say [what future hunting may be like in 10 or 20 years]. So specific to say, my duck hunts, I'm just afraid that there will be fewer duck and fewer places to go to.… Because of that, because you can't just pick any old island. Like when you look at this island here close to town, say the town wasn't there and ducks would not pick that island just because it's too, too hilly. And there's no little ponds at all.… And when you look at a satellite photo, like, what a difference. Like, you know that—it might be harder to predict*

where they might go because they still have to nest, whether there's ponds or not. (C01, September 27, 2021)

Impact of permafrost thaw on hunting leads to decreased hunting success and effort:

Well, like I said, yeah, a lot of people don't hunt as much as they used to due to the climate change, right? And there's a big storm coming up, so people are not moving around too much right now. They're not hunting ducks or moose or woodland [caribou], and so on. So, everybody has to kind of depend on the store, right? Which is not very healthy. (C08, October 19, 2021)

Climate change is affecting food security:

Well, you can kind of look at it this way, too.… If some old folks know where to go to hunt and whatnot … And if they go down there and notice that there's nothing there in their land … so hunting season is in that different area that they used to go—it's not there. So, it really impact on that, too, that way.... And also, kind of less of foods to get at times, again, different season, even winter—they go quite a ways, they have to use winter road … to get caribou, you know? … to get food, or the traditional use, it's—gets pretty hard for them. (C05, October 05, 2021)

Adaptations are required in the pattern of hunting to maintain hunting culture and the supply of country foods:

Yeah, I think, like I said, we're adapting [our caribou hunting] and well organized. And what we do in the winter when caribou migrate, although it's quite a distance, we'll get well organized and, again, we send people out for a community hunt and we'll get enough so that people have meat pretty much with the whole winter. We store them in a freezer. So, we give out to the Elders and other families that don't have any, so we've been doing that every year now. So it's called a community organized hunting, and so that everybody gets to eat. And I think that we'll continue to do that. (C06, October 14, 2021)

Well, [best time of year for caribou hunting is] normally just right after the—usually after the winter road season open, I'll say around January … January to April somewhere. Those are the month that we harvest caribou, and we have to drive out quite a ways…. (C06, October 14, 2021)

The all-season road will increase the length of the hunting season:

Well, so for all-season road, the—like I said, it'll be open next month, and that'll give us an opportunity to go maybe earlier, because where we go for caribou hunting is towards the mine where it's located out in the tundra, and

> *we usually wait for the ice road to there. It usually open early January, and so—and we usually wait for our winter road to come to the community, which sometimes open in February, so this time will be more—we might be going out earlier, which will be, you know, make a really different community. (C06, October 14, 2021)*

3.2.2 Travel, trails, and access: Observed and anticipated permafrost impacts

Permafrost thaw has impacted the mobility of Northern Indigenous communities on the land. Being able to use traditional trails and access key sites requires conditions on the land to remain within the bounds of collective memory, and so large melting and slumping events that alter trails will dislocate the accumulated knowledge of the group. As one participant described, muskeg used to have sufficient surface integrity to provide access to various sites—sites that are now inaccessible because the ground has become impassable.

In the western Arctic, particularly in the Mackenzie Delta where river travel is more common, permafrost thaw is creating erosion along shorelines and riverbanks, which is having a noticeable impact on riverine travel routes (depicted in Figure 3). Landslides called thaw slumps are a common type of thaw-driven land erosion (Wallace 2019, Inuit Tapiriit Kanatami 2019). As one participant from Inuvik explained, slumping acts to accelerate the sedimentation of rivers and channels, adding time to journeys, which affects the cost of travel (in gas and equipment) while exacerbating the limits on time created by waged employment. Participants also described how permafrost thaw also leads to landslides.

In some contexts, the impacts of permafrost thaw are felt with some time lag. For many participants, when permafrost melting is occurring at the height of summer, they are in fact not on land but out in boats using waterways. It is during the winter season when people return to the shoreline—using skidoos to move around in the bush—that participants noted encountering terrestrial slumping, as is depicted in Figure 4.

Transportation networks are essential to Northern communities, facilitating the movement of food, supplies, and people over huge distances. Improving these links has a direct impact on the cost of living in Northern Indigenous communities. One participant described how the Tlicho All-Season Road (TASR)—a replacement for a pre-existing and increasingly vulnerable ice road—creates access to the road network, which will decrease household costs for access to food and building supplies. However, roads warp, twist, and crack open from the effects of permafrost thaw. The cost of road construction and maintenance is high in Northern communities and results in poor-quality transportation infrastructure. Investigations into bridge collapses have cited permafrost melt and increased spring run-off as the cause (Downing and Cuerrier 2011). Between 2014 and 2017, permafrost-related damage to the Iqaluit airport landing strips and facilities required repairs costing $300 million just to

maintain functionality (Wallace, 2019). Roads and airstrips form vital connecting links for food, education, and medical services, but they are also critical to maintaining family and community connections among isolated and remote communities. With slumping and damaged roads comes vulnerability to these networks of connectivity. While construction of all-season roads reduces communities' vulnerability to impacts of climate change on ice roads, the all-season roads may be exposed to permafrost thaw.

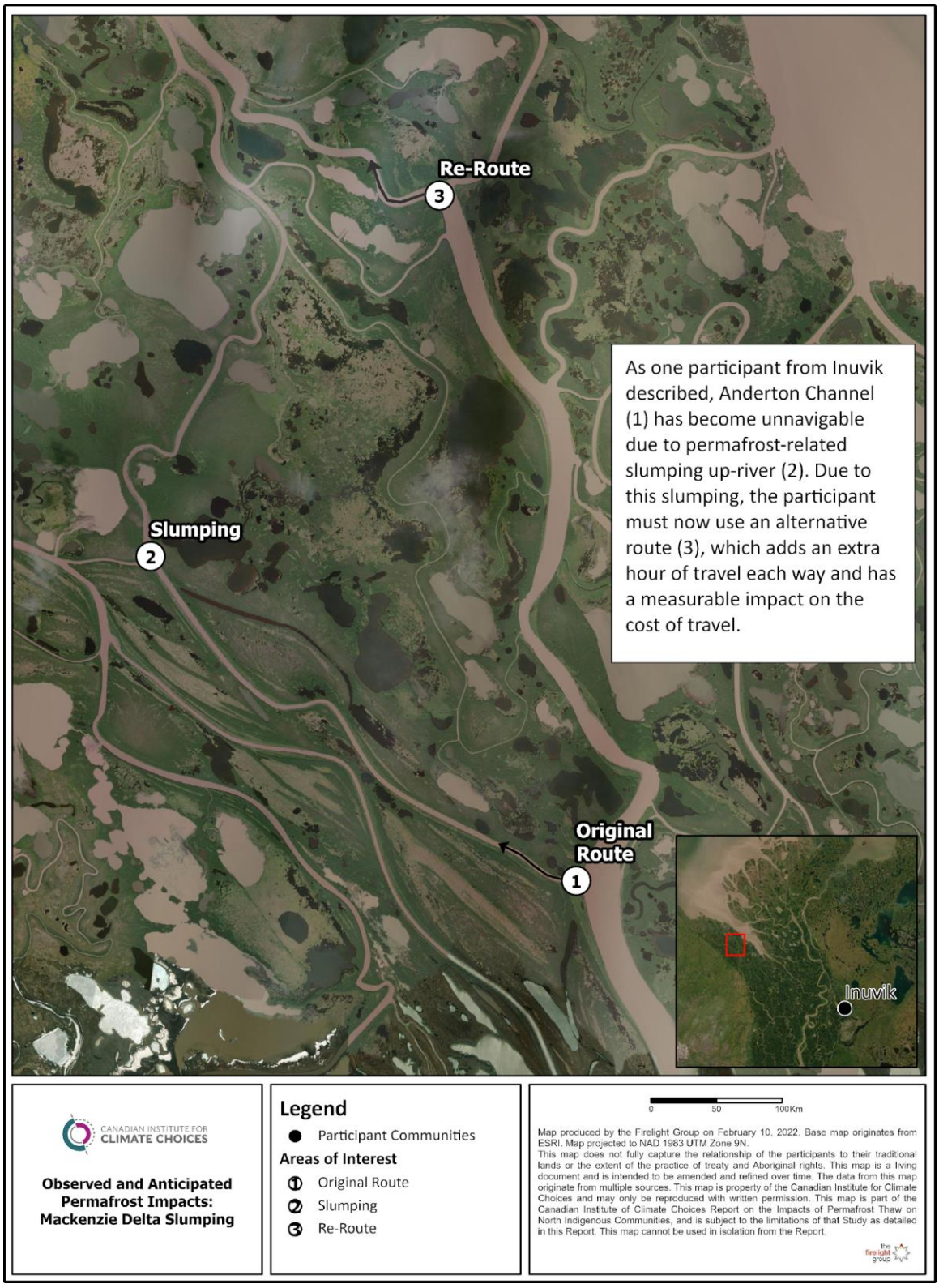
Re-Route
3
Slumping
2
Original Route
1
As one participant from Inuvik described, Anderton Channel (1) has become unnavigable due to permafrost-related slumping up-river (2). Due to this slumping, the participant must now use an alternative route (3), which adds an extra hour of travel each way and has a measurable impact on the cost of travel.
Inuvik
CANADIAN INSTITUTE FOR CLIMATE CHOICES
Observed and Anticipated Permafrost Impacts: Mackenzie Delta Slumping
Legend
Participant Communities
Areas of Interest
1 Original Route
2 Slumping
3 Re-Route
0 50 100Km
Map produced by the Firelight Group on February 10, 2022. Base map originates from ESRI. Map projected to NAD 1983 UTM Zone 9N.
This map does not fully capture the relationship of the participants to their traditional lands or the extent of the practice of treaty and Aboriginal rights. This map is a living document and is intended to be amended and refined over time. The data from this map originate from multiple sources. This map is property of the Canadian Institute for Climate Choices and may only be reproduced with written permission. This map is part of the Canadian Institute of Climate Choices Report on the Impacts of Permafrost Thaw on North Indigenous Communities, and is subject to the limitations of that Study as detailed in this Report. This map cannot be used in isolation from the Report.
the firelight group

Figure 3. Slumping in the Mackenzie Delta caused re-routing, observed by one participant.

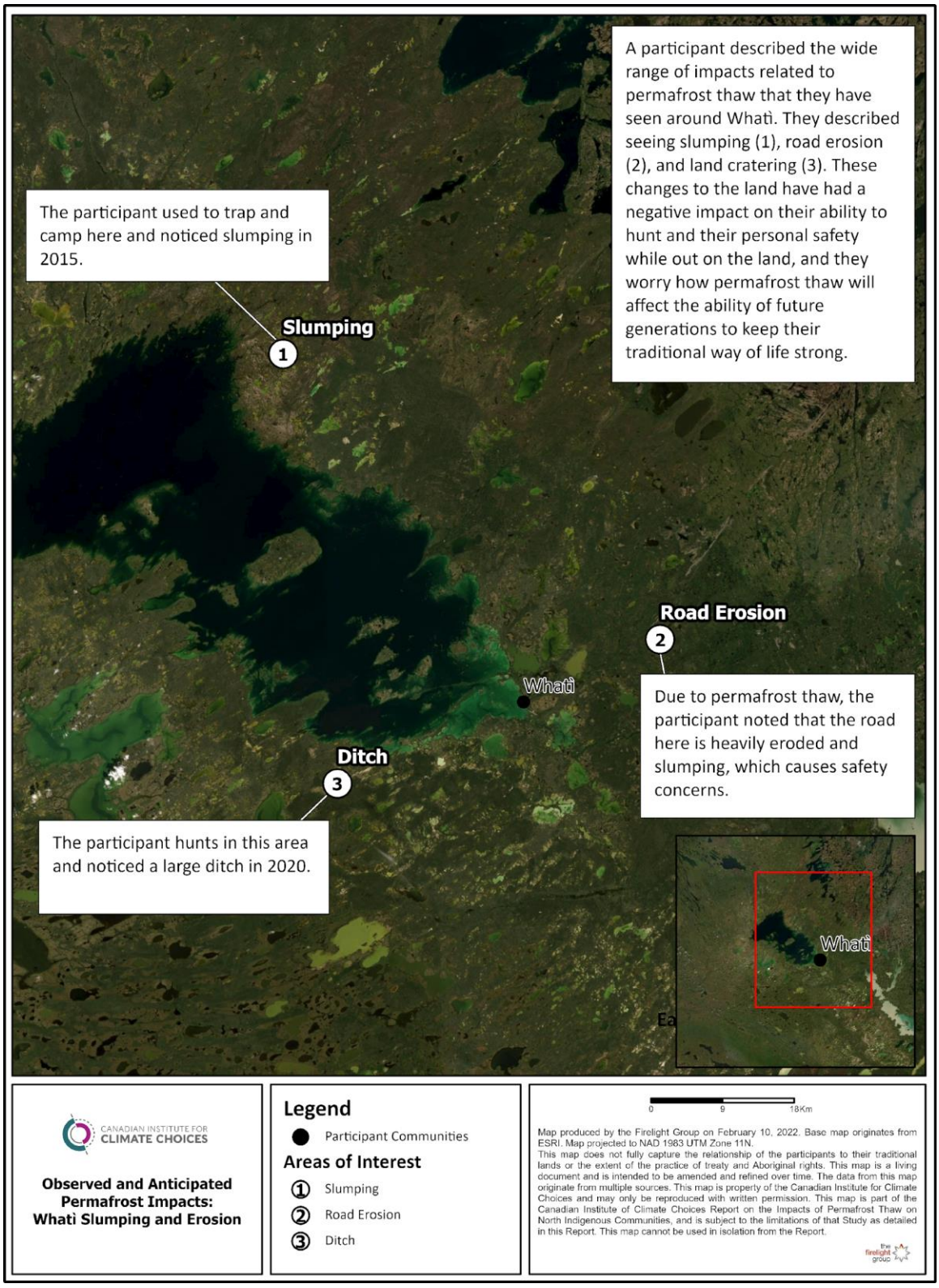
A participant described the wide range of impacts related to permafrost thaw that they have seen around Whatì. They described seeing slumping (1), road erosion (2), and land cratering (3). These changes to the land have had a negative impact on their ability to hunt and their personal safety while out on the land, and they worry how permafrost thaw will affect the ability of future generations to keep their traditional way of life strong.
The participant used to trap and camp here and noticed slumping in 2015.
Slumping
1
Road Erosion
2
Due to permafrost thaw, the participant noted that the road here is heavily eroded and slumping, which causes safety concerns.
Whatì
Ditch
3
The participant hunts in this area and noticed a large ditch in 2020.
Whatì
CANADIAN INSTITUTE FOR CLIMATE CHOICES
Observed and Anticipated Permafrost Impacts: Whatì Slumping and Erosion
Legend
Participant Communities
Areas of Interest
1 Slumping
2 Road Erosion
3 Ditch
0 9 18Km
Map produced by the Firelight Group on February 10, 2022. Base map originates from ESRI. Map projected to NAD 1983 UTM Zone 11N.
This map does not fully capture the relationship of the participants to their traditional lands or the extent of the practice of treaty and Aboriginal rights. This map is a living document and is intended to be amended and refined over time. The data from this map originate from multiple sources. This map is property of the Canadian Institute for Climate Choices and may only be reproduced with written permission. This map is part of the Canadian Institute of Climate Choices Report on the Impacts of Permafrost Thaw on North Indigenous Communities, and is subject to the limitations of that Study as detailed in this Report. This map cannot be used in isolation from the Report.
the firelight group

Figure 4. Examples of terrestrial slumping impacts observed by one participant on trails and roads in the Whati area (Tlicho region of the NWT).

