# TECHNICAL SUPPORTING DOCUMENT

Mary River Project | Phase 2 Proposal | FEIS Addendum | August 2018

## TSD 06

## Climate Change Assessment





# CLIMATE CHANGE TECHNICAL SUPPORTING DOCUMENT SUMMARY

The Climate Change Technical Supporting Document provides an assessment of the Phase 2 Proposal's effects on climate change including meteorology and climate and includes new information collected or published since submission of materials for the Approved Project. The Phase 2 Proposal builds on the extensive baseline studies and assessment carried out since 2011 for the larger Approved Project and is thus closely linked to the FEIS and previous addendums.

GHGs include carbon dioxide and other gases that act to trap heat within the earth's atmosphere, thereby changing the climate over the long term. Releases of GHG emissions associated with the Project are mainly from combustion of diesel fuel for construction, operation, and transportation purposes. Shipping ore to market will result in emissions of GHG due to fuel combustion. In addition, construction and operation activities will cause disturbances of the underlying permafrost, which may lead to GHG releases mostly in the form of methane.

Releases of GHGs from the Project will approximately double Nunavut's GHG emissions as it has a small population and manufacturing base, however, these are anticipated to be small in comparison on Canadian totals. GHG releases will not have a measurable effect on global climate change. The project itself will not cause measurable effects related to climate change and has taken into consideration current climate change scenarios and local risks and vulnerabilities in development of the project.

Based on the present assessment and planned mitigation, Project activities proposed as part of the Phase 2 Proposal are not predicted to result in significant adverse residual effects on climate change.

# RÉSUMÉ DE LA DOCUMENTATION TECHNIQUE COMPLÉMENTAIRE SUR LES CHANGEMENTS CLIMATIQUES

La documentation technique complémentaire sur les changements climatiques comporte une évaluation des effets de la proposition de la phase 2 sur les changements climatiques, y compris la météorologie et le climat, et comprend de nouveaux renseignements recueillis ou publiés depuis la soumission des documents pour le projet approuvé. La proposition de la phase 2 est fondée sur les études préliminaires et les évaluations complètes réalisées depuis 2011 pour l'ensemble du projet approuvé et est donc étroitement à l'énoncé des incidences environnementales (EIE) et aux addendas précédents.

Les GES comprennent le dioxyde de carbone et d'autres gaz qui agissent pour piéger la chaleur dans l'atmosphère terrestre, modifiant ainsi le climat à long terme. Les rejets d'émissions de GES associés au projet proviennent principalement de la combustion du carburant diesel à des fins de construction, d'exploitation et de transport. L'acheminement du minerai exploité vers le marché entraînera des émissions de GES attribuables à la combustion du carburant. De plus, les activités de construction et d'exploitation causeront des perturbations du pergélisol sous-jacent, ce qui pourrait entraîner des rejets de GES, principalement sous forme de méthane.

Les rejets de gaz à effet de serre du projet doubleront approximativement les émissions de GES du Nunavut, car sa population et sa base manufacturière sont peu importantes; toutefois, on s'attend à ce que ces rejets soient faibles par rapport aux totaux canadiens. Les rejets de gaz à effet de serre n'auront pas d'effet mesurable sur les changements climatiques mondiaux. Le projet lui-même ne provoquera pas d'effets mesurables liés au changement climatique et a pris en considération les scénarios actuels de changement climatique et les risques et vulnérabilités au niveau local dans le développement du projet.

Selon la présente évaluation et les mesures d'atténuation prévues, les activités du projet proposées dans le cadre de la proposition de la phase 2 ne devraient pas entraîner d'effets résiduels négatifs importants sur les changements climatiques.

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ᐅᖅᑰᓯᓇᖅᑐᑦ ᐳᓪᓚᐅᔭᑦ GHG ᐃᓚᕐᑲᖅᑐᑦ ᓯᓚᒻᒧᑦ ᐊᓂᖅᓵᓲᕗᑦ ᐸᐅᖅ ᐊᒻᒪᓗ ᐊᓯᖏᑦ ᐳᓪᓚᐅᔭᑦ ᐅᖅᑰᓯᑎᑦᑎᓲᑦ ᓄᓇᕐᔪᐊᑉ ᓄᕙᔭᕐᑲᕝᕕᖓᓐᓂᒃ, ᕿᐱᒃᑐᑎᑐᑦ ᐊᓯᔾᔩᓪᓗᑎᒃ ᓯᓚᖓᓐᓂᒃ ᐊᕋᒍᓕᓴᓗᒃᑯᑦ. ᐃᓱᐊᕐᑭᓂᖏᑦ ᐳᓪᓚᐅᔭᓂᒃ GHG ᐊᒃᑐᐊᓂᓪᓚᑦ ᐅᓯᕋᓂᐊᖅᑐᒧᑦ ᑕᑯᔅᓴᕈᓪᓗᐊᑕᓱᑦ ᐃᑯᐊᓪᓚᒍᑖᑕ ᐃᒪᓯᐅᑎᐅᑉ ᓴᓇᕙᓪᓕᐊᔪᓄᑦ, ᐊᐅᓚᑕᐅᔪᓄᑦ, ᐊᒻᒪᓗ ᐅᓯᒃᑲᖅᑕᐃᓂᕐᒧᑦ ᑐᕋᖓᔪᒃᑯᑦ. ᐅᓯᒃᑲᖅᑕᐃᓂᖅ ᓴᕙᕋᔭᒃᓴᓂᒃ ᓂᐅᕙᕋᖅᑎᓄᑦ ᓴᖅᑮᓂᐅᓴᑐᐃᓐᓇᕐᒪᑦ ᐃᓱᐊᕐᑭᔪᓂᒃ ᐳᓪᓚᐅᔭᓂᒃ GHG ᐱᓪᓗᒍ ᐅᖅᓯᐊᓗᖓᑦ ᐊᐅᓚᔾᔪᑎᖃᒧᑦ. ᖃᒃᑲᓐᓂᐊᒍᑦ, ᓴᓇᕚᓪᓚᐋᑦ ᐊᐅᓚᑕᕗᓪᓗ ᐱᓕᕆᓂᐅᓰᑦ ᐃᓚᖃᓪᓗᑎᒃ ᐸᒡᕙᓴᐃᓂᕐᒥᒃ ᓄᓇᐅᑉ ᖁᐊᖑᐃᓐᓇᓯᐅᑉ ᐃᑭᐊᖓᓃᑦᑐᒥᒃ, ᓴᖅᑮᒃᑲᓐᓂᓰᖅ ᐊᓂᐊᔭᓂᒃ ᐳᓪᓚᐅᔭᓂᒃ GHG ᓴᖅᑭᕙᔨᓛᖑᔭᖅ ᑕᒪᓐᓇ ᓂᓕᖅᑕᐅᔭᑐᑦ ᑎᐱᓕᒃ ᐱᕈᖅᑐᕙᓂᕐᒦᙵᖅᑐᖅ.

ᐃᓯᐊᕐᑭᓂᖏᑦ ᐳᓪᓚᐅᔭᓂᒃ GHG ᐅᓯᕋᓐᓂᐊᖅᑐᓂᒃ ᓇᓚᐅᑦᑖᕙᒃᑯᑦ ᓄᓇᕘᑉ ᐊᓂᐊᓲᖏᓐᓂᒃ ᐳᓪᓚᐅᔭᓂᒃ GHG ᐱᕈᓪᓗᓂ ᒪᕿᐃᓪᓗᐋᓪᓗᒍ ᐊᑐᓲᖓᑕ ᐃᓄᑭᓗᐊᕐᓂᖓᓄᑦ ᓴᓇᔪᓕᕆᓂᒃᑯᓪᓗ ᓂᐅᕿᑎᒃᓴᓂᒃ ᑐᙵᕝᕙᖅᑲᕆᓪᓚᑕ, ᑭᓯᐊᓂᓕ, ᑕᒪᒃᑯᐊ ᑕᑯᓪᓗᑦ ᑲᓇᑕᓕᒫᖅ ᐃᓗᐊᒍᑦ ᒥᑭᑦᑑᔩᓚᓗᐊᑦ ᓴᓂᕌᒍᑦ. GHG ᐃᓯᐊᕐᑭᓂᖏᑦ ᐳᓪᓚᐅᔭᓂᒃ ᐊᒃᑐᐃᓂᖅᑲᕋᔭᕆᑦᑐᖅ ᓇᐋᓴᐅᑎᓕᖅᑕᐅᔭᓇᙱᑦᑐᖅ ᓄᓇᔾᔭᐊᑉ ᓯᓚᖓᑕ ᐊᔾᔨᒋᐊᓐᓃᓐᓂᐊᓄᑦ. ᐅᓯᕋᓐᓂᐊᖅᑐᑦ ᓴᖅᑮᓕᔭᕋᑎᒃ ᓇᓗᓇᐃᖅᓯᒪᔪᒃᑯᑦ ᐊᒃᑐᐃᓂᖃᐅᓯᓂᒃ ᐊᒃᑐᐊᔪᑦ ᓯᓚᐅᑉ ᐊᔾᔨᒋᐊᓐᓃᓐᓂᖓᓄᑦ ᐃᓱᒪᓕᐊᓇᔭᐅᖃᓯᐅᑎᓯᒪᓪᓗᑎᒃ ᓇᓚᐅᑦᑖᓗᓇᔾᔪᑦ ᐅᓪᓗᒥ ᓯᓚᖓᓄᑦ ᑕᐅᑐᙳᐊᕈᑎᒧᑦ ᖃᓄᖅᑐ ᓄᓇᓕᐅᑉ ᐊᕙᑖᒍᑦ ᐅᓗᓈᕈᓇᖅᑐᑦ ᓴᙾᓐᓂᐅᔪᓪᓗ ᓴᓇᔭᐅᕙᓪᓕᐊᓂᖓᓄᑦ ᐃᓚᒋᐊᕈᑖ.

ᑐᙵᓪᓗᓂ ᐅᓪᓗᒥ ᕿᒥᕐᕈᐃᓂᐅᔪᒧᑦ ᐸᕐᓈᙳᔪᓄᓪᓗ ᓄᖅᑲᖓᑎᑦᑎᔾᔪᑎᒃᓴᓄᑦ, ᐅᓯᕋᓐᓂᐊᖅᑐᑦ ᐱᓕᕆᓂᖏᑦ ᐊᑐᖅᑕᐅᔪᒪᔪᑦ ᐃᓚᒋᔭᐅᔪᑦ ᑖᔅᓱᒪ ᐱᓕᕆᐊᒃ ᒪᕈᑎᓕᖅᑕᖓᓄᑦ ᐆᒃᑑᑎᖓᒍᑦ ᓇᓚᐅᑦᑖᖅᑕᐅᓯᒪᖏᑦᑐᑦ ᓴᖅᑮᓕᔭᓐᓂᕐᒥᒃ ᐊᖏᔪᒥᒃ ᐱᐅᙱᑦᑐᒥᒃ ᐊᒃᑐᐃᓂᕐᒥᒃ ᓯᓚᐅᑉ ᐊᔾᔨᒋᐊᓐᓃᓐᓂᖏᓄᑦ.

# TSD 06 Climate Change Assessment
# Phase 2 Proposal – Mary River Project

Baffinland Iron Mines Corporation
Mary River Project
NIRB File No. 08MN053

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# ABBREVIATIONS

| | |
|---|---|
| Mary River Project | the Project |
| ALT | active layer thickness |
| AMJJAS | Average of the months of April, May, June, July, August and September |
| Baffinland | Baffinland Iron Mines Corporation |
| CEAA | Canadian Environmental Assessment Agency |
| CEPA | Canadian Environmental Protection Act |
| CFS | Canadian Forces Station |
| CMIP5 | Coupled Model Intercomparison Project Phase 5 |
| DFO | Fisheries and Oceans Canada |
| DOE | Department of Environment |
| DWT | deadweight tonnes |
| ECCC | Environment and Climate Change Canada |
| EF | emission factor |
| ERP | Early Revenue Phase |
| FAO | Food and Agriculture Organization of the United Nations |
| FEIS | Final Environmental Impact Statement |
| GCM | Global Climate Model |
| GHG | Greenhouse Gas |
| GN | Government of Nunavut |
| GPS | Global Positioning System |
| GTNP | Global Terrestrial Network for Permafrost |
| GWP | Global Warming Potential |
| HFO | heavy fuel oil |
| IAMs | Integrated Assessment Models |
| IOC | Iron Ore Company of Canada |
| IPCC | Intergovernmental Panel on Climate Change |
| ITK | Inuit Tapiriit Kanatami |
| MAC | Mining Association of Canada |
| Mt | Million tonnes |
| NAG | non-acid generating |
| NIRB | Nunavut Impact Review Board |
| NOAA | National Oceanic and Atmospheric Administration |
| NRC | National Research Council |
| ONDJFM | the average of the months of October, November, December, January, February and March |
| PAG | potentially acid-generating |
| PC | Project Certificate |
| PUFAs | polyunsaturated fatty acids |
| RCPs | Representative Concentration Pathway Scenarios |
| RWDI | RWDI AIR Inc. |
| SD | Sustainable Development |
| SOC | Soil Organic Carbon Content |

SRES ........ Special Report on Emissions Scenarios
SSTs ........ sea surface temperatures
TAE ........ Total annual emissions
TRU ........ Thompson Rivers University
TSM ........ Towards Sustainable Mining
UNDRIP ........ United Nations Declaration on the Rights of Indigenous Peoples
WISE ........ Waterloo Institute of Sustainable Energy

# 1 INTRODUCTION

## 1.1 Background

The Mary River Project is an operating iron ore mine located in the Qikiqtani Region of Nunavut. Baffinland Iron Mines Corporation (Baffinland; the Proponent) is the owner and operator of the Project. As part of the regulatory approval process, Baffinland submitted a Final Environmental Impact Statement (FEIS) to the Nunavut Impact Review Board (NIRB), which presented in-depth analyses and evaluation of potential environmental and socioeconomic effects associated with the Project.

In 2012, NIRB issued Project Certificate No 005 which provided approval for Baffinland to mine 18 million tonnes per annum (Mtpa) of iron ore, construct a railway to transport the ore south to a port at Steensby Inlet which operates year-round, and to ship the ore to market. The Project Certificate was subsequently amended to include the mining of an additional 4.2 Mtpa of ore, trucking this amount of ore by an existing road (the Tote Road) north to an existing port at Milne Inlet, and shipping the ore to market during the open water season. The total approved iron ore production was increased to 22.2 Mtpa (4.2 Mtpa transported by road to Milne Port, and 18 Mtpa transported by rail to Steensby Port). This is now considered the Approved Project. The 18 Mtpa Steensby rail project has not yet been constructed, however 4.2 MTPA of iron ore is being transported north by road to Milne Port currently. Baffinland recently submitted a request for a second amendment to Project Certificate No.005 to allow for a short-term increase in production and transport of ore via road through Milne Port from the current 4.2 Mtpa to 6.0 Mtpa.

The Phase 2 Proposal involves increasing the quantity of ore shipped through Milne Port to 12 Mtpa, via the construction of a new railway running parallel to the existing Tote Road (called the North Railway). The total mine production will increase to 30 Mtpa with 12 Mtpa being transported via the North Railway to Milne Port and 18 Mtpa transported via the South Railway to Steensby Port. Construction on the North Railway is planned to begin in late 2019. Completion of construction of the North Railway is expected by 2020 with transportation of ore to Milne Port by trucks and railway ramping up as mine production increases to 12 Mtpa by 2020. Shipping from Milne Port will also increase to 12 Mtpa by 2020. Construction of the South Railway and Steensby Port will commence in 2021 with commissioning and a gradual increase in mine production to 30 Mtpa by 2024. Shipping of 18 Mtpa from Steensby Port will begin in 2025.

Phase 2 also involves the development of additional infrastructure at Milne Port, including a second ore dock. Shipping at Milne Port will continue to occur during the open water season and may extend into the shoulder periods when the landfast ice is not being used to support travel and harvesting by Inuit. Various upgrades and additional infrastructure will also be required at the Mine Site and along both the north and south transportation corridors to support the increase in production and construction of the two rail lines.

The Project is expected to be multi-generational, and therefore the Project may experience climate-related effects over the duration of the Phase 2 Proposal and any subsequent project phases. Adaptation to a changing climate is therefore a key component of Project execution. To appropriately address climate change and provide a thoughtful action plan, Baffinland has assessed its potential to contribute to climate change, as well as how the Project may be affected by a changing climate in the arctic.

The climate is changing at an accelerated rate - in Canada and throughout the World (Bush et al. 2014; Warren and Lemmen 2014; IPCC 2014a). There is evidence to suggest that the accelerated rate has been induced by human activity (IPCC 2014a). Climate models suggest that Canada's northern coast will experience some of the most pronounced changes, as much of the landforms (sea ice, freshwater lakes and rivers, ice, snow cover, glaciers, ice caps, ice sheets and permafrost) are highly climate sensitive (Bush et al. 2014, Ford et al. 2016). Collaboration and adaptive management are approaches that governments and industry are increasingly pursuing to allow for adaptation to the effects of rapid climate change (Warren and Lemmen 2014).

## 1.2 Scope of this Report

This Climate Change Assessment involves three main components:

1. **Emissions Forecast -** A Greenhouse Gas (GHG) emissions estimate for the Phase 2 Proposal (Section 2).
2. **Assessment -** An assessment of the climate change likely to be experienced by the Project and the North Baffin Region (Section 3).
3. **Regulatory and Technical Considerations –** A description of climate change legislation and Project Certificate conditions related to climate change, and how Baffinland is meeting these requirements and addressing climate change in its Project planning (Section 4).

## 1.3 Acknowledgements

Baffinland would like to acknowledge the assistance of a number of contributors to this document:

- Knight Piésold Ltd. - Overall coordination and final review and editing of the document; preparation of the climate change effects assessment on the physical environment and to Inuit in Section 3; and preparation of Section 4.
- RWDI AIR Ltd. - Preparation of the GHG emissions estimate and the core components of the climate change assessment presented in Section 3.
- Golder Associates Ltd. - Preparation of the climate change effects assessment on the marine environment presented in Section 3.

# 2 PHASE 2 PROPOSAL GHG EMISSIONS FORECAST

## 2.1 Methods

### 2.1.1 Emissions Factors

Greenhouse gases include carbon dioxide ($CO_2$) and other gases that act to trap heat within the earth's atmosphere, thereby changing the climate over the long term.