Selected Quotes

The quotes below outline participants' experiences and observations of how permafrost thaw affects travel, trails, and access to important areas, as well as anticipated changes or impacts they are concerned may occur in the future.

Frozen ground is easier to walk on than thawed muskeg:

> *… late April, maybe early May, and we would go out to the bay. And we would just live out on the bay.… On the coast of the Hudson Bay, where we are, it's all permafrost, and beyond that it becomes sporadic … and then the environment where you have the permafrost, it feels solid—solid ground. It's good walking. You can go to places where—where no one can really go, like at James Bay, and James Bay is all moss peat there. You can't really walk there … everything's all water.... You would sink here and there.… So, people will be able to travel wherever they can and there would be a lot of caribou use on the permafrost. It's a lot of lichen. It's a lot of wild tea, a lot of berries—all kind of birds. (C02, September 28, 2021)*

Permafrost thaw and slumping increase the potential safety risks of on-the-land travel to people and equipment, limiting access to key areas:

> *Well, I know a fact that safety—if they want to go on the land, you know, in different season ... they have to be careful in the way that—in order not to lose their equipment, like their skidoo—whatever, and they try to go a certain area, different places, because, you know, the ice—not thick, so, they have to be more careful, I guess if they do go on the land. Because sometimes, you know, weather changes and whatnot … these things are happening because of climate change. (C05, October 05, 2021)*
>
> *… the bottom line is we can't go where we once went. It's too dangerous. Ice has changed. The make-up of ice has changed. The ice comes later and leaves early. The winters aren't so harsh. They're not so cold. We get more snow and less ice. We see severe changes in weather patterns. We get a lot more wind. We see higher tides, like there's so much happening.… So, you know, how we travel has changed. Where we travel has changed. (C07, October 15, 2021)*
>
> *It's more, from my perspective, the snow would be like an insulator. So, this year we had very little snow. ... I'd say less than a foot. ... So, that would really keep the ground frozen, and during the spring thaw the water would travel*

> *further, like down from land, into the streams and rivers, and that would create flooding here. (C04, September 29, 2021)*

Permafrost thaw and slumping impacts increase travel times and therefore costs associated with movement on the land:

> *Anderton channel … It's almost unnavigable now, yeah. Where it meets Big Fish River [he noticed it becoming no longer navigable]. About four years ago, four, five years ago … And that Big Fish River is straight from the mountain, so I imagine it probably slumping further up and just brought everything downstream. … [He would come up this waterway] Every year to hunt caribou, yes. … And that's by boat. [With sections unnavigable now,] most people would just take a different route, like I said it's just adding more time and gas. … [Detouring due to unnavigable sections on their route to their destination] Probably an extra hour, hour and a half. … It's adding like 50 kilometres. … [The extra hour running the boat requires additional fuel] 12 litres. Approximately. (C04, September 29, 2021)* (The change in travel route described in this quote is depicted in Figure 3.)

> *I work full-time, so [navigating permafrost thaw is] just adding more time, cost is not an issue, it's the time. It's being able to commit more time and … like I said, most people are travelling farther, to harvest whatever species they want to harvest, especially with caribou or moose, if they're going to the coast it's, like I said, that's when you see most of the slumping, and it changes the effects of the river channels, and making detours. (C04, September 29, 2021)*

> *The way [permafrost thaw] impacts [his and his family's ability to be on the land] is more time, time-related. You're going to have to pack more gas, more groceries. … If you're working full-time you have to take time off to go, you know, to travel farther! Especially with a boat. … Boat motor, and you have to learn to navigate different rivers, even though you know them on a map, it's just, the slumping from downstream, it changes the channels of these rivers. … changes from year to year. … So you'll notice—and it all depends on rain, on how much rain we get in a summer. … Some years we'll see a lot, we'll have the mudslides, and it'll thaw the ground. … You'll see vegetation in the waters and in the streams from landslides. (C04, September 29, 2021)*

> *So where the land's given away and you can see visible permafrost, and, it's changed the dynamics in some of the rivers where we travel, because it's made them shallower or even inaccessible. … Especially in the western part of the Mackenzie Delta, so, like, we've—unable to navigate through the rivers and*

> *channels in some of these rivers just because of the slumping and the mud that has come downstream from thawing permafrost.... (C04, September 29, 2021)*

Limited road access means greater costs for supplies in community:

> *Yeah, well, we … have had a winter road here for many years, and … two communities rely on that ice road, and a few days ago we noticed that the—because of the ice condition the road could not come in time, and the winter road season had shortened, and so we decided that's going to continue and so that we want to get an all-season road to my community of Whati.… But the other two communities will be still using ice road from here. And so, yeah, it's [permafrost thaw] had a great impact. (C06, October 14, 2021)*

> *So, when we make the winter road when all the permafrost is gone, what happens is that on the winter road … the peat, because of the permafrost, it's been disturbed, it raises up too. Sometimes it bulges up to four feet high and pretty well once the—the winter road gets a lot of bogs and it's really hard for transport.… Last year we didn't have a winter road because the—it was too warm … all these things that are happening with the climate change is really affecting us, and those are the main—the main things that are disrupting our way of life with the melting, permafrost … bringing goods. (C02, September 28, 2021)*

> *The ice is not really thick every year, the ice gets thinner and thinner. Like last year the ice here was 18, 19, 20 inches, that's all. Before, it was four feet deep, six feet deep when we were growing up … Last year, the year before, it just barely brought in the fuel because of the ice not thick enough.… Well, us, we've got to, the road's got to be open by end of November here, right? Going to deliver fuel to the community. So, if they can't bring the fuel in on the winter road, I guess they got to fly in, and it's going to cost more, right? (C08, October 19, 2021)*

All-season or permafrost-insulated roads and networks can help to facilitate hunting by mitigating the impacts of permafrost thaw on roads and facilitating the ease of access to key areas:

> *Well, definitely [the Tlicho All-Season Road makes going hunting easier], because in the past [before the TASR] sometimes we have to rush—go there and back, and because over the tundra, you know, the weather changes, you know, quickly, and sometimes you have to rush there and rush back. But now, I think with the road being open it may be—yeah, it'd be easier to plan your*

> *trip and maybe stay out there earlier and take your gun, and so that then will be for the community as well. (C06, October 14, 2021)*

3.2.3 Food sovereignty: Observed and anticipated impacts

Climate change is impacting access to food by Northern communities (Human Rights Watch 2020b). Traditional harvesting and store-purchased southern food are the two primary food systems in the North, and both are impacted by permafrost thaw. The reliance of Northern Indigenous households on these two systems allows for impacts on one system to be offset by increased reliance on the other. However, this pattern of substitution may increasingly be impacted as both food systems are impacted by climate change.

In a 2020 report, Human Rights Watch described Indigenous communities in the Yukon, northern B.C. and northern Ontario as reporting drastic reductions in the quantity of food they are able to harvest and increased danger in harvesting because of changing ice and permafrost conditions, wildfires, warming water temperatures, changes in precipitation and water levels, and unpredictable weather (Human Rights Watch 2020a). A study of Tthets'ek'ehdeli (Jean Marie River First Nation) in N.W.T. (Calmels, et al. 2015) described a similar pattern of environmental change, in particular permafrost thaw, reducing access to the traditional harvesting of country foods required by Northern Indigenous communities.

Permafrost thaw can expose soil and cause landslides into water bodies that change water colour, increase mercury levels, and can even fill in entire lakes (Lewkowicz and Way 2019, Tarbier et al. 2021). Increased levels of mercury in water can affect insects, plants, fish, land animals, and humans (Nunavut Climate Change Centre, N.D.). These contaminants can accumulate in fish and animals, making them sick and unfit for harvesting.

Traditional food caches are still used by Inuit but are less effective due to thawing permafrost, which may result in food spoilage (Nunavut Climate Change Centre N.D.). Across the North, food storage on the land (for both caching and fermentation) has previously relied on permafrost lockers. These chambers, usually submerged or semi-submerged underground, and rely on stable permafrost conditions to hold their temperatures in the summer in order to preserve meat. This pattern of food storage is important in a Northern context, where harvests occur on a highly seasonal basis and meat (when it is procured) is usually harvested in significant quantities and stored for future use. While this seasonal pattern of harvesting is dictated by ecology, it also allows seasonal gatherings of communities on the land and is important for harvesting efficiency in a contemporary context, where the demands of time and cost act to limit time on the land. This cold storage system, which is not reliant on external power supplies, is becoming increasingly difficult to maintain as warm summer temperatures lead to permafrost thaw and decrease the internal temperature and depth of

these chambers, potentially risking spoiled food and lost harvests. As a result, disease contracted through harvested foods may become more common (Cochran et al. 2013).

Southern-oriented food systems are also impacted. Grocery storage, sale, and transportation are affected by permafrost thaw due to degrading essential infrastructure (including road, rail, and air links, as well as impacts to utilities). Grocery stores may become unstable from shifting ground and are susceptible to food spoilage due to a loss of power—for example, from slumping causing the collapse of power lines. In many remote communities, groceries arrive by plane, but runway shutdowns for maintenance due to permafrost thaw are occurring with increasing frequency (Nunavut Climate Change Centre, N.D.). Just as permafrost thaw and related slumping can cause the failure of a power line, thaw could also impact other linear infrastructure. Oil and gas pipelines and sewer lines are all vulnerable, and thaw-induced damage could pose significant risks of releasing chemicals and contaminants into the environment. However, global warming also causes less sea ice and extends the shipping season, which may help to improve access to non-traditional food supplies (Nunavut Climate Change Centre, N.D.).

Both country and store-bought food systems are vulnerable to the effects of permafrost thaw—in the case of country food, through increased costs or diminished harvests, and in the case of store-bought food, through the rising cost and vulnerability to road or refrigeration impacts.

Selected Quotes

The quotes below outline participants' experiences and observations of how permafrost thaw impacts their food sovereignty and food security, as well as anticipated changes or impacts that they are concerned may occur in the future.

Permafrost lockers or cellars are important for food storage:

> *When I was a child, there was no freezers in the communities, other than a man-made freezer that was dug into the ground right into the permafrost … approximately eight to 12 feet into the permafrost.… Once it's into the permafrost, about all the way down into the permafrost, they would then make a moss ceiling, a moss roof, because moss itself is an insulator, and … I remember the walls have very beautiful crystallization—a lot of crystals with different spikes and they became very beautiful, and when you shine the light on them, you would have colours. (C03, September 28, 2021)*

Long-term storage for harvested country foods is important, as a steady supply of country foods cannot always be maintained:

> *I guess it [climate change] do affect food security because it's extended people's ability to ship food to the north coast from areas like Goose Bay or Newfoundland.… In one sense that's a good thing. Because a lot of people in these Northern communities, what they do, they do what they call "bulk orders," so they'll get a container come up, and that's why the people on the north coast got four deep freezes.… Usually, I got two great big 18-foot cubic deep freezes.… That would be unheard of in the city, correct? But on the north coast, guess what? Some fellers got four and five. Because they have to bulk-order their food and also when the caribou's running, they'd shoot four or five caribou and, you know, skin it and joint it—it gotta go somewhere. (C07, October 15, 2021)*

Permafrost thaw is affecting food storage systems (on the land and in the community):

> *We've always had an ice cellar there [at their family cabin on Kendall Island].... And up until, like I said, probably six or eight years ago, we couldn't keep food frozen anymore, any of our meat, caribou meat, geese, so I just bought a chest freezer … brought it out there and bought a generator, started hauling everything out there.... Six or eight years ago we quit using the ice cellar.… It couldn't keep anything frozen.... And it just kept accumulating water more and more every year.... And … just about everybody now is like that. (C04, September 29, 2021)*

> *Like myself, I used to have a store one time, and I—over eight years I had to shut everything down due to the problem with my … building sinking really badly. (C05, October 5, 2021)*

> *You asked a question about specific examples of permafrost, or the effects of changing of permafrost. I can recall in the '70s … the then Labrador Inuit Association had a caribou processing plant in Nain, Labrador.… It's my understanding that, that plant was shut down because all the floor chain that was affected by that.… And the building actually sank.… They had to shut the plant down because of occupational [health] and safety. (C07, October 15, 2021)*

Permafrost has been traditionally collected in its exposed ice form and melted for use as drinking water in some cases:

> *This is the actual place name—Igloolik, and now it's called Igloolik Point, and that's where we got the drinkable water, the permafrost. Today, the permafrost that's drinkable, that the younger generation are seeing, is on this side of the island. (C03, September 28, 2021)*

Being unable to harvest food has impacts beyond food security, including psychological well-being:

> *And when I say how we travel [has changed], it's people are almost scared to go [due to uncertain conditions], so they don't go. So again, that changes what we're consuming with regards to food, and as you people know, permafrost or the decrease in permafrost is actually affecting food security—it's actually affecting, you know, the psychology of people, 'cause we can't get—I just—you know, you asked me a very good question: how do I feel about it on the land and on the ice. Well, if you can't go, that's not a good thing. (C07, October 15, 2021)*

Impacts on the food system affect both men and women and are observed by men and women:

> *… men, we're the ones that hunt and fish and kill the animals and bring home the fish, but it's the women that do the cooking and prepare whatever it is: caribou, porcupine, fish. And they're the first people to notice changes within the fish and birds, more so than the men. 'Cause they'll say, "Well, how come the meat is that colour?" or "How come scales are rubbed off on that side the fish?" So, they're usually more observant with the actual fish and birds than the men are, so we as men will go kill them, and we're very observant about the land and the water and the wind and the rising tide … but the women—and I think that's very important to know, so it's from a social perspective, women are very observant. (C07, October 15, 2021)*

Impacts to gathering country food are the result of a complex calculus of risk and cost-related choices. In many cases, these choices mean that culturally relevant country foods are less readily available:

> *It's forced us to make a choice and it's almost cheaper to go to the North—Northern [store] and get that chicken than it is to go out [hunting on the land] and take the risk from a safety perspective, but also—I don't know if you're a hunter or not, but I mean, just because you go hunting for four or five hours, that don't mean you're going to get something.… I mean, you know, birds move and they're not always there where they once were, and again, it's got to do with climate change and lack of ice and that kind of stuff. Everything has changed, so, you know, where I used to go, guaranteed I'd know I'd get a rabbit or a few partridges—guaranteed, but now I go there and you might never see one. (C07, October 15, 2021)*

3.2.4 Cultural continuity and knowledge transfer: Observed and anticipated impacts

Permafrost thaw has the potential to impact many different aspects of Indigenous culture, including (but not limited to) harvesting and access to the land; knowledge transmission; ceremonies; and other patterns of land use and occupancy central to the cultural life of Northern Indigenous communities. Literature to date has primarily focused on the impacts to harvesting and access to the land.

Traditional harvesting is critical to the provision of food and the subsistence of communities, but it is also an important part of culture. Permafrost thaw is impacting harvesting and will continue to impact it by creating shifts and reductions in game populations, potential impacts to the health of country foods, reduced safety while travelling, and increased costs associated with harvesting.

Climate changes are making access to the land and traditional hunting grounds more difficult for Northern Indigenous communities year-round. While winter access along the coast becomes more difficult due to the changes to the sea-ice platform, summer access is being profoundly changed by permafrost thaw. Landslides and trail erosion make travelling on land dangerous in the summer and can cause ATVs to get stuck (Calmels et al. 2015). Permafrost thaw can make travel hazardous, creating new wetlands and damaging traditional hunting trails. As a result, harvesters may be forced to shift locations or even abandon traditional hunting grounds altogether.

Spending time on the land was emphasized by all participants as being central to their identities and central to maintaining cultural identity by teaching future generations. Perhaps the most significant threat posed by permafrost thaw to cultural continuity is the reduced ability of community members to spend time on the land in the company of family members or other knowledge holders in order to learn by immersion and by doing.

Important gathering places such as ceremonial areas, campgrounds, and even village areas can be made inaccessible or destroyed by slump thaws. Preserved cultural remains such as sod homes and other artifacts are decaying faster now and can be exposed to thaw slumps (Forbes et al. 2015). Erosion of the land and changes to landforms may impact how these sites are used as place-markers in story and in memory.

Selected Quotes

The quotes below outline participants' experiences and observations of how climate changes, including permafrost thaw, impact on cultural continuity and knowledge transfer activities, as well as anticipated changes or impacts that they are concerned may occur in the future.

Participants described the importance of their connection to the land and how this was central to their cultural identity, and the importance of passing this connection on to the next generation:

> *I was born … east of Peawanuck. I was born in what they call a trapline, but we don't consider that a trap area—it's our homeland.… I was the last of my family to be born on our homeland.… And it's really important for me because it has been our way of life and living with seasons. I think out on the land … and the land is really important to me. And because of the way we follow the seasons, it's … an important way of life for us, with our people of Peawanuck. (C02, September 28, 2021)*

> *[Being on the land,] it's who we are. It connects us to our past. It connects us to my grandfather who's no longer here—or my dad.… They passed down their knowledge to me and I try to pass it on … whether it's wisdom or habit—you know, the way I set traps, the way I set snares, the way I fish, the way I hunt. (C07, October 15, 2021)*

Time spent on the land is important to learning about culture and land use and adapting to change:

> *But the changes will affect us big-time in the future, especially the young generation. And the only way is that we want to keep our traditional way of life strong, but in a way the climate change is going to keep happening and we have to send our kids to school and get good education so we can fit in the future in the world, right? Education is going to be the only way of life in the future. I see nowadays the young generation, they're taught about a traditional way of life, but they can't, they're not going to be a hundred per cent Dene way of living.… Everything's changing. (C08, October 19, 2021)*

> *It's just things you do when you've learned to adapt and you've learned to do things with your hands, and read the land, and read the waters, and read the weather. So, that's one thing is the passing of that knowledge, you know, the transfer of knowledge: building that capacity, we'll say, with our youth that I gained from my uncles and father when I was, you know, young.… And that's something I fear that, you know, all this change in climate, permafrost changes, you know, it's taking away who we are, and we're not going to pass it on. (C07, October 15, 2021)*

Participants describe oral history and stories of change and the importance of adapting to change:

> *My grandparents told stories about the land. There used to be certain things that are no longer there.… These are the changes, and we have to adapt to it. So, if you know what is happening, it's not strange to see the land changing, continuous changing. It may be fast. This decade it have been very, very fast. (C03, September 28, 2021)*
>
> *I think it's [future conditions on the land] be more water, standing water, and softer ground, yeah. … I really don't know [how that will impact people's ability to hunt or travel].... Like they say, adapt or die.... I wouldn't have a good answer on that, because I've lived with permafrost all my life, so. (C04, September 29, 2021)*
>
> *The federal government in 1949 told the savages that they should become civilized, and these civilized people—we shall turn them into civilized human beings, rather than being savages.… Because of those issues, I'm worried about my grandchildren and my great-grandchildren. I have four great-grandchildren, and I'm worried about their livelihood because they'll be able to live anywhere in the world once they are educated. They will not even think about the environment and the land itself, and they'll just follow suit.… So, these are the things, if you are able to understand what I'm saying is the reality of a life today.... The understanding of the land … is starting to disappear.... And the environment—the understanding of the environment, and the reason is that they became self-centred, rather than going out on the land, and observing and studying the land and the movement of the animals—that is disappearing (C03, September 28, 2021).*

3.2.5 Household and community infrastructure: Observed and anticipated impacts

The impacts of permafrost thaw on infrastructure have major repercussions for Indigenous communities. Existing literature documents impacts on commonly damaged structures, including homes, roads, bridges, airports, public utilities, power plants, and gas lines (Downing and Cuerrier 2011; Wallace 2019). Impacts to these structures have knock-on effects for community food security, safety, transportation in and out of communities, the health of community members, education and employment, and culture.

House damage can appear as doors not closing properly or window frames letting in cold air. As homes shift and sink, they become less stable and run the risk of collapse. Land erosion threatens coastal homes and increases the risk of landslides called thaw slumps (Wallace 2019; Inuit Tapiriit Kanatami 2019). Whole communities have been relocated due to these dangers, a trend that the literature identifies as likely to continue, particularly along coastlines with a highly active thawing cycle, such as the Beaufort Delta.

The impacts of permafrost thaw create a need for constant maintenance of public utilities such as drinking water, sewage, gas, and electrical lines. While regional efforts have been made to bury utilities as far underground as possible so they are not in the active layer of permafrost, this process is expensive and laborious and may not be helpful as more permafrost thaws—and thaws deeper. Broken water lines cause people to lose access to clean drinking water, while broken sewer and gas lines cause detrimental effects to the environment (Wallace, 2019). Changing weather patterns, faster spring run-offs, and landslides may reduce the potential for hydroelectricity (Nunavut Climate Change Centre N.D.).

The participants interviewed for this study described experiencing a range of infrastructure impacts in their communities, all of which were associated with increased costs for construction, maintenance, and insurance. Larger community structures are often administered by external bodies, for example school boards, regional agencies, or territorial governments that can meet upkeep costs. While costs may not be defrayed by communities or individuals, they may still experience diminished access or quality in their use of impacted facilities. When it comes to household infrastructure, while there were cases described by participants where the landlord (for example, an Indigenous housing body) might meet the costs of upkeep caused by thawing permafrost, participants also described instances where homeowners' costs cannot be recovered through insurance.

Homeowners described the significant potential liabilities involved when buildings shift due to permafrost thaw and the challenges of obtaining adequate insurance. According to participants, permafrost thaw can lead to damage or concerns that include damage to the housing envelope (with knock-on effects on heating, moisture, and associated costs), damage to systems (like water or gas) entering the house from outside (from building shifts that result in leaks, for example, affecting utilidors, piping, and tanks), and damage to the structure of the house from shifts in the foundation of the structure. One participant noted that in their experience as a homeowner in Iqaluit, households could potentially be liable for the environmental damage of spills should their connections to public utilities (e.g., natural gas, oil or other fuel lines) be damaged or severed.

Participants described these challenges as difficult and expensive to remedy due to the dynamic nature of permafrost. As participants described it, one either lives with a steady cost bleed or a large outlay to (temporarily) resolve the problem. While adaptations like special levelling pilings or other engineering solutions may lower maintenance costs in the intermediate term, some participants suggested that there might be no way to definitively reduce the financial costs of thaw on homeowners. In the experience of these participants, the unpredictable nature of the thaw meant that one's house could be repaired only to be significantly impacted the following year. When it comes to community infrastructure, these adaptive measures, even if they are quick fixes, may be necessary to avoid lasting damage to homes.

Selected Quotes

The quotes below outline participants' experiences and observations of how permafrost thaw impacts household and community infrastructure, as well as anticipated changes or impacts they are concerned may occur in the future.

Permafrost thaw is affecting buildings:

> *I mean, yeah, the biggest impact that permafrost thaw has had on me is probably my house shifting, and that's ... the foundation is still sound. But my drywall, especially around my windows, has cracked. And actually, a window on my north side of my house has cracked twice. So, we've replaced it twice ... Due to shifting of the house. Yeah, it's—that's how much it has moved. ... And it's not too bad where I am, right? So, there is people that are, you know, drilled, their piles are right in bedrock. But I think mine has a little bit of ground until it reaches bedrock.... But yeah, the insurance doesn't cover it and how I just deal with it, I just make the repairs. I keep buying windows and then that's it. (C01, September 27, 2021)*
>
> *Yeah, definitely, there's lots of cracks in the walls, drywalls. Some windows are damaged because of the shifting. (C06, October 14, 2021)*

Repairing and re-levelling buildings costs vary:

> *I've already spoken to a contractor asking for a quote … it's going to cost me money to re-level my home.... Yep, and I'm on pads so it should be fairly cheap, other than, you know, probably a few thousand dollars. ... I don't think it will be [covered by insurance], no.... My supervisor at work has noticed because he's on piles. ... But like his balcony sometimes is shifted up a few feet like, wow, like not a few inches like my house, his is feet! ... I don't know if he's exaggerating, but that's what he's told me. (C04, September 29, 2021)*
>
> *Most of my concerns are more about within town limits and the financial obligations that I might have to my shifting house ... So, when you have, when the permafrost is a little bit deeper now and constantly shifting, you've got to drill those piles deeper. And as it is right now, the cost is actually on how deep they go and how big the pile is. (C01, September 27, 2021)*
>
> *The Tlicho government had some funds to get materials required, labour costs, and we do all the repair work for the Tlicho citizens, so it's no cost to the homeowner. (C06, October 14, 2021)*
>
> *[increased cost for housing in Iqaluit when piles need to be bigger and deeper to support housing on thawing permafrost] I mean, and that's the thing, if it's*

> *we'll see real-term, real financial impacts within like immediately, but over the years, it might get even more so.… Yeah, that's when you look at housing and how expensive it is, I mean, there's no one thing that makes it expensive, it's all the, it's everything that makes it expensive. So, the pile driving, the import of material, import of the workforce. The transportation is, you know, has gone up significantly. So, building materials associated with fuel costs of transport. And when you just add all those things up, it just makes housing that much more unattainable. (C01, September 27, 2021)*

Re-levelling a building temporarily solves the problem, but it may recur:

> *[lifting your home and levelling it again doesn't solve the problems] Nope! It could be just a quick fix, or it could be several years—it's unpredictable! (C04, September 29, 2021)*

> *We've seen a lot of shifting on our buildings in our communities. I think every year we have to level some of the buildings, and that seems to be the norm—buildings are shifting and all the homes, so we have to level the buildings every year now. (C06, October 14, 2021)*

3.3 ADAPTING TO THAW

Communities are adapting to permafrost degradation and thaw at individual, household, and community or regional levels. The primary challenge described by participants across the North revolved around meeting the financial costs of permafrost thaw at the household level.

For land users, changes in travel routes, damage to equipment, or the need to purchase new equipment to manage the impacts of unstable permafrost all add costs to time spent on the land (and, as a result, add costs to any harvests from the land). Faced with these challenges, many hunters are adapting to changing conditions by finding new ways to travel on the land and investing in techniques and equipment that enhance safety. New types of equipment—from new outboard motors to inReach communication devices (allowing satellite location and communication) or diesel generators to run freezers—do constitute an additional financial cost for land users. However, they are also an adaptive measure being embraced by hunters and fishers across the North attempting to maintain their harvesting culture and output in the face of rapid changes.

Permafrost thaw impacts not only harvesting but the storage and long-term value of the harvest. To avoid the loss of harvested meats due to thawing permafrost lockers, hunters are resorting to using generator-powered freezers that are carried while out on the land.

For participants, new equipment represents one key part of resilience. Another is families and social networks, particularly for knowledge or information sharing around changes to local conditions and travel routes. One participant described how, through the use of GPS devices and a range of communication methods, they share information about the rapidly changing Beaufort Delta environment.

Off the land and in communities, participants described changing their own household approaches as well as community approaches to self-reliance. Trying to insulate oneself from a system—whether food, power, water, or transport—that is prone to interruption through permafrost thaw or other climate-related impacts is a priority for participants.

Selected Quotes:

The quotes below outline participants' experiences and observations of adaptations that they or their communities have undertaken to address the impacts of permafrost thaw, as well as anticipated changes or adaptations.