Greenhouse gas emissions from diesel combustion comprise $CO_2$, methane ($CH_4$), and nitrous oxide ($N_2O$). They were calculated by multiplying the estimated annual fuel needs by the associated emission factor for diesel or aviation fuel combustion. Emissions factors are taken from Environment and Climate Change Canada's (ECCC's) National Inventory Report for GHG (ECCC 2018c), presented in Table 2.1.

**Table 2.1 Emission Factors for Fuel Combustion**

| Fuel Type | Emission Factors (g/L) | | |
|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ |
| Diesel Train and Truck[2] | 2,681 | 0.15 | 1.0 |
| Diesel Ship | 2,681 | 0.25 | 0.072 |
| Heavy Fuel Oil Ship | 3,156 | 0.29 | 0.082 |
| Aviation Fuel | 2,365 | 2.2 | 0.23 |

NOTES:
1. Source: Table A6-12 of ECCC 2018c.
2. $N_2O$ emission factor for uncontrolled heavy-duty diesel vehicles is 0.075 g/L but assumed to be equal to diesel train emission factor of 1.0 g/L.

Emissions of individual gases are expressed in $CO_2$ equivalent ($CO_2e$) using Global Warming Potential (GWP) values for each gas for a 100-year reference period. GWP values compare the integrated radiative forcing over a specified period of time for each GHG. By definition, the GWP of $CO_2$ is 1. The GWP of $CH_4$ and $N_2O$ are taken based on guidance by ECCC (2017a). In the context of the Mary River Project, other GHGs (i.e., water vapour, ozone) can be neglected. The GWP values used in this report are provided in Table 2.2.

**Table 2.2 Global Warming Potentials**

| | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|
| **100-year Global Warming Potential** | 1 | 25 | 298 |

NOTES:
Source: ECCC (2017a).

### 2.1.2 Sources of GHG Emissions

GHG emissions are categorized under one of three types as follows (World Resources Institute and World Business Council for Sustainable Development 2017; Mining Association of Canada (MAC) 2014:

- **Scope 1 Emissions -** Direct GHG emissions from sources that are owned or controlled by the emitter.
- **Scope 2 Emissions –** Indirect GHG emissions from consumption of purchased electricity, heat or steam.
- **Scope 3 Emissions –** Other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the emitter, electricity-related activities (e.g. transmission and distribution line losses) not covered in Scope 2, outsourced activities, waste disposal, etc.

Scope 1 Emissions are generated at the Mary River Project from the following activities/sources:

- All onsite arctic diesel fuel consumption (used to operate mobile equipment and power generators);
- Marine diesel used by tugs at both ports and ice management vessels at Steensby Port; and

- Releases of methane ($CH_4$) from disturbances to permafrost that occur mainly during construction, which can result in the release of $CH_4$ bubbles and an increased exposure of the organic matter stored in permafrost to microbial activities, leading to GHG emissions mostly in the form of $CH_4$ under anoxic conditions.

Scope 2 Emissions (indirect emissions) are the result of company activities but occur at sources not controlled or owned by the company. This includes energy purchases from a local utility. There is no local utility from which Baffinland can purchase electricity, and therefore the Project does not and will not generate any Scope 2 Emissions.

Scope 3 Emissions are those resulting from other indirect emissions resulting from the Project but by others. In the context of the Mary River Project, this includes fuel consumption associated with the following transportation-related activities:

- Ore carriers that ship iron ore to market;
- Sealift delivery of materials and fuel; and
- Air transport of workers and supplies.

The estimation approaches for the applicable sources of Scope 1 and Scope 3 Emissions are presented in Sections 2.1.3 to 2.1.5.

### 2.1.3 On-site Fuel Combustion Generating Scope 1 Emissions

As noted above, relevant Scope 1 Emissions from the Project occur from the combustion of onsite arctic diesel associated with mobile equipment and stationary sources (i.e., on-site diesel power generation), as well as marine diesel fuels used to power support vessels at the two port sites. Table 2.3 identifies the relevant Project activities and arctic and marine diesel fuel consumption by year. Quantities presented for the period of 2013 to 2017 are actual volumes, and 2018 onward are forecasted volumes.

**Table 2.3 Estimated On-Site Fuel Consumption and Anticipated Project Activities**

| Year | Project Phase | | | | | | | Arctic Diesel (ML) | Marine Diesel (ML) |
|---|---|---|---|---|---|---|---|---|---|
| | Construct ERP | Operate ERP | Construct 12 Mtpa | Operate 12 Mtpa | Construct 18 Mtpa | Operate 18 Mtpa | Closure | | |
| 2013 | X | | | | | | | 6.77 | 0 |
| 2014 | X | | | | | | | 22.9 | 0 |
| 2015 | | X | | | | | | 30.6 | 0.2 |
| 2016 | | X | | | | | | 38.0 | 0.2 |
| 2017 | | X | | | | | | 43.6 | 0.2 |
| 2018 | | X | | | | | | 57.5 | 0.2 |
| 2019 | | X | X | | | | | 51.0 | 0.2 |
| 2020 | | X | X | | | | | 56.0 | 0.2 |
| 2021 | | | | X | X | | | 146 | 0.2 |
| 2022 | | | | X | X | | | 116 | 0.2 |
| 2023 | | | | X | X | | | 118 | 0.2 |
| 2024 | | | | X | X | | | 171 | 0.2 |
| 2025 | | | | X | | X | | 266 | 50.2 |
| 2026 | | | | X | | X | | 273 | 50.2 |

**Table 2.3 Estimated On-Site Fuel Consumption and Anticipated Project Activities**

| Year | Project Phase | | | | | | | Arctic Diesel (ML) | Marine Diesel (ML) |
|---|---|---|---|---|---|---|---|---|---|
| | Construct ERP | Operate ERP | Construct 12 Mtpa | Operate 12 Mtpa | Construct 18 Mtpa | Operate 18 Mtpa | Closure | | |
| 2027 | | | | X | | X | | 273 | 50.2 |
| 2028 | | | | X | | X | | 277 | 50.2 |
| 2029 | | | | X | | X | | 285 | 50.2 |
| 2030 | | | | X | | X | | 286 | 50.2 |
| 2031 | | | | X | | X | | 269 | 50.2 |
| 2032 | | | | X | | X | | 259 | 50.2 |
| 2033 | | | | X | | X | | 238 | 50.2 |
| 2034 | | | | X | | X | | 227 | 50.2 |
| 2035 | | | | X | | X | | 228 | 50.2 |
| 2036 | | | | | | | X | 30 | 0 |
| 2037 | | | | | | | X | 30 | 0 |
| 2038 | | | | | | | X | 20 | 0 |
| **Total** | | | | | | | | **3,827** | **554** |

### 2.1.4 Permafrost Disturbances Generating Scope 1 Emissions

Permafrost is defined as soil, rock, or sediment that is frozen for two or more consecutive years. Permafrost can be exposed or covered with a thin active layer of 30 to 200 cm (the top layer that is subject to annual cycles of thawing and freezing). Currently, permafrost occurs in as much as 25% of the exposed land surface in the northern hemisphere. However, increasing global temperatures have resulted in reduced permafrost worldwide.

Thawing of permafrost can accelerate global warming by releasing trapped GHGs and exposing the organic matter stored in permafrost to micro-organisms, which release $CO_2$ and $CH_4$. $CH_4$ is of most interest because it has a much higher GWP than $CO_2$ (Table 2.2). The quantity of $CO_2$ and $CH_4$ potentially released from the soil is a function of both the amount of organic carbon in the soil and the amount of microbial activity that occurs to convert organic matter to methane. The magnitude and timing of the effects on climate change from permafrost degradation remain ongoing research topics due to the complexity and difficulty in gathering data (Schuur and Abbott 2011). The Global Terrestrial Network for Permafrost (GTNP 2017) has been established to organize and manage monitoring data on permafrost, including the circumpolar active layer and the thermal state of permafrost. To date, the understanding of carbon content and potential emissions due to degradation of permafrost remains incomplete.

Mechanical disturbance of permafrost by mining activities at the Project can affect the permafrost carbon cycle and cause additional GHG emissions. A previous estimate of GHG emissions released from permafrost disturbances was prepared for the Approved Project (RWDI AIR Inc. 2010a). That assessment was prepared based on the professional judgement of the assessment team as to the organic content of the soil in the Project area. Background information and particular challenges in estimating GHG emissions from permafrost disturbances were discussed in detail in that report.

This updated estimate of GHG emissions from permafrost disturbance incorporates the addition of the North Railway, as well as site-specific data on the organic content of soils in the Project area. Veldhuis (2010) conducted a soil study for the Project which generated data on the organic matter (OM) content of soils in the Project area. Table 2.4 presents the approach used to derive a soil organic carbon (SOC) value from the organic matter data in the Veldhuis study. The average organic matter values for each soil type was converted to average organic carbon values using published conversion factors. Because the proportion of each soil type present at any location is unknown, a weighted average was established based on assumed thicknesses of each soil type in a 1 m soil profile. The weighted values were totaled and converted to a SOC value of 20.6 kg/m$^2$/m (also reported as kg/m$^2$ for the upper 1 m of soil). This SOC value corresponds well with studies by Tarnocai et al. (2009) and Gross et al. (2011).

**Table 2.4 Determination of Organic Carbon in the Soils in the Mary River Study Area**

| Soil Type | Organic Matter (OM; %) | | | | Average Organic Carbon (%) | Assumed Soil Type Thickness (cm) | Weighted Percent (%) | Soil Organic Carbon (kg/m$^2$/m) |
|---|---|---|---|---|---|---|---|---|
| | n | Low | High | Average | | | | |
| A horizon | 10 | 0.17 | 26 | 13.72 | 5.5 | 5 | 0.27 | |
| B horizon | 10 | 0.17 | 2.21 | 0.83 | 0.3 | 31.7 | 0.11 | |
| C horizon | 15 | 0.17 | 0.51 | 0.34 | 0.1 | 31.7 | 0.04 | |
| B+C horizon loamy soil | 15 | 2.38 | 5.44 | 2.81 | 1.1 | 31.7 | 0.36 | |
| | | | | | | | 0.78 | 20.6 |

NOTES:
1. Organic matter data from Veldhuis, 2010.
2. Organic matter (%) was converted to organic carbon (%) using a conversion factor 2.5 applicable to subsoils. From Soil Quality Pty Ltd., 2018.

According to a map in Gross et al. 2011, presented as Figure 2.1, the SOC in the Project area ranges from between 24 kg/m$^2$ in southern areas near Steensby Inlet and 0.2 kg/m$^2$ in northern areas near Milne Inlet. Close to the Mine location, the SOC is around 5-15 kg/m$^2$. In the Mine deposit area, as the soil is mainly mineral and non-organic, the SOC is in the range of 0.2-6 kg/m$^2$.

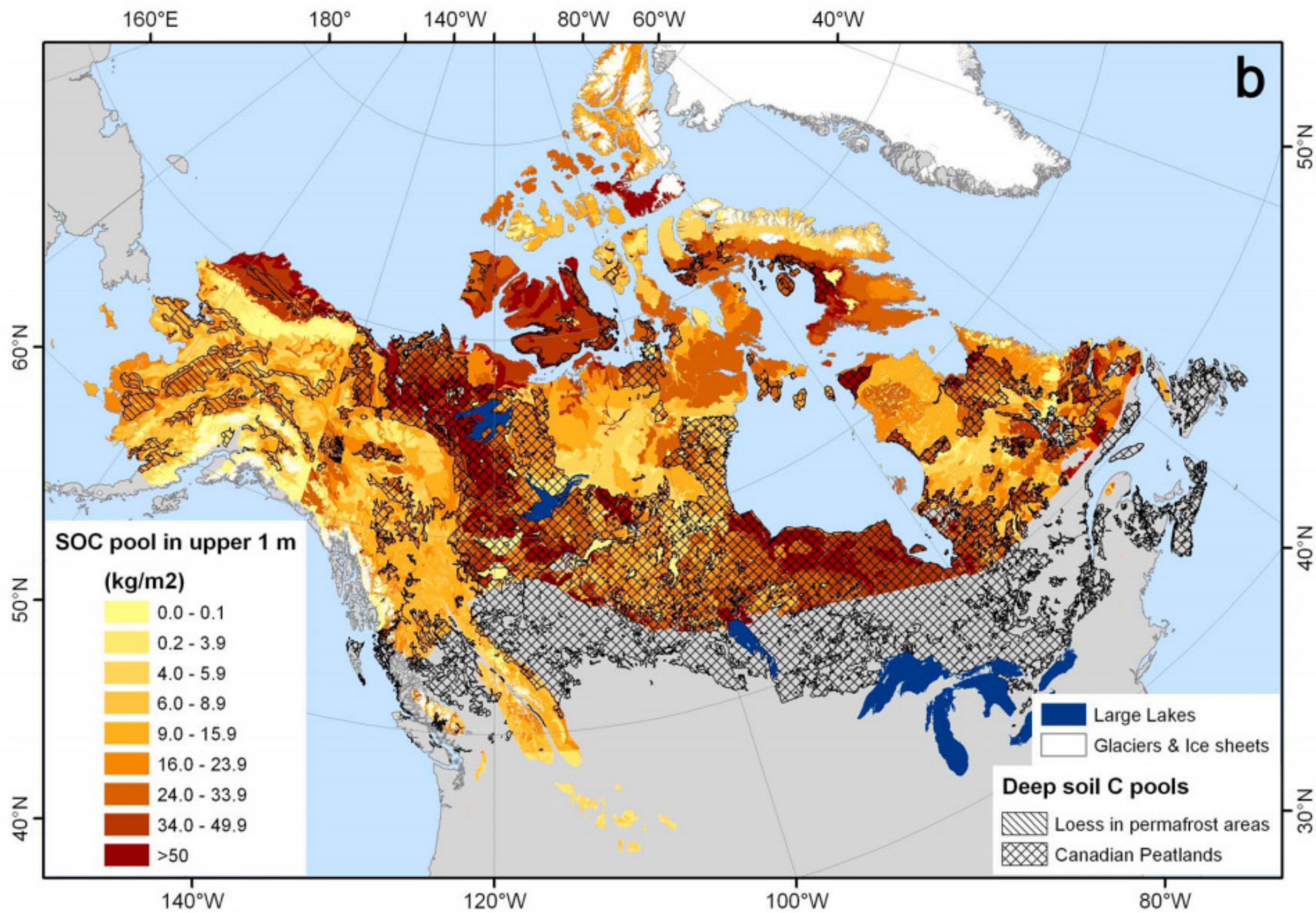



**Figure 2.1 SOC Content in Upper 1 m in Permafrost Regions (from Gross et al., 2011)**

The SOC value of 20.6 kg/$m^2$ was applied to the Project features/areas where permafrost will be disturbed or thawed listed in Table 2.5 to calculate the theoretical maximum amount of $CH_4$ (and $CO_2$e) that could be released from permafrost disturbances (Section 2.2.2).

**Table 2.5 Estimated Permafrost Disturbances**

| Location | Area ($m^2$) | Assumed Thickness (m) | Volume ($m^3$) |
|---|---|---|---|
| **Overburden Excavation** | | | |
| Approved Project borrow areas | n/a | n/a | 80,000 |
| Phase 2 Proposal Rail Sand Pit | n/a | n/a | 80,000 |
| Open Pit overburden stripping[2] | n/a | n/a | 6,132,075 |
| **Overburden Stripping at Development Areas** | | | |
| North Rail Quarries | 5,700,000 | 1.0 | 5,700,000 |
| South Rail Quarries | 2,070,000 | 1.0 | 2,070,000 |
| Soil Spoils from North Rail Construction | n/a | n/a | 650,000 |
| Soil Spoils from South Rail Construction[3] | n/a | n/a | 886,364 |

**Table 2.5 Estimated Permafrost Disturbances**

| Location | Area ($m^2$) | Assumed Thickness (m) | Volume ($m^3$) |
|---|---|---|---|
| Landfill | 76,218 | 4.0 | 304,872 |
| **Total** | | | **15,903,311** |

NOTES:

1. n/a – Not available or not applicable
2. 32.5 Mt of overburden will be stripped from Deposit No. 1 during the life of mine (FEIS Vol. 3, Table 3-3.1). It was assumed that half of the overburden is active layer that does not cause any additional methane release. A specific gravity of 2.65 t/$m^3$ was used to convert from mass in t to volume in $m^3$.
3. Soil spoils from North Rail construction were estimated by Hatch, and soil spoils for the South Railway were estimated by comparing the lengths of the North and South Railways.

### 2.1.5 Transportation Related Activities Generating Scope 3 Emissions

As noted in Section 2.1.2, the Project's Scope 3 Emissions include transportation-related emissions:

- Combustion of heavy fuel oil (HFO) combustion in ore carriers and sealift vessels; and
- Combustion of aviation fuel (Jet A fuel) by aircraft servicing the Project.

Because HFO is not stored at the Project sites, GHG emissions from shipping had to be estimated based on shipping activity information and either fuel consumption rates or emission factors (EF). Two approaches were applied depending on vessel type.

#### *2.1.5.1 Calculation of HFO Consumption by Ore Carriers*

For Panamax and capesize ore carriers, daily fuel consumption and transit times are known (Jared Gardner personal communications). Table 2.6 presents the estimates for the vessel types, including ice classes, routes, and seasons. Total annual emissions (TAE) of GHG from HFO combustion (in t $CO_2e$) were estimated using the equation:

$$TAE = DFC \times TT \times EF \times 2 \times N$$

Here, DFC denotes daily fuel consumption in metric tonnes, TT is transit time per trip in days, EF the GHG emission factor in tonnes $CO_2e$ per tonne of HFO, and N the number of one-way trips.

Transit times were known from 2017 summer shipping, suggesting average travel speeds of approximately 13 knots in open water. While ice breaking, an increase of transit time by a factor of 1.75 was assumed (Baffinland 2017). The corresponding travel speed while shipping through ice of 7 knots is in good agreement with values reported in the scientific literature (e.g. Figure 5.a in Löptien and Axell 2014).