Changes to equipment are required to adapt to changing landscapes and the conditions encountered:

> *Yes, I think a lot of people are moving to buying four-stroke snow machines. … It's, in a very cold environment you can travel twice as far, and also we're starting to use a long-tail boats [engines] … And even like a generator … so we're slowly adapting with new sorts of equipment. … And so I think that … adaptations that we're looking at, transportation being the main one because we hunt a lot with—out on the land. (C02, September 28, 2021)*

> *Up until a couple of years ago, I mean, we had an [underground] ice cellar at our cabin.… Well, we got two, we got one in the Mackenzie Delta cabin, and we clean that out every few years, add fresh snow. And the one at the coast is actually unusable anymore because it keeps accumulating water. … Even though we had it boxed in, insulated. It just couldn't keep food frozen anymore, or to a certain temperature, just because of the fluctuation of the temperature. … [He noticed them starting to thaw out] Probably ten years ago. The one at the coast. The one at the [Mackenzie] delta cabin is still usable. … But the one at the coast, we can't, we quit using it about five years ago, it was just unable to keep anything frozen or cool. … [Now he uses a] chest freezer, with a generator [laughing]. … And that's probably a gallon, what, five to eight litres a day. … So, if I'm there for two weeks, that's 40 litres of gas that I've got to bring for the generator. (C04, September 29, 2021)*

Sharing information and knowledge is an important adaptive mechanism:

> *Basically, it's like having people that's passing on information. … Like, if there's, like I said, if there's slumping on the land or on the river or, the community, especially this small, everybody would basically know within a few days.... So just information sharing stuff like that would, it's always helpful. … [information is usually shared via] Gossip? [Laughing]. I don't know how else to word it. … Yeah, everybody just sharing information … [such as by sharing on Facebook] Yeah absolutely! … And the guys, like we all have hunting buddies, and all my buddies, all of us have inReaches so we're all, if we run into something or there's any trouble, they, somebody has an Inreach, even in the boat or on a backpack, or … So you're able to send text messages from basically anywhere. (C04, September 29, 2021)*

Changes to the food system may be required to maintain affordability and access to food:

> *And I'm also—I'm also experimenting on gardening, so we don't have to buy our food from California or Mexico and if we can grow it here. And it's kind of a—I have to have a science to it because everything up here is peat … and you just can't grow anything, so we have do stuff to it, but I'm not a hundred per cent sure yet.… And then next year I'm buying chickens, so we don't have to buy eggs … six bucks for a dozen, I think. And so I think … adaptations that we're looking at, transportation being the main one because we hunt a lot with—out on the land—and growing our own vegetables. Those are the two main ones. (C02, September 28, 2021)*

Greater road access and enhanced connectivity are important to reducing isolation and enhancing the ability of communities to adapt to change:

> *Oh yeah—the road investment is good, I think. What communities—remote communities—need is more information on climate change and the impact it has, so that people are aware. And right now—I mean, you can find some information on the website and stuff like that, but not everybody have access to that, you know? So, if we get people—resource people that are familiar with these climate situation—come and make presentation, I think people will be aware of it. But they see the changes and they know the impact. (C06, October 14, 2021)*

Some participants identified change as a constant feature of the environment, emphasizing the role of adaptation in Indigenous culture and lifeways:

> *So, it's always changing. And so the best thing to do is, in part of culture, is to adapt—always adapting into new things all the time.… And the Elders who say, "Well, it's always changing and we're not surprised." So, it's all the climate is change—every so often it changes, sometimes very rapidly, sometimes very*

> *slowly. … And these are the results of some of interviews with the Elders. (C03, September 28, 2021)*
>
> *[Indigenous community life is all about adapting to change] Yeah, I think how people have been adapted to changes for many years. I mean we come, you know, we used to live out on the land, and then we moved to the communities in the early '70s, and then, to adapt to the community life, and … keep adapting to a mainstream society, and that means, you know, get our young people educated and, you know, get training, so they have a better life for themselves. So, we've always have been adapting to, yeah, to a new way of life, and with this … change all climate and the people really have an—want to understand more about it and adapt as we go forward. (C06, October 14, 2021)*

4. CONCLUSION

4.1 KEY GAPS IDENTIFIED DURING THE STUDY

While the impacts of climate change in the North are well documented, research into human impacts in this arena has tended to focus on the higher Arctic environment. Climate change in the High Arctic, particularly coastal areas, has hitherto been a focal point for study as the sea-ice platform provides a strong connecting link between highly measurable changes in human behaviour and measurable metrics like ice thickness, temperature, snowfall, and wind force and direction. While permafrost depth is a measurable metric, thus far the bulk of permafrost research has focused on monitoring and measuring subsurface temperatures and slumping in relation to significant pieces of human infrastructure, including roads, airstrips, and building foundations (or pads in many cases).

To date, limited research has focused on human experiences of permafrost thaw and what the implications of thaw and related instability might be for Northern and particularly for Indigenous communities. Northern Indigenous observations, knowledge, oral history, adaptive behaviour, and opinion are largely absent from the Canadian permafrost literature.

This data gap when it comes to the human impacts of permafrost thaw is mirrored by a policy gap. Permafrost-focused policy has centred on acquiring or providing funding for increasingly technocentric approaches to shoring up unstable infrastructure. This approach to infrastructure, focused primarily on a view of permafrost centred on insulating structures from the ground, fails to adequately recognize infrastructure as part of the web of the community. The implication of this failure is that insufficient focus and funding is placed on the infrastructure gaps of Northern Indigenous communities and the vulnerability of community networks and other non-built adaptation supports or capacities.

4.2 KEY IMPACTS IDENTIFIED DURING THE STUDY

The following (non-exhaustive) list identifies key impacts observed by interview participants with respect to the key themes of this report.

Impacts for hunting, trapping, and fishing:

- Changes to the habitat of key species (e.g., impacts from permafrost thaw on caribou habitat or impacts from riverbank slumping and sedimentation on fish)

- Changes to the vegetation and forage of key species (e.g., caribou)

- Decreased harvests and/or increased effort required to successfully harvest country foods (food gathered and harvested from the land) as a result of the changes noted above

Impacts for travel, trails, and access:

- Thawed ground that slumps, slides, or becomes boggy and difficult to traverse
- Increased difficulty travelling on trails, increasing travel time and potentially leading to increased safety risks and increased cost of travel
- Increased costs and travel safety risks, potentially leading to decreased use of certain areas
- Slumping impacts roads and airstrips, reducing inter-community movement and increasing costs (and decreasing availability) for store-bought foods and goods

Impacts for food sovereignty:

- Difficulty harvesting and storing a variety of country foods (e.g., thawing of permafrost lockers or underground cellars)
- Threats to building integrity in communities, creating repercussions for food storage and refrigeration

Impacts for cultural continuity and knowledge transfer:

- Increased difficulties and risks associated with travel and time spent on the land, leading to less time on the land; time spent on the land with Elders is essential to the transfer of many skills
- Decreased travel or use of areas where slumping or degradation of permafrost is occurring, reducing the transfer of Indigenous knowledge relevant to those areas

Impacts for household and community infrastructure:

- Damage to buildings, resulting in increased costs for construction, maintenance, and insurance incurred by both households and communities
- Increased (and potentially prohibitive) costs for construction and maintenance, resulting in substandard housing conditions and exacerbating housing shortages
- Increased insurance costs, impacting households' financial stability and viability

4.3 RECOMMENDATIONS FOR FUTURE RESEARCH

While permafrost thaw or degradation are realities for communities across the Canadian North, there remain regional differences in experience that prevent widespread comparison. While the small sample in this study prevents comparison or generalization, it is clear that activities pursued by participants on the land are different – from the impacts to river travel in the Mackenzie Delta to the challenges of communities in the subarctic coping with unstable ice-roads.

Moreover, just as there are differences in the effects of thawing permafrost, there are also important differences in the social, cultural, and economic systems across the North that have a profound impact on the ability of communities and individuals to effectively adapt. Comments from participants regarding who addresses repairs or meets the costs of permafrost-caused damage to their homes is evidence of these differences (see Section 3.2.5), as are the many different ways communities address food security related issues (see Section 3.2.3). While adapting to permafrost is a priority for Northern Indigenous communities, and should be a priority for Canada at a national level, any policy must acknowledge the regional differences required to respond to this challenge. An effective federal response should be regionally tailored and developed hand in hand with Northern Indigenous communities.

It is evident from this study that future federal and territorial research and policy should first and foremost be focused on assessing the human impacts of climate change. Where those impacts are related to infrastructure, a more holistic approach is recommended: one that situates infrastructure according to its use and purpose within the larger community. For example, what are the implications of poor building stability when the building in question is the warehouse in which the community stores food? In this case, research and policy must push beyond the immediate implications of the costs to run, maintain, or insure the building and into the role the building plays in ensuring the community's food supply remains intact.

As the infrastructure gap between Northern and southern Canada is increasingly addressed by federal and regional research and policy, permafrost thaw and its tracking should be addressed. This infrastructure assessment process should include effective tracking of the costs of infrastructure (including operational costs, as well as the cost to communities of infrastructure gaps or absence, as previously stated). A roadmap to understand how these costs are met by Northern stakeholders—through federal grants and subsidies; by territorial, municipal, or Indigenous governments; or by individual households—would also be a valuable tool to assist in the effective deployment of subsidies or other supports.

Participants in this study consistently identified isolation as an issue being exacerbated by thaw. While facets of isolation like road access or food travel times are explored within the context of food security/sovereignty research, there are important overlaps to be explored when it comes to measuring the risks or costs imposed by permafrost on the relative remoteness of communities.

Permafrost thaw poses a significant challenge to the traditional land uses, activities, and cultural continuity of Northern Indigenous communities. Appropriate mapping of these activities, both historical and contemporary, is necessary to fully understand and track the nature of these impacts. Indigenous communities often undertake these sorts of studies themselves in order to use the data to participate in various legal or regulatory processes or to archive this knowledge for future generations. However, given the significant possible legal repercussions of releasing this material into public spheres, many communities are cautious about using or releasing it for government-led processes. Funding community-led climate risk and vulnerability assessments (including as part of broader climate adaptation planning processes) is a way for federal and territorial leaders to provide communities with the agency to gather, use, and maintain data sovereignty, while also creating valuable outputs that can help shape policy. Approaches along these lines, which emphasize community leadership and empower broader regional action from a community-led base, should be encouraged.

While permafrost thaw is considered a component of climate-related impacts, it is rarely considered within the context of cumulative effects. Climate vulnerability research in the North is only beginning to deal with climate change as an impact on Indigenous life that is occurring in conjunction with other effects. Vulnerability research that focuses on permafrost effects appears further behind in this regard than research on more visible signals of climate change like melting sea ice. The impacts of permafrost thaw must be considered as part of a constellation of climate-related impacts, and within an even broader context of impacts on Indigenous communities. These include the long-term consequences of other processes in the North (whether ongoing or anticipated), including the impacts of past Canadian colonial policy, infrastructure gaps, patterns of federal funding, the impacts of resource development and associated wealth transfers, education, and data gaps, amongst others.

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INTERVIEW CITATIONS

C01. 2021. Transcript of September 27, 2021, interview from the Canadian Climate Institute "Impacts of Permafrost Thaw: Qualitative Research and Storytelling Project." Firelight Research Inc. for the Canadian Climate Institute.

C02. 2021. Transcript of September 28, 2021, interview from the Canadian Climate Institute "Impacts of Permafrost Thaw: Qualitative Research and Storytelling Project." Firelight Research Inc. for the Canadian Climate Institute.

C03. 2021. Transcript of September 28, 2021, interview from the Canadian Climate Institute "Impacts of Permafrost Thaw: Qualitative Research and Storytelling Project." Firelight Research Inc. for the Canadian Climate Institute.

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C06. 2021. Transcript of October 14, 2021, interview from the Canadian Climate Institute "Impacts of Permafrost Thaw: Qualitative Research and Storytelling Project." Firelight Research Inc. for the Canadian Climate Institute.

C07. 2021. Transcript of October 15, 2021, interview from the Canadian Climate Institute "Impacts of Permafrost Thaw: Qualitative Research and Storytelling Project." Firelight Research Inc. for the Canadian Climate Institute.

C08. 2021. Transcript of October 19, 2021, interview from the Canadian Climate Institute "Impacts of Permafrost Thaw: Qualitative Research and Storytelling Project." Firelight Research Inc. for the Canadian Climate Institute.

APPENDIX 1: STUDY METHODS

1.1 LITERATURE SCAN

This environmental scan involved reviewing a range of source material, including peer-reviewed articles, grey literature, websites, and government documents. These materials were retrieved using Google Scholar and Google Search Engine. Some sources were also identified separately by the Institute and Firelight staff. A total of 27 sources were identified in the scan and are listed in Appendix 4, according to their relevance to the goals of the Study and to the permafrost-related impacts that they identified.

The focal search terms and regions are listed below.

Search Terms (searched individually and in combination with each other and with Key Regions)	**Key Regions**
● Permafrost (including: effects, impacts) ● Climate change (including: effects, impacts, adaptation, vulnerability, resilience) ● Indigenous (including: culture, rights, land use) ● Transportation ● Food security ● Food sovereignty ● First Nations ● Inuit	● Arctic ● Circumpolar ● Subarctic ● Yukon ● NWT ● Inuit Nunangat ● Nunavut ● Nunatsiavut ● Nunavik ● Inuvialuit Settlement Region (ISR)

Materials were gathered and reviewed according to both their geographical and topical relevance. The primary focus of the search was on the human experiences of permafrost thaw, with a particular emphasis placed on Northern and Arctic Canadian Indigenous experiences. Materials that described Indigenous experiences of, and responses, to climate change were reviewed to see if they made deliberate and specific reference to permafrost

thaw. The field of research dealing with other climate change impacts (notably, changes to the stability and seasonality of sea ice, snow depth, and wind force and direction) on Indigenous communities is well represented in the literature, and outside of the current bounds of this scan given the permafrost focus. Materials dealing primarily with scientific and specifically quantitative analysis and monitoring of permafrost thaw or other impacts of climate change were excluded in favour of materials connecting these environmental processes to human experiences.

1.2 MAPPING INTERVIEWS

Eight northern Indigenous community members were interviewed in eight separate mapping interviews for the study from September 27, 2021, to October 19, 2021. Interviews were conducted remotely either on Zoom video conference calls or by telephone in some cases where internet access could not support a video call. They ranged from approximately 45 minutes to 90 minutes. Interview teams prioritized the documentation of values relating to observations of permafrost degradation and thaw and those relating to impacts from the same. Other values were documented where time and opportunity permitted.

Participants were identified and contacted by Firelight staff, based on past research experience in various communities impacted by permafrost thaw and in coordination with community liaisons in some cases. Efforts were made by Firelight researchers to ensure that the participant sample covered as many of the Northern regions represented in the study as possible. However, as the study limitations (Section 1.4) note, this was ultimately not possible due to a variety of factors. Snowball sampling was used where possible in order to obtain a larger sample. Participants were offered an honorarium of $300 for their participation.

Participants were chronologically assigned identifier codes in the form of C[##]. Informed consent was obtained for all interviews (see Consent Form in Appendix 2).

Interviews followed a semi-structured format, including open-ended and closed questions (see Interview Guide in Appendix 3). Interview and mapping protocols used were based on standard techniques (Tobias, 2009; DeRoy, 2012). All interviews were conducted in English; all audio was recorded digitally.

Table 1. Consent and associated interview information for participants

Participant Pin #	Oral Consent Recorded (including for use of quotes or mapped material)	Type of Interview (Zoom or Telephone)	Points Mapped	Interview Duration (mins)	Consent to use Personal Name
C01	Yes	Zoom	6	00:55	No

C02	Yes	Telephone	0	00:45	No
C03	Yes	Zoom	4	01:19	No
C04	Yes	Zoom	5	00:47	No
C05	Yes	Telephone	0	00:53	No
C06	Yes	Telephone	0	00:37	No
C07	Yes	Zoom	0	01:04	No
C08	Yes	Zoom	4	00:57	No

Table 2. Regions and communities represented by participants in the study

Region	Communities (Where participant currently resident)	# of participants Interviewed
Inuvialuit Settlement Region (NWT)	Inuvik	1
Tlicho (NWT)	Whatì	3
Nunavut	Igloolik	1
Nunavut	Iqaluit	1
Nunatsiavut	Goose Bay-Rigolet	1
Northern Ontario	Peawanuck	1

1.2.1 Qualitative data collection and analysis

Qualitative data were also collected during the semi-structured interviews. The interviews explored environmental and cultural values of Northern Indigenous community members that may be impacted by the permafrost thaw and the potential impacts from permafrost thaw on these values (thaw interactions). While the interviews were guided by a set of questions, these were adapted or adjusted to focus on key areas of specialization or emphasize what the participant wished to discuss. The Consent Form and Interview Guide used are to be found in Appendices 2 and 3, respectively.

Audio from the interviews was transcribed. Transcripts were then reviewed, coded thematically, and analysed for issues and concerns identified by the respondents. These data are summarized in Section 3. Coding was conducted according to the list of key values identified below.

Indigenous Values Related to Permafrost

Data collection and analysis for this Study is organized around five 'Indigenous Values' related to permafrost. This analytical framework is modelled on the concept of Valued Components (VCs) used in environmental impact assessment processes. A VC is defined as an important aspect of the environment that a project has the potential to affect (Hegmann et al., 1999). VCs may include tangible or biophysical resources (e.g., particular places or species) and may also encompass less tangible social, economic, cultural, health, and knowledge-based values (e.g., place names, Indigenous language, or Indigenous knowledge regarding a particular area).

For the purpose of this Study, the VCs were chosen based on common themes identified in the research data, rather than as predetermined themes driving the collection of the data. These values represent the critical conditions or elements that must be present for the continued practice of Indigenous culture and livelihoods and that may be impacted by permafrost thaw. As such, VCs can range from the direct presence of traditionally hunted animals and gathered plants, to continued habitation, travel, and cultural activities on the land. VCs are also designated to include intangible cultural resources, such as the transmission of knowledge across generations. VCs for this Study are:

- Hunting, Trapping, and Fishing
- Travel, Trails, and Access
- Food Sovereignty
- Cultural Continuity and Knowledge Transfer
- Household and Community Infrastructure

These VCs were determined through an analysis of data collected by Firelight with the Institute for this Study and were informed by themes identified during the Literature Scan.

1.2.2 Site-specific data collection and analysis

For the purpose of this Report, *site-specific data* are values reported by participants that are specific, spatially distinct, and can be mapped (however, exact locations may be treated as confidential).

Site-specific data were mapped and managed using a "direct-to-digital" process, in which the interview-mapper's computer screen was shared via Zoom video-conferencing technology. Google Earth imagery was used as the mapping interface. Points, lines, or polygons, geo-referenced at a scale of 1:50,000 or finer, were used to mark areas of reported use and value. Data collection focused on areas where participants had observed permafrost thaw, areas where they found their activities had been impacted, or other sites of interest and importance related to the interview foci. See Figure 1 for a map of the Project and the Study Area.

Maps of site-specific values presented in this Report are generated from data mapped during the interviews.

The temporal boundaries set for the baseline data collection include past, current, and planned future knowledge and use. For the purpose of this Study:

- A past value refers to an account of knowledge and use prior to living memory, passed down through history;
- A current value refers to an account of knowledge and use within living memory; and
- A planned future value refers to anticipated or intended knowledge or use.

APPENDIX 2: CONSENT FORM

CANADIAN CLIMATE INSTITUTE Impacts of Permafrost Thaw: Qualitative Research and Storytelling Project

Declaration of Informed Consent and Permission to Use Information

I (name) _____, on this day (complete date)

_____, give permission for the Firelight Group to interview me for the Canadian Climate Institute Impacts of Permafrost Thaw: Qualitative Research and Storytelling Project.

I understand that the study is being conducted by the Canadian Climate Institute (the Institute) with consultants, the Firelight Group. The purpose of the study is to document the experiences, interests and concerns of permafrost-impacted Northern Canadian Indigenous communities.

By signing below, I indicate my understanding that:

(a) I consent to have my words and responses recorded on maps, in notes, and using audio and video recording equipment.

(b) I am free to not respond to questions that may be asked and I am free to end the interview at any time I wish.

(c) I will maintain intellectual property rights over information and recordings collected through my participation, but by signing this waiver the Institute may use the information and recordings, including audio, video, or pictures, in pursuit of its objectives in describing Northern Indigenous experiences of climate change and particularly permafrost thaw. This includes, but is not limited to, sharing information for the purposes of publicly accessible communication and storytelling materials, and developing analysis to support policy and funding proposals.

(d) Prior to publication of the materials listed in (c) which include a quote from you, the Institute or Firelight will provide an opportunity for you to review and provide feedback on a draft. A period of no less than 2 weeks will be given to you. The Institute will not use information you provide for products beyond those listed in (c) without your full permission.

(e) The Institute will ask permission from me or my descendents before using my information for purposes not indicated above.

(f) I consent that the Institute does not have control over how these reports will be cited in or used by other external viewers.

(g) All data will be stored on the Institute password protected googleshare drive, and should you wish to have a copy for your records will be provided by Firelight. All data will be destroyed by 2024.

For more information, please contact Dylan Clark, Senior Advisor the Institute, 416-557-1630

I would like my quotes included in reports: **yes** **no**

I would like my name included in reports: **yes** **no**

Should at any time you wish to withdraw from this study please contact Dylan Clark.

Signature of participant Witness

_____ _____

PIN #:

APPENDIX 3: INTERVIEW GUIDE

CANADIAN CLIMATE INSTITUTE IMPACTS OF PERMAFROST THAW IN NORTHERN COMMUNITIES: INTERVIEW GUIDE

INTRODUCTION

Introductions:

- Introduce yourself and the research team, who you work for, who you were hired by and who you report to.

Introduce the Canadian Climate Institute and Firelight.

Who We Are

The Canadian Climate Institute (the Institute) is a publicly-funded non-partisan organization that does climate change research. Their focus is on providing decision-makers with information to help move forward solutions and actions that respond to impacts posed by the changing climate.

The Firelight Group (Firelight) is a majority Indigenous-owned consulting group specializing in community-based research related to culture, health, socio-economics, ecology, and governance. Firelight has worked with Indigenous nations and communities across Northern Canada. The Institute has contracted Firelight to carry out the interview portion of the Project and report back to THE INSTITUTE on what is shared with us through these interviews.

Give the participant an overview of the Project

The Project

The Institute is doing research to study the potential economic impacts of permafrost thaw that are facing Northern communities. The research has two components. One component looks at the economic impacts (i.e., the financial costs) of permafrost thaw in Northern communities. It is especially focused on the built infrastructure relied on in Northern communities such as roads, buildings, and runways.

The second component is the reason for this interview and it is being carried out by The Firelight Group. In addition to impacts on built infrastructure, this research also seeks to understand how permafrost thaw affects other aspects of life in Northern communities, such

as health, harvesting activities and food security, incomes and livelihoods, and other vital elements of culture, and personal and community well-being. For this component, we are talking with individuals across Northern Canada who are living in communities that are on the forefront of permafrost thaw and other climate changes.

If you are willing to share your knowledge and experience, we wish to ask you questions about the permafrost thaw that you may be already seeing and experiencing in your personal and community life, and/or what changes you anticipate in the future. We are interested in any information you are willing to share on this topic.

The interviews for this study are being conducted remotely using Zoom video-conferencing technology during Spring 2021. The knowledge and perspective shared by yourself and other individuals interviewed for the study will be compiled by The Firelight Group. It will both inform and be presented alongside the Institute's report on economic impacts. It will help the Institute tailor recommendations that are responsive to the unique impacts facing Northern communities. The information will also be displayed in an interactive storymap online. Storymaps display information visually using written materials, maps, images, audio, and other media. The Storymap will be available for viewing online and accessible to the public.

[Share screen and show participant the Tłı̨chǫ storymap for Rayrock]

Provide an opportunity for the participant to ask questions

- Providing accurate answers to participants' questions is an important aspect of free, prior and informed consent.
- Technical questions relating to the Project should only be answered if you have the necessary Project information.
- Questions that you cannot answer should be directed to the community coordinator, principal investigator or the Institute, as appropriate.

Review the consent form

- Once the participant's questions have been answered, ask them if they give their consent and remind them again that information they share will go into the public domain and potentially be shared in reports and on the storymap. As interviews will be conducted remotely, it is important that verbal consent for the interview is recorded on the tape. Ensure that the audio recorders are on, read through the consent form, and have the participant provide their verbal consent for the recording.
- Review the consent form aloud with the participant.
- Ask the participant if they have any questions.

- If the participant does NOT sign the consent form or provide recorded verbal consent, do NOT continue with the interview.
- Remind participant to only share what they feel comfortable sharing knowing it will go into the public domain.

Provide participant an outline of honorarium protocol.

Start the Interview

[Complete the interview checklist and pre-interview section above, then read the text below with AUDIO & VIDEO RECORDERS ON at the start of each interview.]

Today is [DATE]. We are interviewing [PARTICIPANT NAME] for the Canadian Climate Institute Study focused on the impacts of permafrost thaw in Northern communities. Thank you for coming.

My name is [NAME] and my co-researcher(s) is/are [NAME]. [PARTICIPANT NAME] has provided verbal consent, and we have assigned him/her participant ID [#]. We are conducting this interview remotely using Zoom video conferencing software using a shared screen and screen control techniques. We have explained the purpose of the study, and interview plan.

PARTICIPANT HISTORY

Can you please provide your name?

Where do you live? Have you always lived there?

Do you consider yourself a member of a certain community or nation? If so, which community or nation do you identify with?

LAND USE CONTEXT

Interviewer will have the map of the community area on hand, and use it to locate important areas and activities as necessary. The goal of these questions is to situate the conversation, and so interviewers should be detailed where possible, but ensure the conversation moves forward to climate change/permafrost. The nature of the responses will determine the depth and focus of future questions and mapping.

If the participant provides negative responses move questioning into community land uses/ land use focal activities in a broader sense.

Can you describe your relationship to the land?

If you go out on the land, are there certain areas you enjoy spending time? If so, which areas?

- What do you most enjoy about these areas?
- How do you access these areas?
- Are there certain activities that you participate in at these places? If so, what are they?

If relevant, ask about the activities. For example:

  - *Are there certain animals you go for when you're out hunting? Are there certain types of berries or plants that you look for?*
  - *Where do you usually find these? What types of environments? (e.g., near water, in muskeg, in forests, etc.)*

- What are the most important times of year for these activities?
- How long have you been going to these areas? *[establish time frame for future observations – year/decadal range]*

PERSONAL EXPERIENCES OF PERMAFROST

Interviewer will have access to the map available for these questions and be prepared to record important sites arising on the map.

When I say the word 'permafrost, what do you think of?

Have you noticed any changes in your community that would describe as being related to or driven by permafrost thaw?

To your knowledge, have other people in your community expressed any concerns about permafrost thaw?

Can you identify permafrost-effected areas close to your community?

- Where? [MAPPING PROMPT]

Can you describe what it's like to be in those areas?

- What does permafrost thaw in those areas look like?
- What time of year is this impact most strongly felt? *[E.g. season]*

What impacts does permafrost thaw in these areas or others have on your life (or on important activities?)?

- Is permafrost thaw changing where or how you perform certain activities?
- Is permafrost thaw changing what plants and/or animals are available to you for harvesting?
- Is permafrost thaw affecting your health or wellness in other ways?

Have you noticed [or are you concerned about] any changes in the built environment in and around your community (e.g., the buildings, the roads, the airstrips) that you associate with permafrost thaw (or other climate changes)?

- Where? [MAPPING PROMPT]

COMMUNITY EXPERIENCES OF PERMAFROST

Is permafrost thaw affecting your community's:

- Health, water, and food security? If so, how?
- Travel or transportation links? (e.g. roads, airstrips etc.)
- Cultural activities? (e.g. hunting or trapping)

Is permafrost thaw affecting your community in other ways? If so, how?

- E.g., Other aspects of social life, political life, economic life (e.g., jobs, income, economic development opportunities), cultural life?

Do you think that permafrost thaw will impact future generations? If so, how?

ADAPTATION

Are you and your community already adapting or coping with the changes brought about by permafrost thaw?

- Are you personally having to change your behaviours to respond to the changes brought about by permafrost thaw? If so, how? *[local conditions – as previously discussed/listed by the participant]*
- What changes have you seen others making? Or your community making?

Are there particular barriers to adaptation you have experienced? What prevents your community adapting to these new challenges?

- What supports do you wish you could access?
- What would help you adapt to these changes?

Are you/ Where are you finding optimism or hope in relation to permafrost thaw?

- What are sources of strength and resilience in your community that are helping it adapt or cope with these challenges?
    - How are these holding up under the stress of permafrost thaw?
- Would you consider any of these changes as positive? Are they provoking any adaptative changes that you think are positive?

Is there anything else you like to talk about today? Or is there anything important for to know that we haven't asked about?

CLOSURE

Read with audio & video recorders on after every session.

Today is [DATE]. We have just finished interviewing [PARTICIPANT NAME] for the Canadian Climate Institute Study focused on the impacts of permafrost thaw in Northern communities.

My name is [NAME], my co-researcher is [NAME]. We conducted this interview remotely using Zoom video conferencing software. We've recorded a total of [#] tracks on the digital recorders. Notes are recorded in/on [notebook/computer]. This interview has taken approximately [#] hours [#] minutes.