Shipping from Milne Port will occur during ice-free summer months. Shipping from Steensby Port is expected to encounter sea-ice with an extent seasonally varying from no ice coverage for several months in late summer to maximum ice extending from Steensby Port to the edge of the shelf approximately 200 km east of Hudson Strait for several months in late winter (National Snow and Ice Data Centre 2017). To simplify the estimation of GHG emissions, it was assumed that six months per year will require no ice breaking and six months per year will require ice breaking along the full distance from Steensby Port to 200 km east of Hudson Strait, and no ice breaking for the remainder of the route to Rotterdam.

**Table 2.6 Estimated Per Voyage Fuel Consumption by Ore Carriers**

| Vessel Type | Route | One-way Distance (km) | Daily Fuel Consumption (t/d) | One-way Transit Time (d) | Fuel Consumed Per Round Trip (t) |
|---|---|---|---|---|---|
| **Summer Shipping from Milne Port** | | | | | |
| Panamax Ore Carriers (Up to Ice Class 1A) | Milne Port - Rotterdam | 6,019 | 30 | 10.95 | 657 |
| Capesize Ore Carriers (Non-Ice Class) | Milne Port - Rotterdam | 6,019 | 50 | 10.95 | 1,095 |
| **Summer Shipping from Steensby Port** | | | | | |
| Panamax Ore Carriers (Polar-Ice Class) | Steensby Port - Rotterdam | 5,741 | 35 | 9.94 | 696 |
| Capesize Ore Carriers (Polar-Ice Class) | Steensby Port - Rotterdam | 5,741 | 50 | 9.94 | 994 |
| **Winter Shipping from Steensby Port - Ice Breaking Section** | | | | | |
| Panamax Ore Carriers (Polar-Ice Class) | Steensby Port - Hudson Strait | 1,722 | 80 | 5.22 | 835 |
| Capesize Ore Carriers (Polar-Ice Class) | Steensby Port - Hudson Strait | 1,722 | 100 | 5.22 | 1,044 |
| **Winter Shipping from Steensby Port - Open Water Section** | | | | | |
| Panamax Ore Carriers (Polar-Ice Class) | Hudson Strait - Rotterdam | 4,019 | 35 | 6.96 | 487 |
| Capesize Ore Carriers (Polar-Ice Class) | Hudson Strait - Rotterdam | 4,019 | 50 | 6.96 | 696 |
| **Winter Shipping from Steensby Port - Whole Trip** | | | | | |
| Panamax Ore Carriers (Polar-Ice Class) | Steensby Port - Rotterdam | 5,741 | N/A | 12.17 | 1,322 |
| Capesize Ore Carriers (Polar-Ice Class) | Steensby Port - Rotterdam | 5,741 | N/A | 12.17 | 1,740 |

Based on the round-trip consumption of HFO outlined in Table 2.6 and the expected number of each vessel type, the annual HFO consumption over the life of the Project was derived (Table 2.7).

#### *2.1.5.2 Calculation of HFO Consumption by Sealift Vessels and Tankers*

For sealift vessels and tankers, daily fuel consumption data were unavailable. Instead, total annual GHG emissions (TAE) from HFO combustion by sealift vessels and tankers were estimated from publicly available emission factors (EF) specific to the vessel type and ship size, deadweight tonne (DWT) of shipped product per trip, and total annual round trip distance travelled (D) using the equation:

$$TAE = EF \times DWT \times D$$

The resultant GHG emissions from sealift vessels and tankers are presented in Section 2.2.3.

#### *2.1.5.3 Calculation of Aviation Fuel Consumption by Project Air Traffic*

Air traffic including Boeing 737 jets fly from Montreal to the Mine Site via Iqaluit and Dash-7 aircraft between the five North Baffin communities and the Mine Site. A portion of the fuel for these aircraft is derived from site and the remainder from off-site fuel supplies. It was assumed that the doubling the annual consumption of aviation fuel at site would adequately represent the total consumption of aviation fuel related to the Project (Table 2.7).

**Table 2.7 Estimated Fuel Consumption by Ore Carriers and Aircraft**

| Year | Project Phase | | | | | | | HFO (ML) | Aviation Fuel (ML) |
|---|---|---|---|---|---|---|---|---|---|
| | Construct ERP | Operate ERP | Construct 12 Mtpa | Operate 12 Mtpa | Construct 18 Mtpa | Operate 18 Mtpa | Closure | | |
| 2013 | X | | | | | | | 0 | 2.3 |
| 2014 | X | | | | | | | 0 | 2.3 |
| 2015 | | X | | | | | | 2.63 | 3.7 |
| 2016 | | X | | | | | | 26.7 | 3.6 |
| 2017 | | X | | | | | | 62.6 | 4 |
| 2018 | | X | | | | | | 89.3 | 4 |
| 2019 | | X | X | | | | | 89.3 | 6 |
| 2020 | | X | X | | | | | 89.3 | 6 |
| 2021 | | | | X | X | | | 122 | 6 |
| 2022 | | | | X | X | | | 122 | 6 |
| 2023 | | | | X | X | | | 120 | 6 |
| 2024 | | | | X | X | | | 119 | 6 |
| 2025 | | | | X | | X | | 250 | 6 |
| 2026 | | | | X | | X | | 250 | 6 |
| 2027 | | | | X | | X | | 250 | 6 |
| 2028 | | | | X | | X | | 250 | 6 |
| 2029 | | | | X | | X | | 250 | 6 |
| 2030 | | | | X | | X | | 250 | 6 |
| 2031 | | | | X | | X | | 250 | 6 |
| 2032 | | | | X | | X | | 250 | 6 |
| 2033 | | | | X | | X | | 250 | 6 |
| 2034 | | | | X | | X | | 250 | 6 |
| 2035 | | | | X | | X | | 250 | 6 |
| 2036 | | | | | | | X | 0.44 | 6 |
| 2037 | | | | | | | X | 0.44 | 6 |
| 2038 | | | | | | | X | 0.44 | 4 |
| **Total** | | | | | | | | **3,596** | **134** |

## 2.2 Estimated GHG Emissions

### 2.2.1 Scope 1 Emissions from Fuel Combustion

The Project's total annual Scope 1 Emissions from on-site fuel consumption (including arctic diesel and marine diesel) is presented in Table 2.8.

**Table 2.8 Total Annual Scope 1 Emissions from On-Site Fuel Combustion**

| **Year** | **GHG Emissions (in t $CO_2e$)** | | |
|---|---|---|---|
| | **Mobile and Stationary Equipment (Arctic Diesel)** | **Port Support Vessels (Marine Diesel)** | **Total** |
| 2013 | 20,193 | 0 | 20,193 |
| 2014 | 68,305 | 0 | 68,305 |
| 2015 | 91,401 | 542 | 91,942 |
| 2016 | 113,472 | 542 | 114,013 |
| 2017 | 129,991 | 542 | 130,532 |
| 2018 | 171,587 | 542 | 172,129 |
| 2019 | 152,120 | 542 | 152,662 |
| 2020 | 167,034 | 542 | 167,576 |
| 2021 | 435,482 | 542 | 436,023 |
| 2022 | 345,999 | 542 | 346,541 |
| 2023 | 351,965 | 542 | 352,506 |
| 2024 | 510,050 | 542 | 510,592 |
| 2025 | 644,274 | 135,977 | 780,251 |
| 2026 | 665,153 | 135,977 | 801,130 |
| 2027 | 665,153 | 135,977 | 801,130 |
| 2028 | 677,084 | 135,977 | 813,061 |
| 2029 | 700,946 | 135,977 | 836,923 |
| 2030 | 703,929 | 135,977 | 839,906 |
| 2031 | 653,222 | 135,977 | 789,199 |
| 2032 | 623,395 | 135,977 | 759,372 |
| 2033 | 560,757 | 135,977 | 696,734 |
| 2034 | 527,947 | 135,977 | 663,924 |
| 2035 | 530,930 | 135,977 | 666,907 |
| 2036 | 89,483 | 0 | 89,483 |
| 2037 | 89,483 | 0 | 89,483 |
| 2038 | 89,483 | 0 | 89,483 |
| **Total** | 9,778,836 | 1,501,165 | 11,280,001 |

### 2.2.2 Scope 1 Emissions from Permafrost Disturbances

The methodology for quantifying disturbances to permafrost that may result in the release of $CO_2$ and $CH_4$ is presented in Section 2.1.4.

The $CH_4$ equivalent to the total organic carbon content of the disturbed soils equates to approximately 10.9 Mt $CO_2e$. Only a portion of the available SOC will be converted by microbial action to $CH_4$, and even then, it takes roughly one hundred years for all the $CH_4$ to be released to the atmosphere when the permafrost thaws (Zimov et al. 2006). Mechanical disturbances will, however, result in the release of any pre-existing $CH_4$ present in the soil. Currently, the active layer depth varies depending on ground conditions between 0.2 m and 3 m, with typical values of 1 to 2 m. The overturning of the current ground layers will expose some permafrost to thaw-freeze cycles while embedding current active layers into permanent permafrost. It can be conservatively assumed that initially about one-tenth of the total soil organic carbon will be released directly as trapped $CH_4$ or converted into $CH_4$ through anoxic microbial activity due to disturbances. No further releases are expected once the stripped overburden has settled and is no longer disturbed as the vertical temperature profiles become similar to those before the disturbances. The remaining carbon will therefore remain trapped.

Based on the above, the Phase 2 Proposal is expected to generate approximately 1.1 Mt $CO_2e$ due to permafrost disturbances.

### 2.2.3 Scope 3 Emissions from Transportation

As noted in Section 2.1.2, Scope 3 Emissions will be generated by marine shipping traffic (ore carriers, sealifts and tankers) and by the air transport of workers and supplies. An estimate of the annual fuel consumption by ore carriers and aircraft was presented in Table 2.7. Excluded from this estimate was fuel consumption from sealift vessels and tankers. As noted in Section 2.1.5.2, though fuel consumption estimates for these vessels was not available, it is possible to calculate annual GHG emissions from publicly available emission factors. The estimated GHG emissions generated by sealift vessels and tankers on a single round trip to each of the ports, calculated using emission factors, is presented in Table 2.9.

**Table 2.9 GHG Emissions of Shipping for Sealift Vessels and Tankers**

| Vessel Type | Deadweight Tonnes (metric) per Trip | Route | Distance per One-Way Trip (km) | Ship Type | Ship Size Category | Emission Factor (g/t/km)[1] | Emissions per Round-Trip (t $CO_2e$) |
|---|---|---|---|---|---|---|---|
| **Summer Shipping from Milne Port** | | | | | | | |
| Sealift Vessels (Dry Freight) | 8,500 | Milne Port - Valleyfield | 4,630 | General cargo | 5,000-9,999 dwt, 100+ TEU[2] | 17.5 | 1,391 |
| Fuel Tankers (10-15ML/vessel) | 14,000 | Milne Port - St. John's | 3,334 | Products tanker | 10,000-19,999 dwt | 18.7 | 1,763 |
| **Summer Shipping from Steensby Port** | | | | | | | |
| Sealift Vessels (Dry Freight) | 8,500 | Steensby Port - Valleyfield | 4,213 | General cargo | 5,000-9,999 dwt, 100+ TEU(2) | 17.5 | 1,266 |
| Fuel Tankers (10-15ML/vessel) | 14,000 | Steensby Port - St. John's | 2,917 | Products tanker | 10,000-19,999 | 18.7 | 1,542 |

NOTES:
1. Source: Table 7 in Cefic-ECTA (2011).
2. Twenty-foot equivalent (roughly 33.2 $m^3$).

The estimated volumes of aviation fuel and HFO totals presented in Table 2.7 were converted to GHG emissions. The GHG emissions for sealifts and tankers derived from the emission factors presented in Table 2.9 were added to the total for marine shipping. The resultant estimate of GHG emissions from aviation and marine shipping is presented in Table 2.10.

**Table 2.10 Estimated Scope 3 Emissions from Aircraft, Ore Carriers, Sealift Vessels and Tankers**

| Year | GHG Emissions (in t $CO_2e$) | | |
|---|---|---|---|
| | Aviation | Marine Shipping | Total |
| 2013 | 5,724 | 19,202 | 24,925 |
| 2014 | 5,724 | 15,028 | 20,751 |
| 2015 | 9,208 | 8,382 | 17,590 |
| 2016 | 8,959 | 85,104 | 94,063 |
| 2017 | 9,954 | 199,602 | 209,557 |
| 2018 | 9,954 | 284,707 | 294,661 |
| 2019 | 14,931 | 284,707 | 299,638 |
| 2020 | 14,931 | 284,707 | 299,638 |
| 2021 | 14,931 | 346,036 | 360,967 |
| 2022 | 14,931 | 346,313 | 361,244 |
| 2023 | 14,931 | 338,083 | 353,015 |
| 2024 | 14,931 | 335,413 | 350,344 |
| 2025 | 14,931 | 661,784 | 676,715 |
| 2026 | 14,931 | 661,784 | 676,715 |
| 2027 | 14,931 | 661,784 | 676,715 |
| 2028 | 14,931 | 661,784 | 676,715 |
| 2029 | 14,931 | 661,784 | 676,715 |
| 2030 | 14,931 | 661,784 | 676,715 |
| 2031 | 14,931 | 661,784 | 676,715 |
| 2032 | 14,931 | 661,784 | 676,715 |
| 2033 | 14,931 | 661,784 | 676,715 |
| 2034 | 14,931 | 661,784 | 676,715 |
| 2035 | 14,931 | 661,784 | 676,715 |
| 2036 | 9,954 | 17,753 | 27,707 |
| 2037 | 9,954 | 17,753 | 27,707 |
| 2038 | 9,954 | 4,559 | 14,513 |
| **Total** | **333,216** | 9,866,966 | 10,200,182 |

### 2.2.4 Summary of Scope 1 and Scope 3 Emissions

The estimated life of mine (LOM) emissions by type of activity / source are summarized in Table 2.11.

The Project will result in 12.4 Mt $CO_2$e of direct (Scope 1) GHG emissions over its lifetime, or 0.476 Mt $CO_2$e/y on average over the expected 26-year lifetime.

The Project will generate an estimated 22.6 Mt-$CO_2$e in direct and indirect GHG emissions over the LOM. Slightly more than half of the total GHG that will be generated over the LOM are Scope 1 Emissions associated with mining and port operations. The other almost half of the LOM GHG emissions are indirect emissions associated with transportation, reflecting additional fuel needs because of the remoteness of the Project site.

**Table 2.11 Life of Mine GHG Emissions by Source**

| Scope Category | Scope 1 (Direct) Emissions | | | Scope 3 (Indirect) Emissions | |
|---|---|---|---|---|---|
| Activity(s)/Source(s) | Equipment (Arctic Diesel) (Mt $CO_2$e) | Port Vessels (Marine Diesel) (Mt $CO_2$e) | Permafrost Disturbances (Mt $CO_2$e) | Aviation (Jet A Fuel) (Mt $CO_2$e) | Marine Shipping (HFO) (Mt $CO_2$e) |
| LOM Emissions by Source | 9.8 | 1.5 | 1.1 | 0.33 | 9.9 |
| Annual Average Emissions | 0.476 | | | 0.013 | 0.38 |
| LOM Emissions by Scope | 12.4 | | | 10.2 | |
| **LOM Total Emissions** | **22.6** | | | | |

## 2.3 Evaluation of Significance

These updated estimates of Project annual emissions are compared with previous estimates, with emissions from other mining projects, and with jurisdictional and industry totals. An estimation of the potential climate impact of the Project's GHG emissions is also provided.

### 2.3.1 Comparison with Previous Estimates

The estimate of 22.6 Mt $CO_2$e for the Phase 2 Proposal represents a reduction in GHG emissions compared to the estimate for the Approved Project of 25.2 Mt $CO_2$e (Baffinland 2013). The GHG emissions reported in the FEIS (Baffinland 2012) incorrectly estimated GHG emissions at 21.0 Mt $CO_2$e. The Phase 2 Proposal will involve a reduction in GHG emissions from 25.2 Mt $CO_2$e (the corrected value for the Approved Project) to 22.6 Mt $CO_2$e, a reduction of 10.3% (Table 2.12).

The Scope 1 Emissions of the Phase 2 Proposal are about equal to that of the Approved Project. The Phase 2 Proposal includes the switch from truck haulage of a portion of the annual ore production to the use of rail. Rail haulage is preferred over trucks as railroads are four times more fuel-efficient than trucks (Association of American Railroad 2017). This comparison is based upon the use of existing transportation infrastructure (roads and railways), and therefore do not account for construction of the rail infrastructure. Baffinland's GHG estimate for the Phase 2 Proposal includes construction of both the North and South Railways. Over the timeframe of the Phase 2 Proposal, the switch to rail does not result in a significant reduction in GHG emissions. However, Baffinland expects to continue to mine iron ore at other adjacent and nearby deposits. Over the long-term (that is, beyond the life of the Phase 2 Proposal and into subsequent project phases), the significant GHG reduction benefit of using rail over trucks to haul ore to the ports will be realized.

The Scope 3 Emissions estimate (10.2 Mt $CO_2e$), Mikayla21however, does vary meaningfully from the previous estimate (12.8 Mt $CO_2e$) for the following reasons:

- Estimates of marine shipping emissions increase from 7.8 to 9.9 Mt $CO_2e$. (As noted in Table 2.11, the original estimate of 3.6 Mt $CO_2e$ was based on an incorrect combination of fuel consumption, round-trip duration, and number of trips per year.) With the Phase 2 Proposal, a larger proportion of shipping will take place using smaller (Panamax) vessels. The Approved Project assumed that more of the ore would be transported from Steensby Port using mainly capsize ore carriers.
- New aircraft emission estimates are an order of magnitude lower based on revised estimates based on actual fuel consumption.