APPENDIX 4: LITERATURE SCAN SOURCES CONSULTED

Source (Citation)	Year of Publication	Focal Region	Permafrost Impact Themes Identified
Allard, Michael, Mickaël Lemay, Carl Barrette, Emmanuel L'Hérault, and Denis Sarrazin. 2012. "Chapter 6. Permafrost and Climate Change in Nunavik and Nunatsiavut: Importance for Municipal and Transportation Infrastructures." In *Nunavik and Nunatsiavut: From Science to Policy. An Integrated Regional Impact Study (IRIS) of Climate Change and Modernization*, eds. Michel Allard, Mickaël Lemay. Quebec City, QC: ArcticNet Inc.	2012	Nunavik and Nunatsiavut	Infrastructure Food Security Transportation
Baird, Kim & Mark Podlasly. 2020. "The Opportunity for Indigenous Infrastructure." Public Policy Forum. https://ppforum.ca/publications/the-opportunity-for-indigenous-infrastructure/	2020	Non-specific	Infrastructure
Calmels, Fabrice, Cyrielle Laurent, Ryan Brown, Frederique Pivot, and Margaret Ireland. 2015. "How Permafrost Thaw May Impact Food Security of Jean Marie River First Nation, NWT." In *Proceedings of the 7th Canadian Permafrost Conference, Quebec City 2015.* GeoQuebec 2015 Conference Paper.	2015	Jean Marie River FN, NWT	Food Security
Centre for the North at the Conference Board of Canada. 2014. *Study on Addressing the Infrastructure Needs of Northern Aboriginal Communities*. Developed for the National Aboriginal Economic Development Board. http://www.naedb-cndea.com/reports/northern-infrastructure-report.pdf	2014	Non-specific	Infrastructure

Source (Citation)	Year of Publication	Focal Region	Permafrost Impact Themes Identified
Cochran, Patricia, Orville Huntington, Caleb Pungowiyi, Stanley Tom, F. Stuart Chapin III, Henry Huntington, Nancy Maynard, and Sarah Trainor. 2014. "Indigenous Frameworks for Observing and Responding to Climate Change in Alaska." In *Climate Change and Indigenous Peoples in the United States: Impacts, Experiences and Actions,* eds. Julie Koppel Maldonado, Benedict Colombi, & Rajul Pandya. Cham, Switzerland: Springer International Publishing.	2013	Alaska, USA	Climate Change
Downing, Ashleigh and Alain Cuerrier. 2011. "A Synthesis of the Impacts of Climate Change on the First Nations and Inuit of Canada." *Indian Journal of Traditional Knowledge* 10 (1): 14.	2011	Non-specific	Climate Change
Fortier, Richard, David-Roy Banville, Richard Lévesque, Jean-Michel Lemieux, John Molson, Rene Therrien, and Michel Ouellet. 2020. "Development of a Three-Dimensional Geological Model, Based on Quaternary Chronology, Geological Mapping, and Geophysical Investigation, of a Watershed in the Discontinuous Permafrost Zone near Umiujaq (Nunavik, Canada)." *Hydrogeology Journal* 28 (3): 813–32.	2020	Umiujaq, Nunavik	Food Security Drinking Water
Fortier, Richard, Anne-Marie LeBlanc, and Yu Wenbing. 2011. "Impacts of Permafrost Degradation on a Road Embankment at Umiujaq in Nunavik (Quebec), Canada." *Canadian Geotechnical Journal* 48 (5): 720–740.	2011	Umiujaq Airport, Nunavik (Quebec)	Infrastructure
Flynn, Melanie, James Ford, Jolene Labbé, Lothar Schrott, and Shirley Tagalik, 2019. "Evaluating the Effectiveness of Hazard Mapping as Climate Change Adaptation for	2018	Non-specific	Infrastructure

Source (Citation)	Year of Publication	Focal Region	Permafrost Impact Themes Identified
Community Planning in Degrading Permafrost Terrain." *Sustainability Science* 14 (4): 1041–56.			

Source (Citation)	Year of Publication	Focal Region	Permafrost Impact Themes Identified
Fritz, Michael, Bethany Deshpande, Frederic Bouchard, and Elin Högström. 2015. "Brief Communication: Future Avenues for Permafrost Science from the Perspective of Early Career Researchers." *The Cryosphere Discussions* 9 (February): 1209–25.	2014	Non-specific	Landscape
Human Rights Watch. 2020. "Canada: Climate Crisis Toll on First Nations' Food Supply." Press release, October 21. https://www.hrw.org/news/2020/10/21/canada-climate-crisis-toll-first-nations-food-supply	2020	Non-specific	Food security
Human Rights Watch. 2020. "My Fear Is Losing Everything." https://www.hrw.org/report/2020/10/21/my-fear-losing-everything/climate-crisis-and-first-nations-right-food-canada	2020	Vuntut Gwitchin FN, Skeena River, Treaty 9	Food Security
Inuit Tapiriit Kanatami. 2019. *Inuit Nunangat Housing Strategy*. Crown-Indigenous Relations and Northern Affairs. Government of Canada. http://publications.gc.ca/collections/collection_2019/rcaanc-cirnac/R5-737-2019-eng.pdf	2019	Nunangat	Housing
Kintisch, Eli. 2015. "These Ice Cellars Fed Arctic People for Generations. Now They're Melting." *National Geographic*, October 30. https://www.nationalgeographic.com/news/2015/10/151030-ice-cellar-arctic-melting-climate-change/	2015	Alaska, USA	Food Security Culture

Source (Citation)	Year of Publication	Focal Region	Permafrost Impact Themes Identified
Lewkowicz, Antoni & Robert Way. 2019. "Extremes of Summer Climate Trigger Thousands of Thermokarst Landslides in a High Arctic Environment." *Nature Communications* 10 (1): 1329.	2019	Banks Island, High Arctic Canada	Culture Climate Change
Mercer, Greg. 2019. "Labrador's Melting Landscape: Cultural Centre Offers Lesson on How to Build on Thawing Permafrost." *The Globe and Mail,* 17 December 2019. https://www.theglobeandmail.com/canada/article-cultural-centre-offers-labrador-a-lesson-on-how-to-build-on-melting/	2019	Nain, Labrador	Infrastructure Climate Change
Nunavut Climate Change Centre. N.D. "Climate Change Impacts." N.D. https://www.climatechangenunavut.ca/en/understanding-climate-change/climate-change-impact	N.D	Nunavut	Food Security Infrastructure Housing Culture Travel
Nunavut Government. 2010. "Upagiaqtavut - Setting the Course: Climate Change Impacts and Adaptation in Nunavut." Strategic Document. https://www.climatechangenunavut.ca/sites/default/files/3154-315_climate_english_reduced_size_1_0.pdf	2010	Nunavut	Food Security Infrastructure Housing Culture

Source (Citation)	Year of Publication	Focal Region	Permafrost Impact Themes Identified
			Environment
Penney, Jessica, and Patricia Johnson-Castle. 2020. "COVID-19 and Inuit Nunangat: Research, Responsibility & Infrastructure Inequality." Yellowhead Institute (blog), March 31. https://yellowheadinstitute.org/2020/03/31/covid-19-and-inuit-nunangat-research-responsibility-infrastructure-inequality/	2020	Nunangat	Infrastructure

Source (Citation)	Year of Publication	Focal Region	Permafrost Impact Themes Identified
Schreiber, Melody. 2018. "The Housing Crisis in the Arctic, Caused by Melting Permafrost." *Bloomberg*, May 10. https://www.bloomberg.com/news/articles/2018-05-10/melting-permafrost-and-the-housing-crisis-in-the-arctic	2018	Iqaluit	Housing
Shah, Maryam. 2019. "'Our Very Right to Be Inuit' Violated by Global Inaction on Climate Change, Activist Says." *Global News*, 29 December. https://globalnews.ca/news/6343382/climate-change-canada-arctic/	2019	Nunavut	Culture
Tenpenny, John. 2019. "Building Infrastructure in Inuit Canada." ReNew Canada, 18 November. https://www.renewcanada.net/building-infrastructure-in-inuit-canada/	2019	Nunangat	Infrastructure
Vincent, Warwick, Mickaël Lemay, and Michael Allard. 2017. "Arctic Permafrost Landscapes in Transition: Towards an Integrated Earth System Approach." *Arctic Science, Vol 3, Number 2* April.	2017	Non-specific	Infrastructure Landscape
Wallace, Kenyon. 2019. "Beyond Frozen." *The Star,* July 4. https://projects.thestar.com/climate-change-canada/nunavut/	2019	Non-specific	Infrastructure Housing Culture Environment

APPENDIX 5: ADDITIONAL QUOTES

This Appendix includes additional participant quotes, describing aspects of the five themes described in Sections 3.1–3.3 of the Report.

1.1 HUNTING, TRAPPING, AND FISHING

1.1.1 Observed impacts of permafrost thaw

Fish habitat is changing:

> *And there's this particular river … at Steensby Inlet. We used to have a lot of fish—a lot of people would fish from those—and these are sea-run char. And I think about 15–20 years ago, one person actually went there and tried to—there's not as many as fish as before mainly because there may have been an underground lake in that area, and that lake may have collapsed because of the permafrost, and it had—it crashed down and there was hardly any fish there left. And that was one of the things that they talked at the—this lake in the river sort of had disappeared because of the melting. (C03, September 28, 2021)*

Duck habitat is changing:

> *… so it was these islands here. They're so, they're called Ahoqaluit. But also, my favourite duck hunting area is actually this island here.… It's like, looks like a green spot, but that's a pond. That's a pond which might be actually a tidal pond because it's so close to the shore. But ducks actually would really love that because the ducklings can be born and hang out here.… But this, yes, is my favourite island. And again, when I get dropped off on the shore, wherever it might be, I head for these, I head for these ponds.... And they're drying, they're drying up. (C01, September 27, 2021)*

The land is changing:

> *And it's not just only one area. Like I have area by my cabin up there, I used to have road to go hunting every year and the early, early November before the snow, the snow get too thick, I go out there by skidoo and make a trail. I go hunting up there, every chance I get I go up there, because the trail is there, so I go up there and I go hunting for woodland or moose, right? But we have to keep it maintained because when the snow gets deep it's hard to make a skidoo trail, so you have to get in this area to keep that snow packed. But when that permafrost is melting, it's creating more work for us, it's getting harder to hunt for us. You have*

> *to find more hunting ground, you have to get used to the new hunting area. It's take much work, yeah. (C08, October 19, 2021)*

> *Yeah, winter hunting, yeah. Winter trapping and hunting. In the summertime, we go, the only problem we have is when we go out by boat, it gets too windy all of a sudden, and we can't hunt, can't idle in one spot for too long, right? So yeah. But in the winter yeah it gets really, more complicated. But maybe that's the reason why we lose a lot of hunters like that, we don't see too much hunters go out on the land anymore. I remember when I go out bow hunting and we used to have a lot of bows going around, all everybody's hunting on a skidoo. You see a lot of people hunting on a skidoo. But I noticed that last couple of years there's not much activities, people don't go out as often as they used to. Maybe it's got to do with the permafrost melting for sure. It's damaged their hunting area. So a lot, like last year nobody hardly went trapping at all. We're losing our traditional way of living due to the changes. It's really bad. Because you know, if you go to the store and buy a pound of meat, right, it costs like $30. And jobs are hard to come by, and it affects our eating habits, you know. Most of us were born on a traditional food and we can't go hunting, we can't—so there's a lot of problem from climate change. (C08, October 19, 2021)*

1.1.2 Projected change and anticipated future impacts

Changes are happening fast:

> *[Interviewer: Do you do you find yourself going to different places, changing the time of year that you go?] No, I say no major adjustments right now. … But yeah, but I mean, we'll see next year. Some—just the changes are happening so fast that from one year to the next, there might be some big stuff happening. (C01, September 27, 2021)*

1.2 TRAVEL, TRAILS, AND ACCESS

1.2.1 Observed permafrost impacts

Permafrost affects ground stability:

> *The only worry I have is—especially with the—in the community of Igloolik and the whole beach is the permafrost—the disappearing of permafrost. … Because then we would have a lot of mud; we would have landslides; we would have a lot more mud in the surrounding areas. That's my biggest worry, is the actual mud being developed over time. … And the shifting of the land itself. … Because in the hills the mud would start sliding down. … Mudslides. (C03, September 28, 2021)*

Observations of impacts vary with the season:

> *Yeah, my primary, so when we see the effects of permafrost, it would just be in the summer because regardless everything will freeze in the fall and in the winter and starts to thaw in the spring. But when we see the actual impacts, which is in the summertime, I'm, I'm mostly on the boat. And so, we not really have any, too much contact with land-based travel. We have some land based, they will do some camping and some short hikes here and there. But for the most part, I'm on the water in the summer. So, the, my observations have been somewhat limited to what I see around town from other people's observations that they've passed on to me and just things that I read in, in the news really. (C01, September 27, 2021)*

Detours are required while travelling on the land:

> *Snow machine. … You can actually see it. … [permafrost thaw is visible on the land as] Cratering, like a big hole. … And you'd have visible mud and permafrost. … Usually I'll take a GPS point and map it on my phone. … No [the permafrost thaw doesn't slow down his travel on the land]. Not on the snow machine, no, no. … Easy to detour with a snow machine. It's not as easy with a boat. (C04, September 29, 2021)*

Participant has noticed erosion related to permafrost thaw at key sites around the coastline of Igloolik island and elsewhere in Foxe Basin:

> *And also—that's on the scientific part, but also amongst the Inuit side, it's not coming from the air, it's coming from underground. The heat is actually developed, being developed, so rapidly from underground and they—it's very, very noticeable, especially in the Gulf of Boothia, and northern part of Foxe Basin. We no longer have any multi-year ice, and any icebergs that we do see are not multi-year ice. They are ice from last year, and you can actually recognize these, and they melt much, much, faster than multi-year ice. And so, the land itself because of the multi-year ice that had disappeared so rapidly and very quickly, we had huge problems with erosion along the shores, along the northern shore, especially with the limestone gravel, and it's pushing a lot of the shore inward into—inland. … And so there's a lot of exposures to the—along the shorelines you have less permafrost, and there are some mudslides as well because of the permafrost, but what we have seen about the permafrost, the changes of the landscape and the shorelines. (C03, September 28, 2021)*

> *Yes, the one that I spoke about—the new one, the new exposed permafrost is on this side, in this area. … And also, the drinkable freshwater permafrost is in this—in this area here. … And the most noticeable erosion is this shoreline here and this shoreline here, and also this side of the island—and there's —the erosion is so*

> *rapid. Where it's shallow, like in this area, the erosion is not as fast, and where it's very shallow along here, there's hardly any erosion. But where it's deeper along here, you have a lot of erosion along the shores. And also there's, in this area, is now becoming very shallow. We used to drive there without any worries, and now during low tide, it's almost impossible to go in this certain area, and it could be that the—well, like the scientists say that the Island of Igloolik is all limestone, including this island here, these are nothing but limestone, and all this along here is all limestone. This part of Melville Peninsula is all limestone. And there's a lot of muddy areas, especially along here—and very muddy, and this hill is covered in mud, and it's more visible than ever before. When there's mud, there's hardly any vegetation. And where swamps are, and where the permafrost, and where the moss are, like in this area, you have—you're able to expose some of the permafrost, so—but this is all bedrock here, but the type of rock that you see in Naujaat and also in Iqaluit, exactly the same type of geology, and this side is all nothing but—this part will have a lot of impact, whereas these islands will have … impact because they're bedrocks.... So, with the permafrost, it's something that we're concerned about, and also that this area here, there used to be a cliff and the cliff no longer exists. (C03, September 28, 2021)*

Unpredictable seasons and poor ice roads mean reduced access:

> *... the winter … last year. That was an eye-opener.... Many people had … their goods from driving out to … to a city or another town to pick up goods. So we learned from that because … what happened, something like you just can't plan … whether it's going to be a mild winter. (C02, September 28, 2021)*

There are barriers to adaptation:

> *And the other thing we have to learn too is like with gardening—you just can't put a seed in the ground and expect things to grow the way they grow down south because the—the peat is different. It's acidic up here because this was once under an ocean, so we have to learn how to grow stuff on peat.… We have to learn all of these things, and those are the barriers. And also the extreme cold that we have every now and then—because what's happening is that, according to our research, a lot of warm air is getting displaced in Alaska. It goes to the Arctic Ocean, and it—because warm air is more denser than cold air, it's pushing down the cold front south. And … it really impacts us because we're still way up north. That's why we get those really cold weathers.… (C02, September 28, 2021)*

Water levels are changing:

> *When I mention the high water—we get a lot of high water, and it comes up really fast. To give you an example is that—you know that hurricane down south*

> *and our water goes way, way, south—our river system. We went for a boat ride overnight on Saturday, and on my way back, the water went up a foot … really, really, high, and … so many creeks up here. So, after freezing up this, this water that came up—will freeze—I will say an average of seven inches, and then … drop back to normal after that—it will drop maybe three feet. So we have this ice hanging over the water, under that and it will crash in in your bow. It happened to me.... And it happened to other people too.… I nearly broke my leg and then … is happening just about every year now. (C02, September 28, 2021)*

Walking can be difficulty out on the land:

> *One of the things that—many of the direct impacts that we have is recognizing people that live in the area is travel during the summer. When you go out hunting—is they're walking on solid ground … you'll be walking on muskeg.… We can't even use the community with the—access the community.… They're—they're in water—ponds and muskeg and swampland … no permafrost up top, but up here—there's a lot of peat. (C02, September 28, 2021)*

It's now more difficult to move around on the land in Northern Ontario:

> *I think when I was growing up … my mom used to tell they used to walk from … "Pike River" … And they used to go to this place—they would be walking down … here … and now it's all swampland—like muskeg.… There was muskeg then too, like not all of it was—not all of it was permafrost.… Like I could walk there when I was a kid. You grew up and you seen swamp, and—and now I can go there with my—I think I can almost—I'm pretty sure I can walk there with hikers.… It's really dry, but at the same time, in the natural state of the last ice age … all the places that—where there used to be swampland, that's also disappearing. Everything is drying up now. Muskeg is gone and it's turning into a different kind of environment—but most of it's—you can see from the air where the permafrost is kind of disappearing. You can see from the air where it's all sinking. I have pictures of permafrost—where it sinks, it turns into muskeg ... swampland.… It's just really fully changes the environment. It's just like you're walking on cement and then ten years later it's like swampland there kind of thing. (C02, September 28, 2021)*

The Iqaluit airstrip is sinking:

> *[Nunavut Research Institute has a project] with the [Iqaluit] airport and measuring permafrost because that is the biggest paved road or paved area that you can think of. And so, they've been monitoring that over the last few years because it's, it sits on marshland. Like it's insane, like if you, here, so here's the, here's the runway. And it is the second longest runway in Canada, next to the one*

> *in, I think Toronto. So built by military, of course. But this entire area, like so this is all rock here, but the drains. And then there's the river here. And this entire area, say from around here, running all along the length and up here is marshland.… So, it's on marshland, and so that thing is monitored because it's been sinking for I don't know how many years due to permafrost. (C01, September 27, 2021)*

The winter road network is vulnerable:

> *Well, sometimes, like for example, like people work on a winter road.... Yeah, at times it's, you know, it's, they're behind schedule to build that winter road ... due to the thickness of the ice—it's not there. It's something to do with the climate change ... And, so it's, at times like during the winter it gets different—warmer weather sometimes, so they have to—the crew that—building the road pretty well have to keep an eye out at times.… And that's happened sometimes, even now our winter road—also the roads to the mines as well.... [If the winter roads are behind schedule in their construction due to warm patches mid-winter, communities like Whati] ... we don't necessarily just depend on our winter road. We get regular flights ... Yellowknife and so we can get our stuff in and travel in and out that way as well.... But now, sometimes, the delay in construction, it does happen like due to the weather—it's warmer—it's 10 or 12. Really, you know, we need the cool weather to have a good kind of solid ice in place, eh? (C05, October 5, 2021)*

Permafrost thaw is affecting the quality of roads:

> *Yeah, the roads are pretty bad [laughing]. Yeah, any, and where there has been pavement. So, the pavement, especially the new pavement, it gets hot and melts what's underneath it and then it just collapses. There's a few roads in town where you could tell a section of the road has collapsed, but it's collapsed so slowly that the road has formed to the kind of almost like a giant divot. And yeah, so you have that all over town, especially like we—the pavement in town on the main streets is, you know, 30 years old. But then you have other parts of town that recently received it and already you can see it collapsing in some areas, bumpy in others, eroding on the side. It's pretty bad. (C01, September 27, 2021)*

Increase in cost or any impact to the community due to weather-related delays in winter road construction typically results in increase in cost of good/supplies:

> *Construction is all pretty well almost complete [on the Tlicho All Season Road], and I'm hearing that it might be opening—grand opening might be happening at the end of next month.... So, if it does happen and definitely it's—really would be happy that they don't have to pay too much of a price on the food and whatnot....*

> *I'm concerned about the, you know, also using the aircraft at times—different weather.… It could be in fall times, you know that thing could be cancelled.... And they're also sent in with your—whatever the goods that you might have wanted to get but can't get right away because you've got—going to have to wait a day or two, waiting for good weather.… It happened in our time in the past, and so these kind of issues they did raise about that.... You go out of the community, get your stuff that you need. You know, in terms of—other than groceries—building supplies, that ... you need, and the other way around, it's too pricy too.... (C05, October 5, 2021)*

Permafrost thaw is affecting trails and roads:

> *All the permafrost is melting.… About 10 or at least, it's got to be at least 20 kilometres out of here there's an area where there's a road, and on the road there was permafrost, right? So now there's a big hole in the ground now, and the road you have to make it right, they have to move the road a little bit to the left in order to get into that area. So things like that are happening. (C08, October 19, 2021)*

> *I got this trapline and that was about at least 30 kilometres out of here. I go up this river and it comes to this little lake and there was an area where there was a thick forest, and I used to have my camp there every year.… What happened is it went into the water. This was by the pond and that whole land, the whole island had a big forest and it just disappeared.… I think what happened is the high ground sank into the lake. I don't know what happened, but it's not there anymore. Like for example, like here, if we go to the, by the lake, you know some of the bank slope decay, right? So it's not the same anymore. Like we have a beach, a beautiful beach, and now there's too much water and the slope decayed so it all goes into the lake, right? (C08, October 19, 2021)*

> *There's another area where I'll tell you about is the big slope on the road from the permafrost … I think I seen somewhere in this area in here. It's right by the road. Where there used to be a road, all the permafrost is just, the whole land sank in, so they have to build a road right by, but every year is dangerous because you know, if you make a big mistake just go right into that crack in the land, right? But just have the road by it, probably not going to use it.… Well because of, because of the permafrost melting there's a big slope in the ground now so they built a road right by it. So the road is really sloped, right by the edge. Somebody make mistake and just go over the edge, right? (C08, October 19, 2021)*

> *Well, there's a, the biggest one is that like I said, the storm come up all of a sudden and we have more problem with the winter road. Like some people try to get from their home to their hometown and a big storm come up and the road*

> *gets drifted in, snow drift and they can't get home, right? And they get stuck in the small ones. A couple of times people almost froze on the way to Waiti a couple of years ago because they were stuck in the road. Luckily, they had enough gas and a big storm came up, they were stuck on the road there for a couple of days. And these things happen all the time, yeah. Sometimes you don't see it when you get a blizzard, you don't see a snowbank and you hit it, stuff like that happens, you know. (C08, October 19, 2021)*

> *There's really, it's not good because when there's permafrost it just creates a big ditch, slope. You have to build a whole road around that area. And it takes a lot of work, right? And you know that island that I talked to you about, it didn't, it just disappear, like must have just gone down into the ground. Because I tried to find it, I remember that area pretty well because I went trapping there for I don't know, seven, eight years, and so I almost kind of puzzled so I came back and asked the Elders and they said this happens once in a while due to climate change, and everybody says when the permafrost melts and it creates the land to fall out, and the land just sinks and just a big slope. (C08, October 19, 2021)*

> *[seasonal impact is offset—summer is in boats but melting happens, then in winter they are on land but feel the impacts] Yeah, yeah. Because of, like I said, when the permafrost is melting it creates these big slopes, and it's just too much work to rebuild a trail, right? Everybody has got their own trail. People really respect that, right, nobody's going to go on my hunting trail, nobody's going to go on my trapping trail because every family's got their own trail and every family's got their own trapping area. (C08, October 19, 2021)*

Climate change is creating lake overflow events:

> *No, another big problem I see is with the climate change is that the lakes get flooded every year, you know. There's—what do you call it, overflow. There's a lot of overflow on the lake due to climate change. Some time they just freeze, and when it snow lots and there's a crack in the snow, then it gets flooded, the lakes get flooded. I wouldn't try to go anywhere, get in trouble by the land. The lake get flooded, can't be on the road, nothing. It happens every year now, yeah.… I think it's got to do with climate change. The snowfall, the ice freeze and then too much snow, and then the ice crack and the water, the ice is too heavy so it gets flooded. Every year it's like that. So you go out in the woods, you go on the lake, you want to go to a spot where there's woods and it's overflowed you get stuck by skidoo. The skidoo gets stuck and it's really hard to pull out, especially when you're far on the land, right? (C08, October 19, 2021)*

Climate change is affecting to river flows and the seasonal hydrological cycle:

> *We've seen tremendous, tremendous, change in river patterns, the flow—more flow on some, and less on others, and the way—like it's almost like especially the Churchill River, we have a community seven kilometres away, which is an isolated community called Mud Lake.… And even like for me travelling—when I used to trap, to go up the river, I mean, I'd be up on the river probably anywhere after November 11th holiday.… Now, I cannot go to Mud Lake which is seven across—kilometres across the river 'til about—lucky if you gets there Christmastime.… It's a month later. It's a month later.… Yeah, it's because of the, you know, the temperatures, but it's also because of the way the river is flowing now.… (C07, October 15, 2021)*

Roads are impacting remoteness and community connection:

> *Yeah. Well, that's what happened in Cartwright.… But I will say there are benefits. I don't want to give the impression that I'm against development—roads. You know, the people of Cartwright, they got a lot of family that live here [Goose Bay] for many years.… So, obviously there's a reconnection of family ties too. And some of the people that … go home more often now, but I do think if we did the right research, there's probably less hunting going on.… There's more, again, I said—I think I said we hunt now out of hobby and habit and recreation, rather than necessity.… (C07, October 15, 2021)*

> *Even the development of the road, I mean, I support the development of roads, but I understand what it also brings too.… The loss of these sort of things, and it also, if you open up our communities—Cartwright was an isolated community other than by boat and plan.… Now, as I just mentioned, they're what, 600 kilometres away, maybe less. They're like on a good day on the pavement, they're only like three hours away by—you know, four and a half hours away. Right, so I mean, that isolation, that close-knit community feeling is gone … It's not there now, so we have to think about what that really means. If we build a north coast road to Rigolet, I have relatives there, that close-knit community feeling will be gone because Rigolet is only a hundred kilometres away.… I could get off three o'clock and go home.… So that's going to have major impact on that community and people will probably hunt less, 'cause they're going to come to Goose Bay. (C07, October 15, 2021)*

Climate change is shifting the shipping seasons:

> *And then the shipping season, if you look at the shipping season up here, one time, you know, end of September, they weren't accepting freight for the north coast on the freight boats. Now guess when the freight stops? About the first week of December. (C07, October 15, 2021)*

1.2.2 Projected change and anticipated future impacts

Remoteness increases the cost of living:

> *[Interviewer: What does that mean when the trucks can't come in on the road and presumably people can't go out either? Does that mean everything has to fly in and out?] C02: Yeah, we—we're stuck here and that our community sells gas at a non-profit market.... So, our gas used to be two dollars a litre, and it's now $2.60, but … sometimes … has to go to four dollars a litre.... Gas is very, very, important for us … and we see gasoline as a food security. That's how we travel … winter road's really important I think.… Three years' time, it's going to be no such thing as winter road. (C02, September 28, 2021)*

Participants see potential for leveraging mine developments for road access:

> *[Interviewer: What do you think you would do in the situation where winter roads can no longer be built?] C02: We're fortunate to have Hudson Bay … so we can use that for water [travel routes].... At the same time, we live maybe 100 miles from one of the largest sites in the world [referencing the Ring of Fire developments.... Maybe we would have access to that area out here on the road.… But at the same time, half the people don't want disturbance … been isolated and kind of live their way of life, but I don't know what the younger generation wants. (C02, September 28, 2021)*

> *… the government that build these roads want to make sure that they have a return once they—their project is completed, and I know up here in the North we do have a lot of potential for mining. We have lots of deposits, but—and that, you know, the core infrastructure's in place, so that could yet attract some investors.… You look at potential for the industry to come in, exploration, and, you know, we do have the mine just 50 kilometres north of Whati, and that's been there for quite a while now. I mean, they did need the road to take their product out, and I understand it's a junior company that require some investors, so but they still need money to bring the mine to the operation.… But the government looks at these and that way they'll have their, you know, it's worth building a road.… (C06, October 14, 2021)*

> *[describing All-Season road construction driven by economic motives (e.g., mine development)] I think, yeah, that's the thing. Yeah, we—as long as we have a good infrastructure in place and that's—I think it's—I think the government is looking more of building more roads to the remote area. They've been talking about building a corridor to the mining company up north, so, yeah, there's still lots of discussing around that, yeah, about those roads being constructed. (C06, October 14, 2021)*

1.3 FOOD SOVEREIGNTY

1.3.1 Observed permafrost impacts

Permafrost was a source of drinking water:

> *And some of these permafrost, like in the Island of Igloolik, I know some of the—we—I used to know where we would expose the permafrost and the exposed—when we exposed the permafrost, some of these permafrost would be crystal clear, and we would use that for drinking water, and it's so pure that we'd be using that for human consumption, drinking it and making tea from it.... [he last remembered doing that] About 18 years ago, but this year a lot of the younger generation were very shocked to see permafrost being exposed on a certain part of the island … and they were very excited over that, and I said, "Well, global warming, it should—this should've been—this should've disappeared, but it's exposing." And the Elder said, "Well," and they're just shaking their heads, "and we know that …this type of permafrost, it's drinkable and it's pure, and it's fresh, and it's what we use to drink out of when there's no lakes or streams or rivers. And we would then look for permafrost, and we would then get fresh water from the permafrost." ... Some of these permafrosts are very, very, clear. (C03, September 28, 2021)*

Permafrost storage was used to prepare/ferment special traditional foods:

> *And from our observation and the way we have lived in the past, Igloolik and Sanirajak are very, very, well known for fermenting walrus meat, and fermenting walrus meat is extremely important to us, which deals with the permafrost as well, so in the month of early June—I'm sorry, in the month of July, early parts of July, that's when we start harvesting walrus and making them into huge sausages, tied, and braided, and these are approximately anywhere from 40 to 80 pounds each. And then a female would be—we would have about eight to ten huge sausages, and males would have ten to 14, and each one of them weighs approximately in an average of 60 pounds. So, these are important. When we're actually catching them we would take them and dig the hole, dig into the ground, and Igloolik … the terrain is all gravel, limestone gravel. And limestone gravel with large pebbles type or slates is the best for fermenting walrus because once we go into the—once we dug the hole right down to the permafrost—as soon as we hit the permafrost, that's when the first layer of these chunks of meat going in, and then they would actually normally have two layers: the first layer down and then the second layer on top of it, and then cover it with limestone gravel. And the larger ones are best because it lets a lot of air in, inside, and a human weight would step—start stepping onto the mound and if it's still soft they would then*