**Table 2.12 Comparison of GHG Emissions for the Phase 2 Proposal with Previous Estimates for the Approved Project**

| Emission Source | GHG Emissions (Mt $CO_2e$) | |
|---|---|---|
| | **Approved Project[1]** | **Phase 2 Proposal** |
| **Scope 1 Emissions** | | |
| On-Site Diesel Fuel Combustion | 11.4 | 9.8 |
| Marine Diesel Consumption at Port | | 1.5 |
| Permafrost Disturbances | 1.0 | 1.1 |
| Subtotal – Scope 1 Emissions | 12.4 | 12.4 |
| **Scope 3 Emissions** | | |
| Shipping | 7.8[2] | 9.9 |
| Aviation | 5.0 | 0.33 |
| Subtotal – Scope 2 Emissions | 12.8 | 10.2 |
| **Total** | **25.2[2]** | **22.6** |

NOTES:
1. Emissions were calculated for the combined 18 Mtpa South Rail Operation and a 3 Mtpa Road Haulage Operation in the Draft Environmental Impact Statement (RWDI, 2010a in Baffinland, 2010).
2. The original estimate of 3.6 Mt $CO_2e$ of shipping emissions was based on an incorrect combination of fuel consumption (35 t/day), round-trip duration (30 days), and number of trips per year (40). If all ore was transported by cape size ore carriers with 190,000 DTW, 95 round-trips would be needed per year for an assumed annual production of 18 Mt of ore with an estimated fuel consumption of 50 t/day for a 20-day round-trip. This increases the original estimate of GHG emissions from shipping from 3.6 to 7.8 Mt $CO_2e$ over the 25-year period of the approved project and the total emissions from 21.0 to 25.2 Mt $CO_2e$.

Total indirect GHG emissions of 10.2 Mt $CO_2e$ associated with the transportation of ore to market are not under Baffinland's control and would not be reported annually in Baffinland's GHG inventory. Therefore, to provide an appropriate comparison to other mining projects, Scope 3 (aviation and marine shipping) GHGs are not included in the comparisons presented below.

## 2.3.2 Comparison with Other Mining Projects

Table 2.13 presents the GHG emissions from other representative mining facilities in Canada. The range of emissions includes the Project's estimated average annual emissions of 0.476 Mt $CO_2e$. Although some processes and activities at each site could differ, these mines were selected for comparison as they would have some similar activities or are similarly located in a remote location.

The Carol Iron Mine is thought to be the most comparable in size and operation, with an annual production rate of 23.3 Mtpa; Carol Iron Mine's GHG emissions intensity is more than twice the estimated average emission intensity of the Mary River project over the period from 2013 through 2038; 0.024 Mt $CO_2e$ / Mt ore for Mary River versus 0.059 Mt $CO_2e$/Mt ore for Carol Mine (IOC 2017). This substantially higher emission intensity can be attributed to the energy usage associated with the Carol Mine's pelletizing operation. It is thought that the reported emissions for the Carol Mine do not include GHG emissions associated with the 418 km railway and operation of the Sept-Îles port facility.

Most values in Table 2.13 are actual reported emissions based on known/measured fuel consumptions etc., while the Project's annual emissions are based on conservative future estimates. Overall, the estimated average annual GHG emissions from the Mary River Project appear reasonable by comparison with the other mining projects in Table 2.13.

**Table 2.13 Annual GHG Emissions of the Project and Examples of Other Mining Facilities in Canada**

| Facility | City | Province/Territory | Average Annual GHG Emissions (Mt $CO_2e$) | Reporting Year | Source Types Included |
|---|---|---|---|---|---|
| Mary River Project | Mary River | Nunavut | 0.476 | Estimate | Scope 1 (no Scope 2 emissions associated with project) |
| Carol Iron Mine [1] | Labrador City | Newfoundland and Labrador | 1.075 | 2016 | Scope 1 and 2 [2] |
| Diavik Diamond Mine [3] | Yellowknife | Northwest Territories | 0.187 | 2015 | Scope 1 and 2 |
| EKATI Diamond Mine [3] | Yellowknife | Northwest Territories | 0.216 | 2015 | Scope 1 and 2 |
| Meadowbank Gold Mine [3] | Baker Lake, Kivalliq | Nunavut | 0.187 | 2015 | Scope 1 and 2 |
| Back River Gold Mine [4] | Kitikmeot | Nunavut | 0.156 | Estimate | Diesel, aviation, shipping |

NOTES:
1. Source: Iron Ore Company of Canada 2017.
2. This includes all onsite equipment and GHG emissions associated with the production of purchased electricity used onsite. It does likely not include GHG emissions associated with the operation of the port facility in Sept-Îles and the 418-km railroad to the port.
3. Source: ECCC 2016a.
4. Source: Sabina Gold and Silver Corp. 2015.

### 2.3.3 Comparison with Jurisdictional and Industry Totals

Table 2.14 presents a comparison of the Project's estimated average annual GHG emissions with jurisdictional totals and emissions from all mining activities in Canada.

Due to Nunavut's small population and manufacturing base, total GHG emissions in Nunavut are currently very low. Based on the numbers reported in the Inventory, annual GHG emissions of the proposed mine represent 68% of the territorial emissions as reported in 2016. The annual emissions estimate for the Project is equivalent to 6.8% of GHG emissions from all Canadian mining operations and 0.07% of total GHG emissions in Canada in 2016.

**Table 2.14 Comparison of Estimated Project GHG Emissions to Nunavut, Canada and Mining in Canada**

| | GHG Emissions Mt $CO_2e$ / Year | Percentage (Project Emissions / Sector or Jurisdiction Emissions) |
|---|---|---|
| **Project** | 0.476 | n/a |
| **Nunavut [1]** | 0.7 | 68% |
| **Mining in Canada [2]** | 7 | 6.8% |
| **Canada [2]** | 704 | 0.07% |

NOTES:
1. ECCC 2018c, Part 3, Table A11-27.
2. ECCC 2018c, Part 3, Table A10-2.

### 2.3.4 Expected Impact of Project GHG Emissions on Climate Change

The National Research Council (NRC 2010) expressed the expected climate changes and their impacts per degree Celsius (°C) of global warming as:

- 5 to 10% change in precipitation in a number of regions;
- 3 to 10% increases in heavy rainfall;

- 5 to 15% yield reductions of a number of crops;
- 5 to 10% changes in stream flow in many river basins worldwide; and
- About 15% and 25% decreases in the extent of annually averaged and September Arctic sea ice, respectively.

Low and high estimates are based on ensemble model runs and different values published in the scientific literature. It was demonstrated by Matthew and Weaver (2010) that temperature increases are directly related to cumulative emissions of GHG. Based on the most current modeling results, NRC (2010) suggests that global warming is approximately linearly related to cumulative emissions and estimates roughly 0.27 to 0.68°C warming per 1,000,000 Mt $CO_2e$.

Given the low and high values of the ranges noted in the bullets above, we can estimate climate changes and impacts per 1,000,000 Mt $CO_2e$ cumulative GHG emissions (Table 2.15). For example, the low estimate of precipitation change is 5% per 1°C of warming, and the low estimate of warming is 0.27°C per 1,000,000 Mt $CO_2e$; hence the low estimate for precipitation change is 0.27°C x 5% / 1°C = 1.4% per 1,000,000 Mt $CO_2e$ increase in the atmosphere.

**Table 2.15 Climate Impacts Associated with Cumulative GHG Emissions of 1,000,000 Mt $CO_2e$**

| | Low | High |
|---|---|---|
| Warming | 0.27°C | 0.68°C |
| Precipitation change | 1.4% | 6.8% |
| Increase in heavy rainfall | 0.8% | 6.8% |
| Yield reduction in a number of crops | 1.4% | 10.1% |
| Changes in stream flow | 1.4% | 6.8% |
| Decrease in the extent of annually averaged Arctic sea ice | 4.1% | 10.1% |
| Decrease in the extent of September Arctic sea ice | 6.8% | 16.9% |

Using the Project's total (cumulative) GHG emissions of 12.4 Mt $CO_2e$ over the period from 2013 to 2038 and the expected climate impacts per 1,000,000 Mt $CO_2e$ specified in Table 2.15, low and high estimates of the impact of Project's cumulative GHG emissions can be quantified (Table 2.16). As an example, the low estimate of precipitation changes is 12.4Mt $CO_2e$/1,000,000 Mt $CO_2e$ x 0.000017%.

**Table 2.16 Climate Impacts Associated with the Project's Estimated Cumulative GHG Emissions**

| | Low | High |
|---|---|---|
| Warming (°C) | $3.34\times10^{-6}$ | $8.42\times10^{-6}$ |
| Precipitation change (%) | $1.73\times10^{-5}$ | $8.42\times10^{-5}$ |
| Increase in heavy rainfall (%) | $0.99\times10^{-5}$ | $8.42\times10^{-5}$ |
| Yield reduction in a number of crops (%) | $1.73\times10^{-5}$ | $12.5\times10^{-5}$ |
| Changes in stream flow (%) | $1.73\times10^{-5}$ | $8.42\times10^{-5}$ |
| Decrease in the extent of annually averaged Arctic sea ice (%) | $5.08\times10^{-5}$ | $12.5\times10^{-5}$ |
| Decrease in the extent of September Arctic sea ice (%) | $8.42\times10^{-5}$ | $20.9\times10^{-5}$ |

The Project will generate 12.4 Mt $CO_2e$ cumulative direct emissions over the LOM (2013 to 2038). Based on the National Research Council's high estimate of global warming of 0.68°C per 1,000,000 Mt $CO_2e$, the Project's contribution to global warming would therefore be 12.4 Mt $CO_2e$ x 0.68°C / 1,000,000 Mt $CO_2e$ ≈ 0.000008°C (Baffinland, 2018).

Currently, routine measurements of ambient temperatures are performed with an accuracy of about 0.1°C. Given environmental noise and natural variability in temperature time series, the warming associated with the Project's cumulative GHG emissions will be undetectable. Likewise, the other climate impacts shown in Table 2.16 would be undetectable. Given the Project's individual contribution to climate change is not detectable, the effect of the Project on climate change is not significant.

# 3 CLIMATE CHANGE ASSESSMENT

## 3.1 Objectives

The climate change assessment presented in the FEIS (Appendix 5B; RWDI AIR Inc. 2011) was based on the previous (fourth assessment) report by the Intergovernmental Panel on Climate Change (IPCC 2007) and the best available data at that time. In 2014, the IPCC released its Fifth Assessment Reports (IPCC 2014a, 2014b), which provide improved insights into climate change, including climate change in the Arctic. Substantial changes have been made to global climate models (GCMs) of future scenarios. In addition, a growing body of research on Arctic climate change and Inuit Traditional Knowledge or Inuit Qaujimajatuqangit (IQ) has become available. The need to update the previous climate change assessment for the Project was identified.

## 3.2 Methods and Data

### 3.2.1 Sources of Information

The available sources of data and information can be roughly divided into four categories, which are described in the following subsections:

- High-level technical summaries and review;
- Peer-reviewed publications;
- Documentation of IQ; and
- Publicly accessible data sets.

#### *3.2.1.1 High-Level Reviews*

High-level technical summaries and reviews typically focus on fundamental physical parameters such as temperatures averaged over seasonal and longer scales and over large regional to global spatial scales. They synthesize many (often thousands of) peer-reviewed publications to form a high-level picture and overview of climate change. Examples of such publications include the IPCC's assessment reports (IPCC 2007, 2014a, 2014b) and country or region specific syntheses such as the National Oceanic and Atmospheric Administration's 'Arctic Report Card' (NOAA 2016).

#### *3.2.1.2 Peer-Reviewed Publications*

Peer-reviewed publications are usually focused on small regions, specific parameters or environments, or compound environmental parameters. They usually contain substantial technical detail. Examples could be a publication on global sea-level rise using improved glacier models or a publication on the climate feedback of black carbon deposition in the Arctic. Given the current interest in climate change and its broad relevance, this body of literature is vast, growing quickly, and in constant flux. It is beyond the scope of this research to review original research papers, but the reader is occasionally referred to research papers of particular relevance.

#### *3.2.1.3 Inuit Qaujimajatuqangit*

As defined in IPCC (2014b, Chapter 28), traditional knowledge is the historical knowledge of Indigenous peoples accumulated over many generations. The IPCC notes that traditional knowledge is emerging as an important knowledge base for more comprehensively addressing the impacts of environmental and other changes as well as development of appropriate adaptation strategies for Indigenous communities. Increasingly, traditional knowledge is being combined with scientific knowledge to develop more sustainable adaptation strategies for all communities in the changing climate. For example, at Clyde River, Nunavut, Inuit and scientists both note that wind speed has increased in recent years and that wind direction changes more often over shorter periods (within a day) than it did during the past few decades (Gearheard et al. 2010; Overland et al. 2012).

Acknowledging the increasing recognition of the value of Inuit Qaujimajatuqangit, a summary of IQ provides the starting point for each of the discipline specific subsections in Section 3.4 through 3.6. IQ was incorporated primarily through a documentation of interviews with elders from eight Inuit communities across Nunavut, Nunavik, and Nunatsiavut, ranging from the Low Arctic to the High Arctic, including Pond Inlet within the Project region (Gérin-Lajoie et al. 2016). The interview responses provided by the elders are focused on the more recent past and complex environmental characteristics that are the result of the interplay of many climate parameters.

The broad spatial coverage of Gérin-Lajoie et al. (2016) facilitates cross evaluation of the information and identification of generic trends such as a northward movement of climate zones. In particular, a south-north transect of Eastern Canadian Arctic maritime climates is provided by three communities: Kangiqsualujjuaq in the Low Arctic, Pangnirtung in the Middle Arctic, and Pond Inlet in the High Arctic. For instance, observations by elders suggest a general northward movement of vegetation. In addition to Gérin-Lajoie et al. (2016), responses by local residents in the Mary River Inuit Knowledge Study (Baffinland 2014a) were consulted. In many cases this provided additional support to the general themes identified from the responses in Gérin-Lajoie et al. (2016).

#### *3.2.1.4 Publicly Available Datasets*

Available data sets vary by intended application in terms of spatial resolution, the parameters considered, and the averaging periods. Each discipline would likely require several data sets to meet its information needs and different disciplines would likely require different data sets. The analysis of publicly available data from climate predictions was not within the scope of this report.

The starting point for most data sets are the GCM outputs from the Coupled Model Intercomparison Project Phase 5 (CMIP5). The IPCC's Fifth Assessment Report of Working Group I (2014a) heavily relied on CMIP5 output. Additional data sets have been produced to increase the information at finer spatial scales by downscaling the GCM output over specific regions with numerical models such as regional climate models (dynamical downscaling) or deploying statistical technique (statistical downscaling). It is to be noted, however, that errors from GCM output at coarse spatial resolution are often not corrected by downscaling, so these data sets must be consulted with care.

### 3.2.2 Time Horizons

The IPCC's Fifth Assessment Report (2014a) discusses climate predictions in terms of three time horizons: 2016 to 2035, 2046 to 2065, and 2081 to 2100. Of these, the 2016 to 2035 'near-term' horizon is the most relevant to the Project as it covers the lifetime of the Project. The study of the 2046 to 2065 'mid-term' horizon is also beneficial to provide a trend for the change in climate parameters when the Project is decommissioned. This report focuses on climate change predictions over these two time horizons. Long-term projection for the 2081 to 2100 horizon are more relevant to the public and global policy makers to obtain a general outlook of the future of the planet based on different emission scenarios. Less attention is given to these long-term projections, because:

- Currently, the Project time horizon ends with complete closure in 2038, long before the end of the century.
- It would be unrealistic and overly conservative to assume that the Project needs to adapt to the worst-case climate change with current technology by the end of the century:
    - Estimates of climate change by the end of the century are highly uncertain mostly due to uncertain future anthropogenic behaviours with respect to GHG emissions, and land-use changes, etc. A worst-case future scenario might vastly overestimate future climate change.
    - It is impossible to anticipate new technologies that will be available by the end of the 21st century to adapt the Project's operations to future climate change.
- There is a very long lead time to implement adaptation options beyond the middle of the century.

An exception is potential environmental impacts from the waste rock stockpile, which could occur long after the proposed Project closure in 2038. Therefore, a discussion of potential long-term climate change impacts on the waste rock stockpile is provided in Section 3.4.6.

The sources of information and the associated uncertainties vary substantially for the short- and mid-term horizons as will be explained in the following two subsections.

#### *3.2.2.1 Short-term Climate Change*

Climate change has become measurable and noticeable over the last few decades, particularly in the Arctic. General trends observed in the region of interest over the last few decades are likely to continue over the next ten to twenty years and can serve as a good proxy for more sophisticated modelling approaches. Existing historical observations provide information on basic meteorological parameters. IQ is very valuable for understanding and extrapolating environmental characteristics that are the result of the complex interplay of several environmental parameters, some of which have never been measured.

It is noted that short observational records and IQ that do not extend back in time substantially more than the most recent decade could be strongly affected by natural variability occurring at time scales of up to one or two decades, and these might not be representative of the longer-term climate trend. An attempt was made to gauge the representativeness of available information by cross checking with information from other Arctic regions and longer-term predictions.

#### *3.2.2.2 Mid- to Long-term Climate Change*

Simple extrapolation of historical information is not likely reliable for predicting climate several decades into the future for a number of reasons. Firstly, the main driver for recently observed climate change trends are anthropogenic emissions of GHGs, but long-term future human GHG emissions are highly uncertain. Secondly, the response of the climate system to these emissions does not necessarily continue to be the same as in the past, particularly at regional scales.

GCMs are deployed to model the atmospheric flow coupled with physical processes at the land surface and in the oceans (including sea ice) incorporating aerosols and other components such as carbon cycle, dynamic vegetation, atmospheric chemistry, and land ice (IPCC 2014a; Fig. 1.13). Depending on the model type, future GHG emissions and other relevant emissions (such as aerosols) are accounted for either directly or via their associated effects on solar radiation below the top of the atmosphere (radiative forcing). Different emission scenarios and their associated radiative forcing have been developed and agreed upon. These have changed between the IPCC's two most recent reports of IPCC's Working Group I (IPCC 2007 and 2014a) and are described in more detail in the next section.

### 3.2.3 Emissions and Forcing Scenarios

Forecasts of climate change are inevitably imprecise due to two factors: the inherent uncertainty in GCM predictions and the uncertainty in predicting future human population, economic development, technological advances, and political choices. Uncertainties are not predicted but rather characterized by creating several possible future scenarios. Future scenarios that were used for the last two IPCC assessment reports of Working Group I (IPCC 2007 and 2014a) are explored below.

#### *3.2.3.1 SRES Scenarios*

The emission scenarios of the Special Report on Emissions Scenarios (SRES) by the IPCC (2000) were used in the IPCC's Third and Fourth Assessment Reports as well as in the previous climate change report for the Project.

The SRES scenarios were constructed to explore future developments in the global environment with special reference to the production of greenhouse gases and aerosol precursor emissions. These scenarios were categorized into four 'storylines' to describe a narrative and to highlight the main characteristics, dynamics, and the relationships between key driving forces during the 21st century for large regions and globally. Each scenario was a projection of a potential future, based on a clear logic and a quantified storyline. The SRES storylines include:

- A1: a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies.
- A2: a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines.
- B1: a convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.
- B2: a world emphasizing local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development.

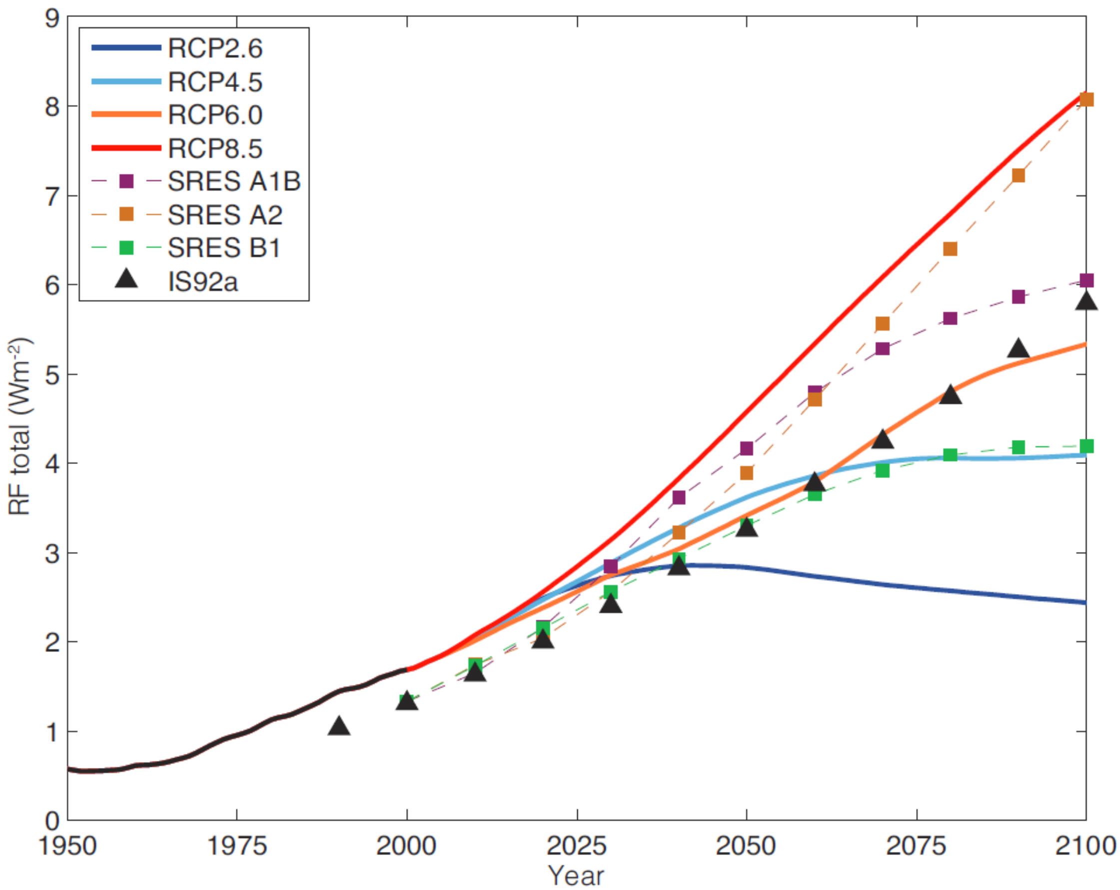
The SRES scenarios were developed for Integrated Assessment Models (IAMs), which incorporate both the physical and social science models that consider demographic, political, and economic variables that affect greenhouse gas emission scenarios in addition to the physical climate system. The capabilities of IAMs in predicting future climate are limited due to the additional computational complexity, diversity of schemes, and uncertainties of coupling physical models with human-dimensions models.

By contrast, GCMs focus on the physical climate system alone, and can provide a better understanding of the climate system based on specified concentrations and corresponding emissions. In addition, since the development of the SRES scenarios two decades ago, our knowledge of historical anthropogenic emissions and other relevant factors has substantially improved, and actual emissions since the publication of IPCC (2000) are known. This led to the development of revised scenarios for use in GCMs.

#### *3.2.3.2 RCP Scenarios*

The new Representative Concentration Pathway Scenarios (RCPs) are based on a different approach than the SRES scenarios and include more consistent short-lived gases and land use changes. IPCC's Fifth Assessment Report (IPCC, 2014a) presents four RCPs, which are identified by value of their radiative forcing (in $W/m^2$) in year 2100 relative to 1750. The RCP scenarios include one mitigation scenario leading to a very low forcing level of 2.6 $W/m^2$, two stabilization scenarios with 4.5 $W/m^2$ and 6.0 $W/m^2$, and one scenario with very high greenhouse gas emissions (8.5 $W/m^2$).

Figure 3.1 compares the radiative forcing of the new RPC scenarios with the old SRES scenarios. In terms of radiative forcing, the four RCP scenarios span a larger range than that of the three SRES scenarios used in the previous assessments. RCP4.5 is close to SRES B1, RCP6.0 is close to SRES A1B (more after 2100 than during the 21st century) and RCP8.5 is somewhat higher than A2 in 2100 and close to the SRES A1FI scenario. RCP2.6 is lower than any of the SRES scenarios.




NOTES:

1. FR = radiative forcing.
2. Source: Figure 1.15 in IPCC, 2014a.
3. Original caption: "Historical and projected total anthropogenic RF (W/m$_2$) relative to preindustrial (about 1765) between 1950 and 2100. Previous IPCC assessments (SAR IS92a, TAR/AR4 SRES A1B, A2 and B1) are compared with representative concentration pathway (RCP) scenarios (see Chapter 12 and Box 1.1 for their extensions until 2300 and Annex II for the values shown here). The total RF of the three families of scenarios, IS92, SRES and RCP, differ for example, for the year 2000, resulting from the knowledge about the emissions assumed having changed since the TAR and AR4."

**Figure 3.1 Comparison of Current RCP with Previous SRES Scenarios**

#### *3.2.3.3 Summary and Comparison of Scenarios*

In the context of the Project, the best case and worst-case scenarios (RCP2.6 and RCP8.5) are discussed. The radiative forcing for the two stabilization scenarios (RCP4.5 and 6.0) follow a similar trend in the near- and mid-term and therefore, only RCP4.5 is selected as the mid-point scenario in this assessment. Table 3.1 summarizes the three RCP scenarios considered in this report and draws comparisons with the previous SRES scenarios.

**Table 3.1 Climate Change Scenarios Relevant to the Project**

| Scenario | Description | Rationale for Selecting Scenario | Comparison with SRES Scenarios(1) |
|---|---|---|---|
| RCP2.6 | Optimistic mitigation scenario with radiative forcing of 2.6 $W/m^2$ in year 2100 | Extreme 'best case' scenario | Atmospheric GHG concentrations are lower than any of the SRES scenarios |
| RCP4.5 | Stability scenario with moderate emissions and radiative forcing of 4.5 $W/m^2$ in year 2100 | Mid-point scenario | Atmospheric GHG concentrations are close to SRES B1 |
| RCP8.5 | Extreme scenario with very high emissions, no mitigation, and radiative forcing of 8.5 $W/m^2$ in year 2100 | Extreme 'worst case' scenario | Atmospheric GHG concentrations are close to SRES A1 in year 2100 |

NOTES:

1. As the SRES scenarios and the new RCP scenarios are defined based on different projection approaches, they cannot be directly compared. However, $CO_2e$ concentrations and global GHG emissions can be used to qualitatively link the former and new scenarios.

### 3.2.4 Climate Parameters

With respect to the predictability of climate parameters, future estimates of temperatures are most reliable followed by precipitation. Other primary parameters such as wind and solar radiation are more uncertain. Parameters affected by several environmental attributes, such as active layer thickness, are harder still to quantify due to the complex interplay of different parameters, dependence on local characteristics, and unknown confounding factors. An effort was made to extract the best available information from the literature for each of the parameters relevant to the Project.

The confidence in predictions increases with the number of available input data; for example, confidence in a global mean value is much greater than confidence in the prediction of local extreme events. Furthermore, there is typically more confidence in relative than absolute predictions; models tend to have biases and may be far off from predicting absolute values reliably (that tends to be the case for precipitation, for example), but the relative change is generally assumed to be less dependent on the bias.

## 3.3 Overview of Climate Change in the High Arctic

Climate change has become measurable and noticeable over the last few decades, particularly in the Arctic. Recent climate impact assessments on polar regions indicate a consistent pattern of climate driven environmental, societal, and economical changes in recent decades (IPCC 2014b, Chapter 28). This subsection provides some key scientific insights into various aspects of climate change in the Arctic, which are mostly extracted from IPCC Working Group I and II reviews (IPCC 2014a; 2014b).

Arctic land surface temperatures have increased substantially since the mid-20$^{th}$ century, and the future rate of warming is expected to exceed the global rate. Sea ice extent at summer minimum has decreased in the past decades, and the Arctic Ocean is projected to become nearly ice free in summer within this century. Since the late 1970s, global permafrost temperatures have increased between 0.5° and 2°C. In the Canadian High Arctic, permafrost temperatures at depths of 12 to 15 m have increased by 1.2 to 1.7°C between 1978 and 2008 (IPCC 2014a, Table 4.8).

Rising temperatures, leading to the future thawing of permafrost, and changing precipitation patterns have the potential to change infrastructure and related services in the Arctic (IPCC 2014b, Chapter 28). Shifts in timing and magnitude of seasonal biomass production could disrupt matched phenologies (periodic plant and animal cycles) in the food webs, leading to decreased survival of dependent species.

The impacts of climate change exhibit strong spatial heterogeneity in the polar regions because of the high diversity of social systems, biophysical regions, and associated drivers of change. The following subsections provide more detailed information with an attempt to extract region specific information relevant to the Project site.

## 3.4 Physical Terrestrial Environment

### 3.4.1 Inuit Observations of Climate Change in the Physical Terrestrial Environment

Gérin-Lajoie et al. (2016) summarized interview responses on climate-change observations by elders in Pond Inlet and seven other Arctic Inuit communities. The responses addressed climate change impacts caused by the combined effect of interacting physical terrestrial parameters. Responses by elders in the interviews across all eight Arctic communities surveyed agree on the general trend of observed Arctic warming. Additional information beyond the general temperature trend was extracted from the responses and is outlined in the following paragraphs.

> "*Climate change is going to affect everyone – the people, the land animals, the sea animals. When I was younger, I used to expect snow in the fall. Now I don't see it as much until November/December.*" (Hall Beach, Caribou Workshop, March 2008; Baffinland 2014a)

Recent climate change has been rapid, and residents of communities have been commenting that their capacity to know the weather is not as effective as it once was, and that the knowledge of the elders is not serving as reliably as in the past (Atkinson et al., 2014; Government of Nunavut, 2011).

Documented changes to the Arctic include: glacier retreat, sea-ice and lake-ice thinning, thawing of permafrost, coastal erosion from wave action, changes in ocean currents, and shifting ranges of plant and animal species (Nelson et al., 2002; Serreze et al., 2000; Smol et al., 2005; Hinzman et al., 2005; Huntington et al., 2007; ITK, 2016).

In Pond Inlet (Gérin-Lajoie et al., 2016), there is mostly agreement that winters have warmed substantially. Winter is reported to have been arriving one to one-and-a-half months later and spring arriving earlier than historically observed. Part of this change is likely caused by reduced winter precipitation, as reported by many elders. For instance, when reduced snow cover melts earlier in the spring it exposes darker ground, which absorbs more solar radiation than snow covered ground, causing earlier warming in the spring.

There is agreement among elders on thawing permafrost, seen through increased occurrence of sinkholes, and receding glaciers, in line with warming temperatures and decreasing precipitation in the winter (Gérin-Lajoie et al. 2016). Glacial retreat is reported to have been ongoing for decades. Lake and sea ice is reported to be thinner and covered with less snow. Rivers tend to carry less water in the spring, likely a result of less snowmelt (because of less winter snowfall) and potentially fewer upstream ice jams (because of thinner ice cover).

In summer, there is an indication of longer-term increases of cloud cover and less predictability of wind and precipitation, likely the result of a northward trend of weather patterns that are unfamiliar to elders in Pond Inlet (Gérin-Lajoie et al. 2016). The same phenomenon has been impacting elders in the two communities further south. In the Mary River Inuit Knowledge Study (Baffinland 2014a), winds were described as stronger now than in the past.

The effects and resultant changes to summer temperatures are unclear. While it has been observed that river flows in the spring are lower now than in the past, it was suggested in the Mary River Inuit Knowledge Study that increased glacial melt in the summer has increased summer flow rates (Baffinland 2014a).

Land is reported to be drier, which is further supported by elders' observations of vegetation changes, which are discussed in the next section. Some responses in Gérin-Lajoie et al. (2016) and the Mary River Inuit Knowledge Study (Baffinland 2014a) suggest more summer rain and also allude to increased river flows after rainfall. This reconciles with rainfall events being heavier now, but not more frequent, than in the past. Immediate runoff after a heavy rainfall and warmer temperatures between rainfalls would cause more soil drying despite average rainfall being unchanged or increased.

### 3.4.2 Temperature

Historical climate normals (ECCC 2017b) at many southern Canada stations such as Calgary and Montreal show more winter than summer warming: Over the 20-year period between the mid-points of the 1961 to 1990 and 1981 to 2010 climate-normal periods, average summer temperatures show little or no noticeable changes, while winter temperatures show 1-2°C warming. Climate normals for Environment Canada's 'Pond Inlet A' station is only available for 1971 to 2000 and 1981 to 2010. Over the 10-year period between the mid-points of these two climate-normals periods show a warming of 0.6°C in the summer (June, July, August) and no change in average winter (December, January, February) temperatures.

The climate normals do not agree with responses by elders in Gérin-Lajoie et al. (2016) that suggest warmer winters and likely no change in the summer. However, natural variability might have caused warmer winters in the recent two decades. During the summer, temperatures are perceived as higher when exposed to the sun than temperatures measured in the shade. Therefore, recent increases in cloud cover (as discussed in the next subsection) might have masked the increase in summer temperature. Short- to mid-term predictions for the RCP4.5 and RCP8.5 emission scenarios suggest a warming trend in all seasons (Table 3.2).

The mean global surface air temperature for the period 2016–2035 will likely be between 1°C and 1.5°C more than the 1850 to 1900 mean temperature (IPCC 2014a, Chapter 11). In general, the projected warming in wintertime shows a pronounced polar amplification in the northern hemisphere, i.e. warming over the Arctic in winter will be greater than the global mean warming over the same period.

Table 3.2 presents the projected temperature changes in the region most representative of the Project area for the near- and mid-term time frames and for the three selected forcing scenarios. Minimum, maximum and median projected change for winter (December, January, February), summer (June, July, August) and the whole year are presented.

Frequency of extreme temperature events is predicted to continue to increase. It is predicted (IPCC 2014a, Chapter 11) that heat waves in most land regions will be more intense, more frequent, and last longer towards the end of the 21st century. Cold episodes are projected to decrease significantly in a future warmer climate.

**Table 3.2 Projected Temperature Changes at High Latitudes (Canada/Greenland/Iceland)**

| Parameter | Scenario | Year | Projected Change in Annual Temperature (in °C) [2] | | |
|---|---|---|---|---|---|
| | | | Minimum | Maximum | Median |
| Winter Temperature (DJF [3]) | RCP2.6 | 2035 | 0.2 | 3.3 | 1.5 |
| | | 2065 | -1.1 | 5.3 | 2.3 |
| | RCP4.5 [4] | 2035 | -0.2 | 3.4 | 1.4 |
| | | 2065 | 1.1 | 4.9 | 3.1 |
| | RCP8.5 | 2035 | 0.6 | 3.4 | 2 |
| | | 2065 | 2.6 | 7.9 | 4.8 |
| Summer Temperature (JJA [5]) | RCP2.6 | 2035 | 0.3 | 2.5 | 1 |
| | | 2065 | -0.4 | 3.9 | 1.4 |
| | RCP4.5 [4] | 2035 | 0.3 | 2.5 | 0.9 |
| | | 2065 | 0.8 | 3.9 | 1.7 |
| | RCP8.5 | 2035 | 0.5 | 2.7 | 1.1 |
| | | 2065 | 1.2 | 5.6 | 2.6 |
| Temperature (Annual) | RCP2.6 | 2035 | 0.4 | 2.7 | 1.2 |
| | | 2065 | -1.1 | 4.4 | 1.8 |
| | RCP4.5 [4] | 2035 | 0 | 2.9 | 1.1 |
| | | 2065 | 0.8 | 4.3 | 2.3 |
| | RCP8.5 | 2035 | 0.6 | 2.9 | 1.5 |
| | | 2065 | 1.8 | 6.3 | 3.6 |

NOTES:
1. Source: IPCC (2014a), Chapter 14 Supplementary Material, Tables 14.SM.1a, b, and c.
2. Climate models predict a range of values for each scenario. Minimum, maximum, and median statistics were calculated over ensembles of 25 to 39 GCM runs, depending on scenario.
3. DJF: Average over December, January, and February.
4. Results shown are for RCP6.0 scenario but are similar to RCP 4.5 for 2035 and 2065.
5. JJA: Average over June, July, and August.

### 3.4.3 Cloud Cover

The study by Norris et al. (2016) focused on regional cloud-cover trends covering the globe from 60° south to 60° north. They compared historical satellite-derived trends with GCM control runs over the same historical period. They found good agreement between satellite observations and GCM model output. Although this study did not include the Canadian Arctic north of 60°, the evidence supports previous hypotheses for recent and predicted future northward movement of the mid-latitude storm tracks and associated cloud-cover increases.

In the winter, the storm tracks are too far south to affect the Project region in the High Arctic. In the summer, however, a northward movement of the storm track increases the frequency of its occurrence in the Project region. The expected changes include increased cloud cover, stronger winds, more variable wind direction, and less predictability of weather in general. All of these model predictions agree with the responses by elders in Gérin-Lajoie et al. (2016) described in Section 3.4.1.