> *start putting in more gravel. And that would make it a perfect type of fermenting walrus meat, and that's very important. (C03, September 28, 2021)*

Use of permafrost lockers is changing:

> *But when we were growing up, we used that permafrost—permafrost to—to leave our food—we used that—I believe for a week. We used to live in a lake. It's like in the interior, so we would eat geese. We would get kagu—fish. So we would dig a hole in the ground, and permafrost's basically frozen ice or frozen peat—most of the stuff here was peat, soil and that. So, we would … bury it back up … for a whole summer. (C02, September 28, 2021)*

> *[impact of the shortening ice road seasons] Well … when the winter road comes, people try to stock up for their, you know, for the year, either they're getting their material for their projects or their food, and so, you know, that have shortened, so people are pretty organized and trying to plan ahead with their yearly supplies, see? But now we have a road here. We're fortunate that we have a—we're getting a road here soon. But climate change is real and it's here and it's going to get worse, and I think, you know, for the other communities that are not connected to the highways. (C06, October 14, 2021)*

> *[impacts of permafrost thaw on food security] You know, we don't have any caribou coming to our area for many years now. I know there's a study been done, but the caribou has been declining, and we have to go further out, further out, for—to harvest. Fortunately we do have a lot of fish in this lake here, so we're good over there. But other, you know, like caribou, we used to really rely on before, has now been a big decline, so we're working with our Tlicho government and the territorial government to—we have a … management body where we're trying to work with everybody to try to have the caribou recover, so but that's taking a lot of time and a lot of work. (C06, October 14, 2021)*

Country food is important for diet, subsistence, and food security:

> *Well, we—the cost [of food in community] is still high.… Especially since Covid, I think the cost of food, gas are pretty way up there, and, you know, lumber I think pretty—tripled, some of them. So, with the road, they'll be—it'll be cheaper for us go out of community to get our supplies, you know, because we—now we don't have to pay for the freight. The freight cost is huge here in the communities that don't have access to the road. (C06, October 14, 2021)*

> *Well, people have always relied on country food they eat, and then mainly Elders, so we still carry on that tradition as—of harvesting caribou although they're further and further out, we still manage to get enough for the communities*

because people are used to the wild meat.… Yeah, I would say that it's just not for the meat, right, we also use the hides for clothing and, you know, for drums—drumming, so yeah, it's a tradition that we want to continue practising. (C06, October 14, 2021)

But for me personally, like I said, it do affect my—it's changed our diet.… And you know, change our travel patterns. The most of all—related to food security on your question is change of diet—bottom line is change in diet.… We'd eat wild meat or country food, you know, five days a week. It was a treat to have a chicken. Now, it's the other way around.… So, I think that's what's important—now it's the other way around, it's flip-flopped. It's that now it's a treat to have wild food.… You know, we eat, you know store-bought food or go to a restaurant, you know, six nights a week, and once a week I might eat wild food, whether it's fish or partridges or rabbits or porcupine or, you know, beaver. (C07, October 15, 2021)

You know, to us it wasn't country food. To us it was food, and we weren't fishing salmon or trout or char or shooting partridges for the fun of it. That's what—you know, I grew up with 11 brothers and sisters. That's what you had for supper.… So, now that we can't do that or do that as often, it changes our diet. (C07, October 15, 2021)

… the times are changing. We live within the rules and regulations, the policies, and it's the law. But, you know, if I can't have them salmon, I gotta go to the store and buy pork chop, right? So, it comes right down to food security, and the issue you have on the north coast as I mentioned, you know, you can't go where we once went—safely, you know, we—so, therefore you have to depend on alternate food from the Northern, and guess what? You might buy a chicken in B.C. at the grocery at Sobeys or Dominion for nine or ten dollars. You know what we pay up here on the north coast for that same chicken?… We probably pay 35 dollars.… So I mean, how can people afford that? (C07, October 15, 2021)

Then on top of that it affects food security and our ability to go hunting as hunters and fishers—gas, you know, is $1.98 a litre. So, I mean, and then bullets are—I'm probably paying twice for a box of cartridges than you would pay. So it's, you know, not only do we have to go farther because of safety and all this kind of stuff, but it's becoming very, very, very expensive to hunt these days.… Because by the time you gases up—time you buys your cartridges, and then you got to say, "Well and geez, I might not even get any, and look at the risk." You know? Look at the safety risk, again, and you know, it's dangerous stuff, right?… Most people I would say hunt more out of hobby, habit, rather than necessity now. (C07, October 15, 2021)

> *Well, I think I'll break that down in two regions for Labrador because the southeast coast is different than the north coast.… The southeast coast—roughly 12 or something communities—they're all connected by highway now to Goose Bay. So, they've adapted by driving to Goose Bay, then going to Walmart and going to the big Co-op and getting those other food because … they can't afford to buy at NorthMart in Cartwright. So, we've learned to adapt, but the building of roads access … the development of that highway is how we've adapted, and now there's advocacy and I guess a lobby effort by politicians and by the communities on the north coast—the six communities including the First Nation community Reserve of Natuashish, to have a road built to the north coast. (C07, October 15, 2021)*

1.4 HOUSEHOLD AND COMMUNITY INFRASTRUCTURE

1.4.1 Observed impacts of permafrost thaw

The depth of permafrost is changing:

> *And Elders have noticed that the permafrost is going deeper and deeper down, and we also start noticing that as well. And so, at this time—for the past 15 to 18 years, the permafrost have been going down rapidly, and before it would be only about anywhere from a foot to 18 inches from above the ground, but amongst—because different layers of permafrost, the depth is in different—the depths are very different in different terrains of the land. Like in the gravel area, it may be about three to—anywhere from a foot to 18 inches at that time, and during that time, where it's mossy, where there's vegetation, the permafrost may be only about six inches to eight inches, and so these aren't very noticeable, and this year, the permafrost is approximately anywhere from three to four feet down on the gravel area. And the permafrost in the vegetative area or the swamps or where there's a lot of moss is about approximately anywhere from a foot to two and a half feet. (C03, September 28, 2021)*

Building foundations are shifting and creating impacts:

> *Because I remember back in 1960 … all the buildings were put on gravel pads, and the gravel pads were meant for the permafrost. It would rise up so it would become a permanent foundation for the buildings. And all the—in 1962, when the first matchbox houses that came in to Igloolik for the Inuit, they also put in—put them into gravel pads, and so the permafrost would raise and make it stable. One thing that they didn't know about during those time is that the climate will change, and the permafrost would change. And so, when the pads, gravel pad, start shifting, the building itself start shifting and there would be cracks and broken windows and cracks along the walls and start losing a lot of heat during*

> *the winter months and becomes very drafty. And then back in 1980s, early—mid-80s, piles were driven, and these were extremely new. And each pile would be driven into the ground approximately anywhere from ten feet to 16 feet into the ground, passing the permafrost, or going directly into the permafrost, but also into the bedrock. And the bedrock of Igloolik is nothing but pure limestone. And so, even though the Canadian Shield is very close to the island of Igloolik, we're—we don't have that. We just have the limestone bedrocks, which is pretty stable, but over time, over centuries, it changes. (C03, September 28, 2021)*

> *Yeah, we're getting a lot of slumping and it's affecting, just where we travel and, like the house I live in—I own my own home, and I can tell when the frost heaving is, when it starts to get warm my—I'm on pads so I'm not on pilings like a lot of the people in, homeowners in Inuvik, so I can actually feel when my house is unlevel, just due to the frost heaving.... In the summer it's most notable, it's when it starts to thaw and warm up, it actually makes the house a little unlevel, doors don't close properly.... [starting in] May and June, depending on how warm the spring is.... And it, once it starts getting closer to October/November it'll, the ground will stiffen up, and my house will almost become level again.... [When the ground underneath the pad thaws] Yeah, it's the—we call it frost heaving. … The permafrost is getting softer, and you know, it's like ice melting, and then the ground is shifting, it's basically moving.... [Interviewer: When it refreezes in October/November the house re-levels itself?] Yeah, yeah, yes it does... (C04, September 29, 2021)*

> *The building are reconstructed back in 1986—'86—'87, and they were—they had double walls.… We built a house last year—two years ago—I was in a work with the housing project here and then where the basement had a little bit of permafrost in it. We had to take seven feet to get rid of the permafrost and we built it back up ... It was kind of amazing how much the permafrost … how much it bulged back up.... Like, what happens with permafrost is that over time, it really gets squished with pressure.... The peat's just made out of dead leaves, grass, and the further you go the more it's squished though. So, when you disturb that, it becomes like a sponge when you put wet water on it. It really drags up, it just bulges up, and that's what happened to this location, and that's what happens to a lot of places.… I know that when we used to live in Winisk, where there was no—there was no permafrost, it was all mud—clay and that would move all the time. It would just—you had to keep moving your foundation. There was mold … it's a lot of moisture … and that happens like all summer long. (C02, September 28, 2021)*

Homeowners pay for the cost of re-levelling:

> *[Interviewer: Yeah. Well so then those costs, I mean those really are being borne by homeowners like yourself, it's not something that, you know, insurance would pay for, or the city pays for, it's—] C04: No, nope. It'd be all on the homeowner.... It's, a lot of the infrastructure now are being built on metal pilings.... With jacks already built into the piling so you can actually level.... And I mean myself, I prefer to be on the way I'm currently built right now, I'm on pads. For me that would be a lot easier to work with, I can level it with a hydraulic jack in some time.... Yeah, as homeowners, it'd be just adding cost. And not only that, buildings are shifting, like my parents are in what they call public housing 'cause they're both retired.... And you can see actually shifting in their home, in the unit that they are, it's cracked drywall.... And that's from the shifting of the building that they are in.... So if they were homeowners, the onus would be on them to do the repairs and that's just added cost as a homeowner from frost heaving.... (C04, September 29, 2021)*

Permafrost thaw means houses have to be re-levelled frequently, but government subsidies to support costs of re-levelling may not be available:

> *And my house has been levelled a lot of times—every—every year maybe, you know?... And also, like, there's a program with the Northwest Territories Housing. Sometimes they were—they were kind of behind, and they were delivering the programs … where work needs to be done doesn't seem to be happening.… It seems to be changed and program's deadlines and you're not qualified for that because of your—your income is high and things like that.... Over the years … all kinds of programs and sometimes they do change their program. Many years ago, they had their different, you know, like one program that … they can help with people with building material, materials, and everything that's required, and once that individual lives in there for five years, yeah, they can take no billing to that individual.... I had it once. So, that was way back many years ago.... So, now it's something different. The program's not there anymore. And what they have … rental agreements to individuals, so in terms of maintenance, I don't know … who takes after responsibilities.... But, in my case, I have to, you know, to find a way to get some kind of help to try to help me ... some that don't have insurance on their—on their house either, you know, so it's another—another problem there.… (C05, October 5, 2021)*

Shifting foundations impact fuel lines and how the house hooks into networked community infrastructure:

> *My biggest concern is our fuel tank. So, every single house here has a fuel tank that has probably—I don't know how big the tanks are—maybe a hundred, a hundred-gallon tanks possibly. And at any given point, that's full of diesel. And so, I have a few friends where their—so there's the diesel tank. And then, of*

course, the pipe attaching it to the house. But there needs to be a flex line within that, within that pipe to adjust for any sort of, what you call it if there should be any shifting. And some of those flex lines are, you know, there might be only six to 12 inches long. But the way the regulations are going now are, the way they should go, is I think the, that should be much longer ... And so, I've had friends that, where that flex line has either broken or something not related is that the water trap was not cleaned properly and it had expanded and froze, expanded, expanded and melted, like expanded when it froze and then melted during the day when it's warm and then refreeze and then the whole pipe busts.... And then you spills on your property, and if your tank is full, you're talking about between a forty- and eighty-thousand dollar environmental cleanup cost.... Yeah. He had to remortgage his house because of that. And that particular one actually was because of that, the water trap broke. So, you know, nothing really to do with permafrost, but in the same breath, you know it could, you know, the flex line is I've seen just walking and seen some of these flex lines that are just flexed to the limit. (C01, September 27, 2021)

So, I mean all those things around construction has changed … You know, the way we lay cement on the north coast now, there's better cement, right?… It's better. It cures faster. One time, you couldn't lay asphalt and cement if you continuously at zero below degrees. It had to be at least five degrees Celsius on a continuous basis.… And now, I mean, like I said, there's a drop down to minus two or something last night, but they're still laying asphalt today.… The construction, environment, or the changing environment is actually having an impact on how we schedule construction. (C07, October 15, 2021)

Buildings on the north coast, you know, again, I said the window for opportunity for construction is longer, shipping is longer, but the actual construction of the building itself is not like it used to be. I mean, before you had jack hammer every day because of ice—of permafrost was so thick and so hard. Now they tell me, the people that are in this business—the construction business—that's not the case anymore.… Like it's—there's less permafrost, less hard ice, and the ice is not so hard as it once was, and that permafrost layer is diminishing. So, they don't have the work—bottom line is they don't have to work so hard. (C07, October 15, 2021)

We get a lot more snow and less ground frost. So is that—you know, is that having an effect on it? I don't know, but I can tell you, even in the last 20 years, even in Goose Bay, and we're central Labrador … totally different environment than on the coast, and it's having a tremendous effect on construction and some contractors. They think it's great because they can get building earlier, 'cause summers and springs come faster and falls come later. I mean, this is October what, 15th, and they're still laying cement out there. (C07, October 15, 2021)

1.4.2 Projected change and anticipated future impacts

Seasonal info about the land should be available to community when trying to adapt to changing permafrost conditions:

> *Well, that's [permafrost thaw] definitely it has to do with climate changes. … And it has to do with the—the impacts of the weather changes and also the, you know, the—when looking at the, you know, the—wanted to—kind of look at the—for example, like the land in different seasons. It's … really warm weather and all that affects the, you know, the ground and the frost for the permafrost and again, would a person build … in there or … you need to have good information available, you know, for that…. All that is good information to have—we're going to have with the good local government, yeah. So they would have—they could have information available for the people…. For example, let's say if I wanted to build a cabin, not necessarily, you know—you could be in the community or in—across the lake or other places, things like that, what should I be looking for—the area—the land—and all that. (C05, October 5, 2021)*

Permafrost thaw is affecting communal infrastructure within the community:

> *Absolutely. Right now, our hospital is growing a pingo under it, from what I understand…. So where they built the hospital was the old site of the older hospital that was here…. And it was on wooden pilings. And from what I understand, I don't think they removed the pilings that were there, they just cut the top of the timber off…. And from what I understand, like I said there's frost heaving, so it's pushing up the pilings from the older hospital into the new hospital…. So, it's making things a little hard to deal with, I guess, at the hospital for, like I said there's—I don't know what it's called, I call it frost heaving…. (C04, September 29, 2021)*