### 3.4.4 Precipitation and Runoff

Chapter 11 of IPCC (2014a) provides a general summary of the global and regional effects of warming on precipitation: A general intensification of the global hydrological cycle, and of precipitation extremes, is expected for a future warmer climate. Simulations predict both global precipitation and global evaporation to increase by 1 to 3% per 1°C of global warming. Changes in near-surface specific humidity are positive, with the largest values at northern high latitudes. The frequency and intensity of heavy precipitation events will likely increase over many land areas in the near term, but this trend will not be apparent in all regions, because of natural variability and possible influences of anthropogenic aerosols. For most places, the general pattern is wet-get-wetter and dry-get-dryer.

The implications of these general observations and predictions for the Project region are less clear. Zonal mean precipitation, i.e. average precipitation across all longitudes for a given latitude, will very likely increase in high latitudes according to IPCC (2014a, Chapter 11). This is in agreement with poleward atmospheric moisture transport and northward movement of the mid-latitude storm track. In many parts of the Arctic, river flow has increased. However, precipitation and subsequently river flow in high-latitude Canadian rivers has decreased by 10% on average between 1964 and 2000 (IPCC, 2014b, Chapter 28).

River flows taken in isolation are likely insufficient indicators of precipitation changes, particularly in the High Arctic. River flows in Pond Inlet and other communities in the Project region are likely affected by reduced snow accumulation in the winter, earlier snowmelt, increased glacial melt, deeper thawing of permafrost, increased surface runoff of precipitation on drier soil, and changes in the frequency and amount of rain.

The rather short historical record at Pond Inlet shows virtually no change in monthly mean precipitation amounts (totals of liquid and solid precipitation) across all seasons between the 1971 to 2000 and the 1981 to 2010 climate normal. However, snowfall dropped by about 10% and rainfall increased correspondingly (i.e., more of the same precipitation fell as rain instead of snow). This finding agrees with reduced snow cover as reported by elders in Pond Inlet. This is in line with general observations reported in IPCC (2014a, Chapter 4). Annual mean snow cover extent has decreased in the Northern Hemisphere, especially in spring over the period 1967 to 2012. The largest decrease in monthly snow cover was reported in June (–40% to -66%). This means that areas are becoming snow free earlier in the spring. Higher summer temperatures without a corresponding increase in precipitation amounts is consistent with observations by Elders of increased dryness of the land (Section 3.4.1).

Similar to changes in river flows, the observation of elders at Pond Inlet that water levels in smaller ponds have dropped are not sufficient indicators of reduced rainfall. Smol and Douglas (2007) argue that reduced ice cover with higher air temperature and evaporation are responsible for the drying of some Arctic ponds. Table 3.3 presents the projected precipitation changes in the region most representative for the Project area for the near- and mid-term time frames and for the three selected forcing scenarios. Minimum, maximum, and median projected change for winter (October, November, December, January, February, March), summer (April, May, June, July, August, September) and the whole year are presented.

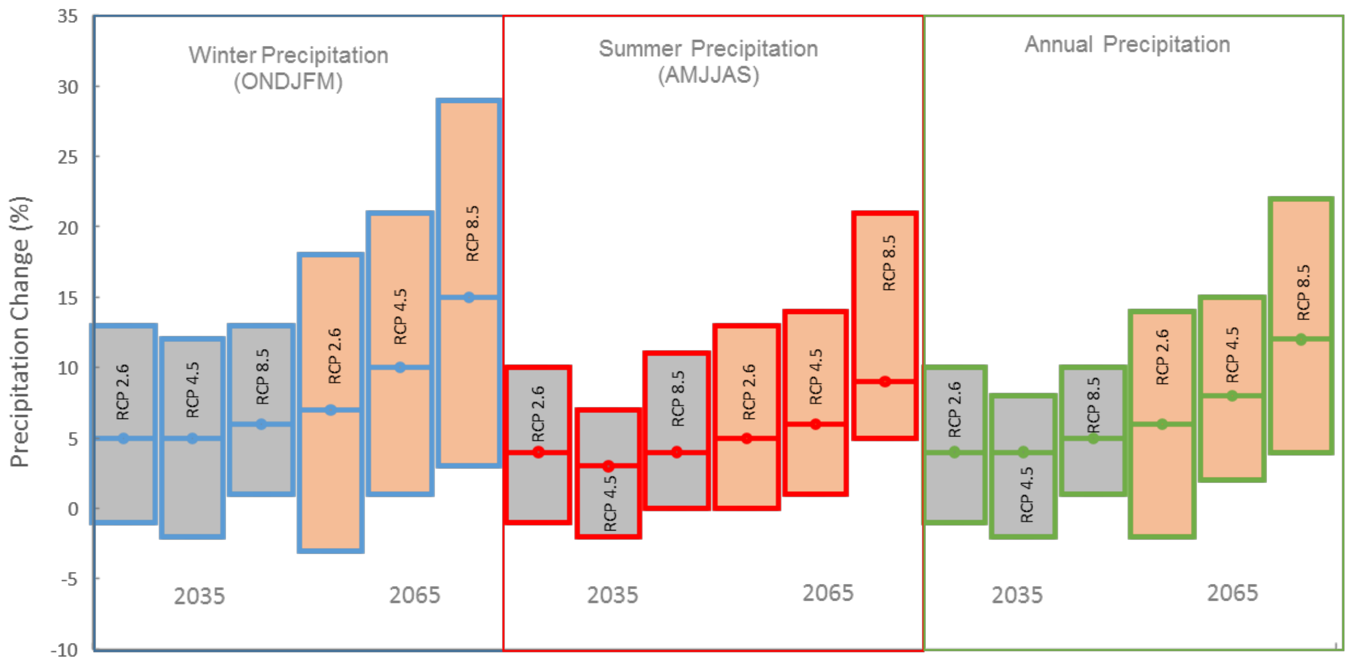
**Table 3.3 Projected Changes in Precipitation at High Latitudes (Canada/Greenland/Iceland)**

| Parameter | Scenario | Year | Changes in Annual Precipitation (in %) [2] | | |
|---|---|---|---|---|---|
| | | | Minimum | Maximum | Median |
| Winter Precipitation (ONDJFM [3]) | RCP 2.6 | 2035 | -1 | 13 | 5 |
| | | 2065 | -3 | 18 | 7 |
| | RCP 4.5 [4] | 2035 | -2 | 12 | 5 |
| | | 2065 | 1 | 21 | 10 |
| | RCP 8.5 | 2035 | 1 | 13 | 6 |
| | | 2065 | 3 | 29 | 15 |
| Summer Precipitation (AMJJAS [5]) | RCP 2.6 | 2035 | -1 | 10 | 4 |
| | | 2065 | 0 | 13 | 5 |
| | RCP 4.5 [4] | 2035 | -2 | 7 | 3 |
| | | 2065 | 1 | 14 | 6 |
| | RCP 8.5 | 2035 | 0 | 11 | 4 |
| | | 2065 | 5 | 21 | 9 |
| Precipitation (annual) | RCP 2.6 | 2035 | -1 | 10 | 4 |
| | | 2065 | -2 | 14 | 6 |
| | RCP 4.5 [4] | 2035 | -2 | 8 | 4 |
| | | 2065 | 2 | 15 | 8 |
| | RCP 8.5 | 2035 | 1 | 10 | 5 |
| | | 2065 | 4 | 22 | 12 |

NOTES:
1. Source: IPCC (2014a), Chapter 14 Supplementary Material, Tables 14.SM.1a, b, and c.
2. Climate models predict a range of values for each scenario. Minimum, maximum, and median statistics were calculated over ensembles of 25 to 39 GCM runs, depending on scenario.
3. ONDJFM: Average change over October, November, December, January, February, and March.
4. Results shown are for RCP6.0 scenario but are similar to RCP 4.5 for 2035 and 2065.
5. AMJJAS: Average change over April, May, June, July, August, and September.

Although recent climate normal suggest that precipitation has not changed notably in the past couple of decades, the latest climate predictions summarized in Table 3.3 suggest an increase in precipitation in the coming decades. To visualize the projected changes in precipitation at high latitudes, the data within Table 3.3 has been presented on Figure 3.2. To simplify the figure, the RCP with the largest change in precipitation (RCP 8.5) was selected and plotted. The winter season is expected to contain the largest projected changes (increases) in precipitation.

Annual precipitation by 2035, is projected to increase by 4 to 5% (median statistical value), and 6 to 12% by 2065. The range presented represent the output of the multiple RCP scenarios.




NOTES:
1. Source: IPCC (2014a), Chapter 14 Supplementary Material, Tables 14.SM.1a, b, and c.

**Figure 3.2 Projected Changes in Precipitation at High Latitudes by 2035 and 2065**

### 3.4.5 Glaciers

Between 1960 and 2000, the glacier area on Baffin Island decreased by 12.5% (IPCC 2014a, Table 4. SM1 in supplementary material for Chapter 4). Current glacier extents are out of balance with current climatic conditions, indicating that glaciers will continue to shrink in the future even without further temperature increase (IPCC 2014a, Chapter 4).

### 3.4.6 Warming of Permafrost Soils

The active layer is the part of the surface layer that experiences seasonal thawing and re-freezing. Near the Project site, its depth varies depending on ground conditions, ranging between 0.2 m and 3 m, with typical depths of 1 to 2 m based on current surface temperatures.

The IPCC (2014a, Chapter 4) reports with high confidence that permafrost temperatures have increased in most regions since the early 1980s, although the rate of increase has varied regionally. With increasing temperature trends in the Project region, active-layer thickness will continue to increase in the future, however future active-layer thickness will vary vastly depending on local conditions. The temperature increase for colder permafrost was generally greater than for warmer permafrost (Gross et al. 2011), however warmer permafrost is more sensitive to these increases. Although snow cover is generally thin in the high Arctic, its variability can be an important factor affecting the response of permafrost temperatures to changes in air temperature (Smith 2011). Changes in snow cover may counteract the impact of air temperature changes occurring over the same period, such that permafrost temperatures may increase in the high Arctic during periods of lower air temperatures combined with corresponding periods of higher snow cover (Taylor et al. 2006).

Increases in the mean annual ground temperatures over the past couple of decades have been documented. Three such studies indicate a similar degree of warming of ground temperatures in the high arctic (Richter-Menge and Mathis 2016; Gross et al. 2011; Smith 2011).

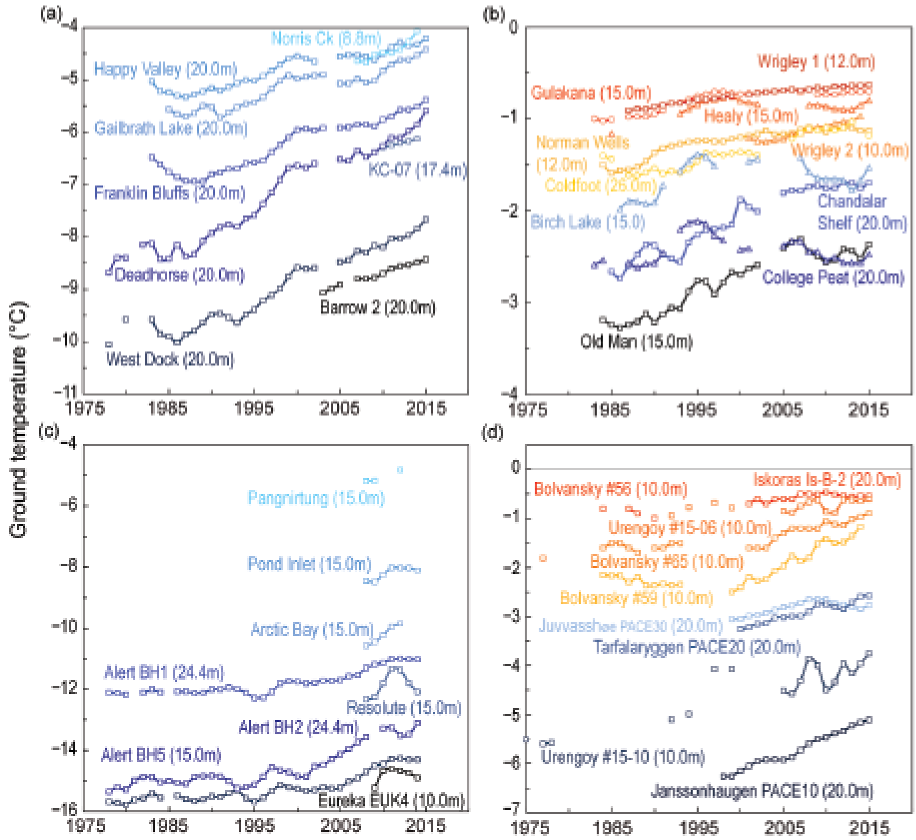
Richter-Menge and Mathis (2016) present mean annual ground temperatures at a number of monitoring locations across the Arctic, including Arctic Bay and Pond Inlet (Figure 3.3; from Richter-Menge and Mathis 2016). Mean annual ground temperature increases of 1°C at 15 m depth have been recorded over a seven-year period: -9 to -8°C in Pond Inlet and -11 to -10°C in Arctic Bay (Figure 3.3). These measurements are consistent with the current (1981 to 2000 average) range of permafrost temperatures of between -12 to -8°C in the Project region in Gross et al. (2011).

This also agrees with permafrost temperature data collected at Canadian Forces Station (CFS) Alert, Nunavut since 1978 (Smith 2011). Although a general increase in air temperatures has been observed at CFS Alert since the 1980s, distinct warming in shallow permafrost temperatures has only been observed since the mid-1990s. Between 1994 and 2001, an increase in permafrost temperatures of about 0.15°C per year occurred at a depth of 15 m. An increase in permafrost temperatures of 0.15°C per year at CFS Alert corresponds well with the documented 1°C change over a seven-year period at both Arctic Bay and Pond Inlet reported by Richter-Menge and Mathis (2016). Although some cooling of permafrost at CFB Alert was observed between 2000 and 2002, data has indicated a warming of permafrost over the period of 1994 through 2008 at an overall rate of approximately 0.1°C per year (Smith 2011).

Modelling results presented in Gross et al. (2011), which take into account heat transport processes in the ground, predict permafrost temperatures of -8 to -5°C for the 2081 to 2100 period, corresponding to approximately 3.5 to 4°C warming of permafrost over the 100-year period in the Project region. This agrees well with the RCP6.0 median predicted warming of 3.9°C for 2081 to 2100 relative to 1986 to 2005 (IPCC 2014a, Chapter 14 Supplementary Material, Table 14, SM.1b, high latitudes [Canada/Greenland/Iceland] region), suggesting that warming of permafrost and air temperatures are very similar for the Project region. The long-term outlook under the more extreme RCP8.0 scenario is a median warming of 6.4°C by 2081 to 2100, which still predicts permafrost temperatures well below 0°C and therefore, that permafrost will remain continuous in the Project region beyond the 21st century.

Changes to vegetation cover may be experience with a warming air and permafrost temperatures. Frozen ground and active layer thickness can influence rooting zone depth and soil moisture conditions, which are important for vegetation succession and growth and also indirectly affect the hydrologic cycle through the influence on evapotranspiration (Woo et al. 1992; Hinzman et al. 2005).

Waste rock management at the Project relies on the encapsulation of potentially acid-generating (PAG) waste rock within permafrost. A 50-m thick cover of non-acid generating (NAG) waste rock is proposed in Baffinland's Life-of-Mine Waste Rock Management Plan (Baffinland 2014b), Interim Closure, and Reclamation Plan (Baffinland 2016). The thickness of the proposed non-acid generating (NAG) cover is adequate to account for conditions identified in this updated climate change assessment.




NOTES:
1. Reference: Richter-Menge and Mathis, 2016.

**Figure 3.3 Mean Annual Ground Temperatures at Arctic Monitoring Stations**

### 3.4.7 Changes in the Base Depth of Permafrost

An average geothermal gradient of approximately 25°C per km of depth (Fridleifsson et al. 2008) implies a permafrost depth of several hundred metres below ground surface in the Project region. Permafrost in the area ranges in thickness from 400 to 700 m (FEIS Volume 6, Section 2.1.1.4).

Thawing at the base of the permafrost is a slow process that would start several centuries or more following a change in the average ambient air temperature (Lunardini 1995; Osterkamp et al. 2003). Deep permafrost (~600 to 700 m) has a time constant of about 2,000 years (Lachenbruch 1982 in Taylor 2007). At depths below 200 m, the ground is in quasi-thermal equilibrium with surface temperatures of 100 or more years ago (Judge 1973 in Taylor 2007).

As such, the effect of a warming climate on the base depth of permafrost at the site will be extremely slow, and will be inconsequential in terms of carrying out the Project.

### 3.4.8 Sub-sea Permafrost

In some arctic regions such as the Beaufort Sea North of Alaska, the subsea permafrost is a relic from periods of lower sea level during the glacial maxima of the Quaternary Period (Smith and Burgess 2004). In these regions, the subsea permafrost is in disequilibrium with the present marine environment such that the sediments are warming gradually, and the permafrost is slowly degrading. This may also be the case for subsea permafrost at Milne Port. However, this disequilibrium is not likely to be as extreme as other areas such as the Beaufort Sea that were exposed to the colder mean air temperatures during periods of lower sea level.

There is potential for local degradation of the subsea permafrost and corresponding large-scale settlement of the sea floor at the project site resulting from long term warming where ice-rich soils and bedrock are present. As discussed previously, the extreme warming scenario involves a median warming of 6.4°C by 2081 to 2100. The gradual large scale and local degradation of the permafrost due to atmospheric warming has the potential to alter the locations of existing shorelines.

Conversely, where well-drained soils and bedrock are present that are absent of ice, settlement induced by climate warming is unlikely.

## 3.5 Marine Environment

Climate change information on key physical parameters were examined for water temperature, salinity, and pH. IQ on the marine environment did not provide specifics on the key physical parameters. The scientific review provides some specific information on the key physical parameters but remains mostly high level covering more generic characteristics of the Arctic marine environment.

A supplemental review of observed and expected climate change impacts in the Canadian eastern Arctic as they relate to marine environment and marine mammals is provided below.

The literature review summarized below indicates that the predicted changes in ice cover that may occur as a result of global climate change have the potential to affect, directly or indirectly, all aspects of the marine ecosystem in the Project area.

### 3.5.1 Inuit Observations of Climate Change in the Marine Environment

Elders in Pond Inlet agree that seal populations have been shrinking and the quality of their fur declining. Fish are reported to be bigger. Changes in fish and whale species are also suggested in the responses in Gérin-Lajoie et al. (2016), but the specifics are unclear. In the Mary River Inuit Knowledge Study (Baffinland 2014a), whales were reported to arrive later in the season.

Elders in several Arctic communities, including Pond Inlet, reported seeing more polar bears near the community or campsites, to the point of them becoming a serious threat (Gérin-Lajoie et al. 2016). One elder reported that hunters no longer cache whale meat over the summer, because the polar bears will eat it. This might be indicative of habituation to humans and easy access to food near human settlements or campsites rather than a consequence of a warming climate. However, regional warming could indirectly confound this issue to the extent that the warming is potentially responsible for reduced seal populations and quality of seal fur. It is plausible that the increased sightings of polar bears are partially the result of polar bear adaptation to climate change impacts on seals and that these behavioural changes of polar bears will continue in the future.

### 3.5.2 Sea Water

Surface water temperatures of large water bodies has warmed, particularly for high latitudes. Increasing water temperatures affect planktonic and benthic biomass and lead to changes in species composition (IPCC 2014b). During the period of 1997 to 2009, a trend toward earlier phytoplankton blooms was detected in approximately 11% of the Arctic Ocean. Satellite data provided evidence of a 20% increase in annual net primary production in the Arctic Ocean between 1998 and 2009 in response to extended ice-free periods. A recent 5-year study (2004 to 2008) in the Canada Basin showed that smaller phytoplankton densities were higher than larger phytoplankton densities in years when sea surface temperatures (SSTs) were warmer, the water column was more stratified, and nutrients were more depleted during the Arctic summer (IPCC 2014b).

### 3.5.3 Sea Ice

There is agreement between elders in Pond Inlet (and in other communities further south) that sea ice is thinner and weaker (Gérin-Lajoie et al. 2016). Generally, multi-year ice (sea-ice that has survived at least one melting season) is stronger than first-year ice, suggesting that elders are observing more first-year sea-ice now than in the past. The Mary River Inuit Knowledge Study captured a number of comments regarding observed reductions in ice cover (Baffinland 2014a):

> "*The ice is different now, because of climate change. There is a lot less ice now. It's a huge difference. We didn't have ice this summer or this fall even.*" (Igloolik, Marine Mammals Workshop, April 2008)

> "*It [ice] used to be so much thicker. Now it is so much thinner. And the floe edge used to be further down, now it is much closer now. It is very different now. I think the water is much warmer now and the ice seems to be thick but it moves. When the weather is clear skies, the ice form very quickly, and it thickens very quickly. Nowadays that doesn't seem to happen anymore. The ice doesn't form as thick; it is very different now.*" (Arctic Bay Interviewee, 2005)

> "*I have not noticed too many changes but I do notice that the glacial ice is melting. Most glaciers have decreased in size. As the glaciers melt, rivers tend to flow more. When rivers flow more or over-flows for a period in the spring, it erodes the river banks.*" (Pond Inlet Interviewee, 2007)

The IPCC (2014a, Chapter 4) summarizes that the annual Arctic sea ice extent decreased over the period 1979 to 2012 by about 3.5 to 4.1% per decade (0.45 to 0.51 million $km^2$ per decade). The average decrease in decadal extent of Arctic sea ice has been most rapid in summer and autumn, but the extent has decreased in every season, and in every successive decade since 1979. The extent of Arctic perennial and multi-year sea ice decreased between 1979 and 2012. The perennial sea ice extent (summer minimum) decreased between 1979 and 2012 at 11.5 ± 2.1% per decade (0.73 to 1.07 million $km^2$ per decade) and the multi-year ice (that has survived two or more summers) decreased at a rate of 13.5 ± 2.5% per decade (0.66 to 0.98 million $km^2$ per decade). The average winter sea ice thickness within the Arctic Basin decreased between 1.3 and 2.3 m between 1980 and 2008. These observations fully support the observations by elders in Gérin-Lajoie et al. (2016).

Predictions from GCM runs agree that the Arctic sea ice cover will continue to shrink and thin all year round during the 21$^{st}$ century as the annual mean global surface temperature rises (IPCC, 2014a, Chapter 11). Under the RCP8.5 high emission scenario, it is projected that the Arctic Ocean will become nearly ice-free in September before the middle of the century. More seasonally detailed quantitative predictions were unavailable. It is reasonable to assume that the trends that have been recently observed by elders will continue: earlier ice break-up in the spring, later freeze-up in the fall/winter, and thinner and weaker winter ice. The specifics will depend on factors that are difficult to quantify such as future anthropogenic GHG emissions, natural variability, and additional regional factors such as wind speed and wind direction.

### 3.5.4 Sea Level

Paleo sea level records from warm periods during the last 3 million years indicate that global mean sea level has exceeded 5 m above present (very high confidence) when global mean temperature was up to 2°C warmer than pre-industrial (IPCC 2014a, Chapter 13). Proxy and instrumental sea-level data indicate a transition in the late 19$^{th}$ century to the early 20$^{th}$ century from relatively low mean rates of rise over the previous two millennia to higher rates of rise. It is estimated that the total global sea level rise between 1910 and 2010 has been 0.19 m, with higher rates towards the end of the 20$^{th}$ century and beginning of the 21$^{st}$ century. The dominant contributors to this increasing rate have been ocean thermal expansion and glacier melting.

The future rate of global mean sea-level rise during the 21st century will exceed the rate observed during 1971–2010 for all RCP scenarios due to increases in ocean warming and loss of mass from glaciers and ice sheets (IPCC 2014a, Chapter 13). The 20-year average of mean sea-level rise in the period 2081–2100, relative to 1971–2010 are projected to be:

- 0.44 m for RCP2.6
- 0.52 m for RCP4.5
- 0.74 m for RCP8.5

In all scenarios, thermal expansion is the largest contribution, accounting for about 30 to 55% of the projections (IPCC 2014a, Chapter 13), followed by glaciers, accounting for 15-35% of the projections.

Regional sea-level changes may differ substantially from a global average, showing complex spatial patterns, which result from ocean dynamical processes, movements of the sea floor, and changes in gravity due to water-mass redistribution (land ice and other terrestrial water storage) in the climate system (IPCC 2014a, Chapter 13). The regional distribution is associated with natural or anthropogenic climate modes rather than factors causing changes in the global average value.

Climate change will affect sea-level extremes and ocean waves in two principal ways (IPCC 2014a, Chapter 13). First, because extratropical and tropical storms are one of the key drivers of sea-level extremes and waves, future changes in intensity, frequency, duration, and path of these storms will impact them. Second, sea-level rise adds to the heights of sea level extremes, regardless of any changes in the storm-related component. Mean sea-level change may also accentuate the threat of coastal inundation due to changes in wave run-up.

## 3.6 Inuit and Economic Sectors

A warming Arctic climate could have both positive and negative consequences for the environment, economic development, and the social well-being of people in the North. Climate change stands to impact cultural practices and traditional activities, food security, health of people and wildlife, community infrastructure, transportation, heritage resources, resource development, and energy, among other aspects of daily life in Nunavut. Inuit populations in the Arctic may be especially vulnerable to climate change because of their close relationship with the environment and its natural resources for physical, social, and cultural well-being.

Inuit knowledge and input from Inuit people is key in understanding and documenting both social and environmental changes and trends, which in turn play an important role in developing future adaptation strategies. As early as the 1990s, beginning in western Canada, Indigenous communities have been reporting climate change impacts (Berkes and Armitage 2010).

The adaptive capacity of Inuit strongly depends on extensive Inuit knowledge, cultural repertoire, and flexible social networks. Cultural values such as sharing, patience, persistence, calmness, and respect for elders and the environment help during adaptation to change. Inuit communities and organizations have been pro-active in leveraging new technologies and information sharing to address climate change impacts on their lives. For example, a number of communities have worked with researchers to map problem ice areas within traditional travel routes; use modern tools such as handheld Global Positioning System (GPS) units to guide travelers; and to map new safer travel routes (Aporta 2003; Laidler et al. 2010; Gearheard et al. 2011; Pan Inuit Trails Atlas 2017).

Some of the more significant impacts Inuit are already experiencing in Nunavut as a result of climate change include (from ITK 2016):

- Decreasing sea ice thickness and distribution, which is changing wildlife habitat and affecting impacting hunters' ability to harvest wildlife;
- Permafrost degradation, changes in ice conditions, rainfall and snow quantity, drainage patterns, temperatures, and extreme weather events can all have implications for existing infrastructure (such as roads and buildings); all of which was designed around a permanently frozen soil regime;
- Increased length of the ice free season may allow for increased shipping through our waterways, including the Northwest Passage; bringing both economic benefits as well as increased risk of waterway contamination through oil spills and other pollution events; and
- Arrival of new insects, birds, fish and mammals previously unknown or rare in Nunavut, and change in the abundance and distribution of familiar animals.

Inuit Qaujimajatuqangit is reinforcing and supporting scientific observations of these changes. It is also providing valuable insight on adaptation, and information on how these changes may affect Nunavummiut and the ecosystems on which Nunavummiut rely.

Additional discussion on the effects of climate change on Inuit is provided below.

### 3.6.1 Health and Well-being

The health and well-being of Inuit may be affected by climate change via several pathways:

- Changes to the physical environment (temperature, precipitation, ice and snow cover):
  - May affect the ability of Inuit to pursue traditional activities; and
  - May increase public safety risks associated with travelling on the land.
- Climate change related impacts to wildlife:
  - May affect harvesting and consequently food security; and
  - May increase the incidence of disease in wildlife, affecting humans through consumption.

Effects on traditional activities influence the health and well-being of Nunavut's communities, families and individuals. Many Nunavummiut continue to depend on hunting, fishing and gathering to support themselves and the local economy in their communities.

Local hunting practices and timing have already been modified, and new technologies are increasingly being relied upon (GN 2011). Inuit elders, who traditionally relied upon their skills to predict the weather, have observed changing cloud and wind patterns. They have observed that some of their weather and climate related knowledge does not seem to fit with the current observed weather conditions and patterns. The unpredictability of weather and climate has increased the perceived risk of travel on the land. This unpredictability has also made it very difficult for elders to pass along their weather prediction skills to younger generations. Some traditional travel routes have become inaccessible, in some cases preventing the usage of traditional campsites. According to numerous elders and community members, decreasing water levels make travelling by boat more difficult; earlier melt of lake, river and sea ice make travel routes unsafe in the spring, and permafrost thaw makes travel by ATV in the summertime more difficult (GN 2011).

Traditional food security may be affected if access to wildlife is affected, by either a reduction in wildlife populations or due to reduced access due to shrinking seasons or higher risks associated with travelling on the land. The overall shift away from country food towards expensive store bought, and often unhealthy food items, has resulted in negative effects on Inuit health and cultural identity (GN 2011). The negative impacts of climate change as described above could worsen this problem.

Storage of food is also affected by warmer temperatures and thawing permafrost. Interviews with elders suggest that outdoor meat caches now spoil, where formerly they remained fresh and preserved in the cold environment. Country food continues to be the healthiest food choice for Nunavummiut.

Climate change may increase human exposure to contaminants as the environment continues to warm. A changing climate may alter air and water currents that bring these contaminants into the Arctic (Inuit Circumpolar Conference Canada 2016; Nunatsiaq News 2014). Though recognized as a key knowledge gap, it is thought that climate change may alter how mercury cycles within the environment and whether or not it is converted to methylmercury to be taken up by wildlife (ECCC 2016a). Climate change can disrupt the physical characteristics and functions of the ecosystem, and these changes affect all of the processes in the biogeochemical cycle of mercury.

Diseases that can be transmitted from animals to humans (in scientific terms referred to as “zoonotic diseases”) are projected to increase as temperatures warm. This includes *trichinella* found in walrus and polar bear meat and *brucellosis* in caribou. The transmission of these and other diseases may increase when previously isolated wildlife populations come in contact with one another as natural barriers decrease.

Direct impacts on human health from a changing climate are related to natural hazards and increases in extreme weather events that may lead to an increased number of accidents and emergency situations. It has been reported that search and rescue missions are also impacted by a rapidly changing climate as searches are hampered by unpredictable weather patterns.

### 3.6.2 Cultural Heritage

Permafrost degradation and coastal erosion increased by later freeze-up of sea ice, also impacts heritage and special places. The cold Arctic climate can preserve organic material in permafrost. Changes in permafrost will continue to result in the destruction of cultural remains and archaeological artifacts that were previously well preserved (GN 2011). Ongoing freeze-thaw cycles promote decay of artifacts such as sod houses (many of which hold their form because of permafrost), and other historical resources such as sites relating to European exploration of the Arctic.

Naturally occurring coastal erosion is expected to be worsened by sea level rise, and increase threats to a number of historic sites on southern Baffin Island, northern Victoria Island and the western high Arctic islands on which little archaeological surveying has been done. Nunavut has seen a marked increase in the number of tourists who come north to experience the unique Arctic environment and to visit our heritage sites, parks and special places. Nunavut’s historic and archaeological resources are key attractions for cruise ships and other visitors. As such, their deterioration could negatively impact tourism.

### 3.6.3 Transportation

The average number of days with ice-free conditions (less than 15% ice concentration) in the Northwest Passage was 35 days in the period 1980–1999. In the period between 1979 to 1988 and 1998 to 2007, this number increased by 19 days. Climate change is expected to lead to a nearly ice-free late summer Arctic Ocean and increased navigability of Arctic marine waters within this century. Annually averaged maritime transportation accessibility by mid-century (2045 to 2059) relative to the baseline (2000 to 2014) is expected to increase by 19% in Canada (IPCC 2014b, Table 28-1).

The transportation sector is expected to experience significant impacts as a result of climate change (IPCC 2014b, GN 2011). The reduction of sea ice thickness and cover, coupled with an increase in the length of the summer shipping season will open up previously inaccessible areas of both land and water. This will lead to increased shipping and industrial activities. Loss of sea ice may open up waterways and opportunities for increased cruise traffic and add to an already rapid increase in cruise tourism. Climate change has already increased the prevalence of cruise tourism throughout Greenland, Norway, Alaska, and Canada. While this will translate to increased economic opportunities for Nunavut, it will also increase risks to the environment, most notably through spills and other pollution incidents.

Other transportation-related challenges have also been identified (GN 2011). For example, sea ice changes present challenges to traditional snowmobile or dog team transportation routes over the sea ice and will require, at the very least, identification of alternate routes for the safe continuation of traditional hunting and recreational activities.

Another significant transportation challenge includes impacts of degrading permafrost and changing freeze-thaw cycles that have visibly shifted and cracked the surface of airport runways throughout Nunavut (ITK 2014). In response to these challenges, Nunavut will require improved research, monitoring and response capabilities, including new and better infrastructure, mapping, and navigational systems. This improved infrastructure will likely include roads, asphalt paved runways, and fixed marine structures in coastal areas.

On the downside of these opportunities, the future status of marine, terrestrial, and freshwater biota may be negatively affected as a result of increased coastal infrastructure. Moreover, the frequency of marine transportation is at its highest during the most productive and vulnerable season for fish and marine mammals, which is the late spring/summer.

### 3.6.4 Infrastructure and Energy

Much of the physical infrastructure in the Arctic relies on and is adapted to local sea ice conditions, permafrost, and snow (e.g. to provide stable surfaces for buildings and pipelines, contain waste, stabilize shorelines, and access to remote communities). Damage from ice action and flooding to installations such as bridges, pipelines, drilling platforms, and hydropower poses major economic costs and risks, which are more closely linked to the design of the structure than with thawing permafrost. Current engineering practices are designed to help reduce the impacts. Northern safety, security, and environmental integrity are much dependent on transportation infrastructure. Ice as a provisioning system provides a transportation corridor and a platform for a range of activities and access to food sources in the Arctic. In northern Canada, climate warming presents an additional challenge for northern development and infrastructure design. While the impacts of climate change become increasingly significant over the longer time scales, in the short term of greater significance will be the impacts associated with ground disturbance and construction. Climate change impacts have increased the demand for improved communication infrastructure and related services and community infrastructure. The access, treatment, and distribution of drinking water are dependent on a stable platform of permafrost for pond or lake retention. Several communities have reported the need for more frequent water-quality testing of both municipal systems and untreated water sources to confirm its suitability for drinking.

In Canada, annually averaged inland transportation accessibility by mid-century (2045 to 2059) vs. the baseline (2000 to 2014) is expected to decrease by 13%, due to rising temperatures and changing precipitation patterns (IPCC 2014b).

Changes in permafrost, ice conditions, precipitation, drainage patterns, temperatures, and extreme weather events can have negative implications for existing infrastructure, which was designed for permafrost conditions. Permafrost thaw has been observed to cause building foundations to shift and destabilize.

Given the time period over which much of the present infrastructure is expected to last, older facilities may be more vulnerable because climate change was not considered when these structures were built. The impacts of climate change are expected to become a major burden on government resources. Municipal infrastructure impacted by degrading permafrost (e.g. sinking/cracking buildings) may divert resources from building new, basic infrastructure. Engineering and construction practices for building on changing permafrost are being adapted and developed. These changing practices will impact the cost of both construction and ongoing lifecycle maintenance of current and future infrastructure. Although new infrastructure is being designed to suit a changing environment, existing water and waste containment facilities may not have been designed to withstand the challenges of current and projected warming trends.

The changing climate will potentially have considerable impacts on Nunavut's energy sector. Warmer temperatures will have a direct impact on Nunavut's heating requirements making it less expensive to heat buildings. However, degrading permafrost has already affected existing power plants and is expected to impact fuel tank farms and transmission lines.

Some studies have suggested that precipitation will increase, which can have a positive effect on the amount of water available for hydroelectric power production. Possible changes in wind patterns may affect the feasibility of wind generation.

### 3.6.5 Tourism, Arts and Crafts

Climate change may impact the tourism industry in Nunavut. Longer summers will potentially result in increased tourism activity and a longer peak tourism season. Projected decreases in ice cover are likely to result in increased shipping traffic, particularly cruise ship activity into areas that were formerly inaccessible and/or had limited access. While beneficial, increased marine tourism brings challenges in the form of impacts on communities, historic resources, and the environment in general.

An increase in tourism activity should lead to an increase in sales of arts and crafts. Milder weather will make access to carving stone possible for longer periods during the year.

### 3.6.6 Resource Development

Current climate change projections, which include reduced sea ice cover and warmer temperatures, are likely to lead to an increase in exploration and industrial activities. The Canadian Arctic Archipelago has the potential for vast hydrocarbon deposits and mineral deposits. Oil and mineral resource development are expected to increase. Renewable resource development such as fisheries will also be impacted by climate change.

Fishing in Nunavut is an important part of the economy and subsistence living. It is likely that the number of fish species present in the waters off Nunavut will increase as sub-arctic species move northward with the warming climate (GN 2011). Although this could result in new opportunities for fisheries it could also add to stressors such as parasites and the appearance of new predators. Current and planned fisheries activities and management will need to be continuously monitored and adjusted as needed to address the impacts of climate change.

### 3.6.7 Mitigation Strategies

Inuit Tapiriit Kanatami is the national representational organization for Canada's 60,000 Inuit, the majority of whom live in four regions of Canada's Arctic, specifically, the Inuvialuit Settlement Region (Northwest Territories), Nunavut, Nunavik (Northern Quebec), and Nunatsiavut (Northern Labrador). Collectively, these four regions make up Inuit Nunangat, our homeland in Canada. It includes 53 communities and encompasses roughly 35 percent of Canada's landmass and 50 percent of its coastline. ITK (2016) presented the Government of Canada with the policy recommendations related to climate change adaptation that fall into five broad categories:

- **Meeting capacity, coordination, and information sharing needs -** Invest in Inuit-specific monitoring and evaluation of climate policies and programs. Ensure Inuit in the development and delivery of federal climate change programs.

Allocate sustained federal funding to support Inuit contributions to ongoing international climate change policy discussions.

- **Fostering Inuit knowledge inclusion, research, and educational goals -** Allocate long-term funding for Inuit-led climate change research to the four Inuit land claim organizations.
- **Strengthening Inuit food and harvesting systems -** Assist Inuit households in achieving food and water sovereignty and in mitigating the effects of climate change on Arctic ecosystems including shifting and/or declining wildlife and fish populations and loss and/or damage to harvesting equipment and infrastructure.
- **Addressing built and natural infrastructure deficits -** Develop a road map to lower carbon emissions in our communities while addressing northern infrastructure deficits that are — or will be — exacerbated by climate change including housing, energy, transportation, health, education, communication, waste water treatment, landfill, and search and rescue infrastructure deficits.
- **Supporting the linked aims of Inuit self-determination, energy independence, and clean technology adoption -** Support economic diversification strategies in Inuit Nunangat, ensuring in the short-term that all decisions follow the principles of free, prior, and informed consent as outlined in the United Nations Declaration on the Rights of Indigenous Peoples (United Nations (UNDRIP) 2008).

The policy recommendations were presented to the Government of Canada for consideration in developing a Canadian climate change strategy, including the Pan-Canadian Framework on Clean Growth and Climate Change (ECCC 2016b).

The Nunavut Climate Change Centre ($NC^3$) is a web-based climate change resource centre intended to provide current climate change information relevant to Nunavummiut, hosted by the Government of Nunavut's Climate Change Secretariat (https://www.climatechangenunavut.ca/en). The $NC^3$ is here to share and distribute climate change knowledge, research, and resources and make information more accessible to the public. The $NC^3$ hosts an impressive collection of information including Nunavut and pan-arctic policy documents, Nunavut and community climate change adaptation plans, and the Nunavut Permafrost Databank, which is a repository for ground temperature data collected by various parties across Nunavut.

# 4 REGULATORY AND TECHNICAL CONSIDERATIONS

## 4.1 Objectives

This section describes the territorial and federal climate change legislation and policies applicable to the Project, as well as Baffinland's approach to address regulatory and project approval conditions related to climate change and integrate climate change considerations into project planning and operations. Environmental Assessments currently being completed for the Project (the Phase 2 Proposal) link project planning to the broader management of key environmental concerns including climate change effects.

## 4.2 Applicable Legislation

There is currently no Nunavut legislation governing GHG emissions or climate change. The Project is currently subject to the federal GHG emissions reporting requirements outlined in the *Canadian Environmental Protection Act* (*CEPA 1999*). Facilities in Canada that emit over 10,000 t of $CO_2$-e must report emissions to Environment Canada for the Greenhouse Gas Emissions Reporting Program (Minister of Justice 2017, ECCC 2018). Baffinland's annual GHG emissions exceeded the previous threshold of 25,000 t $CO_2$-eq starting in 2014. As such, Baffinland reports its annual GHG emissions to ECCC, and to the NIRB under PC Conditions 6 and 9. Baffinland's annual GHG emissions were 135,743 t $CO_2$-eq in 2016 and 160,000 t $CO_2$-eq in 2017 (Baffinland 2017 and 2018).

In 2016, the Government of Canada released "the Pan-Canadian approach to pricing carbon pollution" (ECCC 2016b). This plan outlines criteria that carbon pricing systems implemented by provinces and territories need to meet. A central component of the Pan-Canadian Framework is the commitment to pricing carbon pollution by 2018.

The Government of Canada has requested that provinces and territories that choose the federal backstop, in whole or in part, confirm this by March 30, 2018. The Government of Nunavut does not plan to establish its own carbon pricing system, and therefore the federal carbon pricing backstop will apply in Nunavut starting on January 1, 2019. All revenue from the federal carbon pricing backstop program will be returned to the Government of Nunavut (Nunatsiaq News 2018).

The federal carbon pricing backstop is comprised of two elements (ECCC 2017c):

- a charge on fossil fuels that is generally payable by fuel producers or distributors, with rates that will be set for each fuel such that they are equivalent to \$10 per tonne of carbon dioxide equivalent ($CO_2e$) in 2018, rising by \$10 per year to \$50 per tonne $CO_2e$ in 2022; and
- an Output-Based Pricing System (OBPS) for industrial facilities.

The aim of the OBPS is to minimize competitiveness risks for emissions-intensive, trade-exposed industrial facilities, while retaining the carbon price signal and incentive to reduce GHG emissions. The charge is not intended to apply to fuel used at a facility that is part of the OBPS. Each OBPS facility will instead be subject to the carbon price on the portion of emissions that exceed an annual output-based emissions limit. In jurisdictions where the backstop applies, the OBPS will apply to industrial facilities that emit 50 kilotonnes (kt) $CO_2e$ or more and for which an output-based standard is specified, or that emit between 10 and 50 kt $CO_2e$ per year and whose application for voluntary participation is approved. The Mary River Project will be subject to the OBPS.

The Government of Nunavut will reportedly receive 100 per cent of all revenue that the federal government will collect from its backstop carbon tax, estimated at \$15 million in 2019-2020.

## 4.3 NIRB Project Certificate Requirements Regarding Climate Change

Nunavut's regulatory system was established by the Nunavut Agreement (Indian and Northern Affairs Canada 2009), and has been further defined by the *Nunavut Planning and Project Assessment Act* (Minister of Justice 2015). The Nunavut Impact Review Board (NIRB) undertakes environmental screenings and reviews of major development project proposals, and issues successful proponents a Project Certificate with terms and conditions to be met during the project life. The Project operates in accordance with Project Certificate No. 005, which contains more than 182 conditions governing its operations. Project Certificate (PC) Conditions 2, 3 and 4 relate to climate change (Table 4.1). Two PC conditions (PC Conditions 6 and 9) require Baffinland to report of annual emissions of GHGs and other air contaminants in its annual report to the NIRB.

**Table 4.1 How Climate Change PC Conditions Are Being Fulfilled**

| PC Condition No. | PC Condition Requirement | Baffinland Action |
|---|---|---|
| 2 | The Proponent shall provide the results of any new or revised assessments and studies done to validate and update climate change impact predictions for the Project and the effects of the Project on climate change in the Local Study Area and Regional Study Area as defined in the Proponent's Final Environmental Impact Statement. | Section 2 of this report provide an updated assessment of the effects of the Project (the Phase 2 Proposal) on GHG emissions and climate change. Section 3 of this report is an assessment of the effects of climate change on the Project. |
| 3 | The Proponent shall provide interested parties with evidence of continued initiatives undertaken to reduce GHG emissions. | Challenges and opportunities with respect to reducing GHG emissions is described in Section 4.5. |
| 4 | The Proponent shall endeavor to include the participation of Inuit from affected communities and other communities in Nunavut when undertaking climate-change related studies and research. | Baffinland's stakeholders have identified climate change as a key issue in Nunavut, with communities reporting observations of the changing climate. Participants from the Mary River Inuit Knowledge Study (2007-2010; Baffinland, 2014a) shared observations related to climate change in the Arctic. In 2015 and 2016, Baffinland engaged the communities of Pond Inlet and Arctic Bay through workshops to discuss the Phase 2 Proposal, and a limited amount of feedback was received in regard to observations of climate change (TSD-3; JPCSL, 2017).<br>Baffinland has not yet initiated Project-specific climate change research. |
| 6 | The Proponent shall provide the results of any emissions calculations conducted to determine the level of sulphur dioxide ($SO_2$) emissions, nitrogen oxide ($NO_X$) emissions and greenhouse gases generated by the Project using fuel consumption or other relevant criteria as a basis. | PC Conditions 6 and 9 are fulfilled annually when Baffinland reports its annual GHG emissions in its annual report to the NIRB. |
| 9 | The Proponent shall provide calculations of greenhouse gas emissions generated by activities at the Steensby Inlet and Milne Inlet port sites and other Project sources including aircraft associated with the Project. Calculations shall take into consideration, fuel consumption as measured by Baffinland's purchase and use as well as the fuel use of its contractors and sub-contractors. | |

The Project also operates under a number of licences, permits, authorizations and approvals. These include a comprehensive water licence, various land tenure instruments, authorizations under the *Fisheries Act*, and approvals under the *Navigation Protection Act*. None of these authorizations impose climate change related requirements on the Project.

## 4.4 Applicable Policies and Other Guidance

The Government of Nunavut (GN) and other Inuit organizations have been proactive in evaluating the risks that climate change represents to Inuit, developing the following policies and strategies to address climate change:

- Climate Change Secretariat Strategic Plan (GN 2017);
- Upagiaqtavut - Setting the Course - Climate Change Impacts and Adaptation in Nunavut (GN 2011);
- Pan-Territorial Adaptation Strategy (Government of the Northwest Territories, GN and the Government of Yukon 2011);
- Nunavut Climate Change Strategy (GN 2003); and
- Inuit Priorities for Canada’s Climate Strategy: A Canadian Inuit Vision for Our Common Future in Our Homelands (Inuit Tapiriit Kanatami [ITK] 2016).

These documents state that there is evidence that climate change is occurring; provide priorities for policymaking or are policies themselves; and describe adaptive management strategies to be employed by governments and other organizations. The GN addresses climate change in Nunavut in two ways; mitigation and adaptation. Mitigation involves finding and implementing methods to reduce greenhouse gas emissions. Adaptation includes actions to reduce the negative impacts and increase potential benefits from a changing climate (GN 2011).

The Canadian Environmental Assessment Agency (CEAA) provides guidance on incorporating climate change considerations in environmental assessments (CEAA 2003). This guidance provided a general framework that is being used within this Report.

## 4.5 Challenges and Opportunities to Reduce Project GHG Emissions

The climate and remoteness of the Project plays a key role in establishing the current level of GHG emissions, and in identifying opportunities for GHG reduction. There are a number of factors that make the Mary River Project a relatively energy intensive operation:

- The remote location requires equipment, materials and consumables to be transported by annual sealift or by airlift, and ore to be transported by ship to markets;
- The Mine’s inland location requires overland transport of ore to the coast;
- The fly-in/fly-out operation requires heavy reliance on air travel to move workers in and out of the site;
- The cold climate requires more fuel for heating and for diesel engines to idle; and
- The remote location means that grid power is not available and the project must generate all of its own power from diesel (as the transport of other lower GHG intensive fuels such as natural gas to site is not feasible).

The Project’s high-grade iron ore does not require processing however, and so there are no GHG emissions associated with processing or the management of processing waste (tailings) which are required in processing lower grade ores at some other mine sites. In terms of lifecycle GHG emissions, this would partially offset the higher energy requirements related to transportation and on-site energy production. Additionally, the Project has incorporated lower GHG intensive transportation methods where feasible. Rail haulage is preferred over trucks as railroads are four times more fuel-efficient than trucks (Association of American Railroad 2017). That means moving freight by rail instead of truck reduces greenhouse gas emissions by 75 percent. These comparisons are based on the use of existing railways and therefore do not account for construction of the rail infrastructure, which Baffinland's GHG estimate for the Phase 2 Proposal includes.

Other GHG reduction opportunities for the Project may exist with energy conservation measures, the conversion of on-site power generation from diesel to a renewable energy source, and changing the mode of ore haulage from trucks to less energy intensive rail. The switch from road to rail is proposed as part of the Phase 2 Proposal. The Phase 2 Proposal will generate approximately 22.6 Mt $CO_2e$ of GHG emissions to mine 366 Mt of iron ore from Deposit No. 1, a reduction of 10.3% relative to the Approved Project (Section 2.3.1). The switch to rail and the use of larger ore carriers are among the contributing factors to this reduction.

Regarding renewable energy opportunities, several Arctic mines have recently employed wind farms to reduce GHG emissions. These include the Diavik Diamond Mine in the Northwest Territories (Rio Tinto 2015), and the Raglan Mine in Nunavik (Glencore 2017). Studies have been conducted evaluating the potential for wind, solar and hydroelectric power to serve communities in Nunavut (Qulliq Energy Corporation 2017a; Waterloo Institute of Sustainable Energy (WISE) 2016; Karanasios and Parker 2016; Knight Piésold 2006a, 2008, 2011 and 2013). Pilot solar photovoltaic projects are presently being initiated in several Qikiqtani communities by Qulliq Energy Corporation (2017b) and Greenpeace Canada (Nunatsiaq News 2017).

Baffinland's recent efforts to investigate the viability of wind power at the Mine Site and Milne Port is described in TSD-2. Baffinland previously conducted a pre-feasibility study on a potential hydroelectric project at Separation Lake, located approximately 35 km southeast of the Steensby Port (Knight Piésold 2006b). The Separation Lake hydroelectric project is a significant distance from the Mine Site, but may warrant further investigation of its potential viability when Steensby Port is constructed.

## 4.6 Incorporating Climate Change Predictions into Project Design

The Mary River Project incorporates the following design measures to project infrastructure to address climate change predictions:

- Rail embankment design to account for permafrost ground conditions including predicted changes to permafrost conditions over time due to climate change;
- Designing railway crossings to a higher return period to account for more extreme flows due to climate change;
- Dock design accounting for potential sea level rise; and

These design mitigation measures are described further below.

### 4.6.1 Rail Embankment Design

As noted in Section 3.4.2, Climate Normals for Environment Canada's 'Pond Inlet A' station show a warming of 0.6°C in the summer (June, July, August) and no change in average winter temperatures (December, January, February) over the period of 1971 to 2010. The mean global surface air temperature for the period 2016–2035 will likely be between 1°C and 1.5°C more than the 1850-1900 mean temperature. Increasing ambient atmospheric temperatures are inducing a reduction in the extent of permafrost by altering the thermal regime of permafrost soils, and depending upon the ground conditions can cause both thaw settlement and weakening, as well as slope instability.

A warming of permafrost has been documented to have occurred over the past couple of decades (Section 3.4.6). Ground temperatures at 15 m below surface have been observed to increase in the order of 0.1 to 0.15°C annually (Richter-Menge and Mathis 2016; Gross et al. 2011; Smith 2011). Moderate climate change forecasts predict a 3.5 to 4°C warming of permafrost over the 100-year period in the Project region, and more extreme climate change scenarios predict a median warming of 6.4°C by 2081 to 2100.

The long-term performance of embankments constructed in permafrost regions requires specialized design considerations, particularly in areas dominated by ice-rich soils (i.e., creep, and thaw settlement). The following mitigation measures that were identified for the South Railway in the FEIS (Volume 6, Section 2.3.2; Baffinland 2012) will be implemented during construction of the North Railway to account for the effects of climate change on the underlying permafrost:

- Excavations will be minimized, especially in areas of known ice-rich permafrost.
- Prior to embankment construction, ground disturbance will be minimized and vegetative or organic cover left in place to provide the maximum protection of the thermal regime.
- In areas where excavation is required, the foundations will be over excavated and backfilled with 0.8 m of non-freeze/thaw susceptible fill to minimize frost heaving and settlement.
- Excavations in ice-rich permafrost will include the installation of a geotextile layer and a high-density insulation layer.
- Slopes will be flattened as necessary when being constructed in ice-rich or thaw sensitive materials, and will be protected with erosion protection material, if required. This will include a geotextile layer as well as an engineered backfill.
- For high embankment fills on ice-rich materials, the side slopes may be flattened significantly or stabilization berms constructed to reduce the creep deformation potential.
- For construction during the summer, woven geotextile may be required over unstable ground.
- Proper runoff collection and diversions drainage systems will be used to control runoff and erosion from affecting the modified thermal regime. As part of basic design, thermal modeling will be conducted for each typical embankment condition and configuration to identify the actual permafrost protection measures required and to predict the nature of the active layer and the effect that construction will have on the thermal regime over the life of the Project. The thermal modeling will incorporate potential warming trends resulting from climate change based on world-recognized global warming scenarios.
- Thaw settlements and surface sloughing of cut slopes is expected, particularly during the thaw seasons immediately following construction. The behaviour of both cut slopes and embankment fills will be monitored throughout these thaw seasons and remedial measures will be implemented as necessary. For example, it is expected that many of the cut slopes will need to be monitored as thaw settlements occur. Silt fences and other erosion protection measures will be installed as necessary to prevent siltation of adjacent drainage courses and water bodies.
- Minimize changes to the hydrologic drainage patterns.

### 4.6.2 Design Return Period for Railway Watercourse Crossings

A general intensification of the global hydrological cycle is expected to occur with a future warmer climate (Section 3.4.4). Simulations predict both global precipitation and global evaporation to increase by 1 to 3% per 1°C of global warming. With respect to the Project area, zonal mean precipitation (i.e., average precipitation across all longitudes for a given latitude) will very likely increase in high latitudes. The increases in precipitation will be largely met with an increase in evaporation. Though increased evaporation will largely offset the increased precipitation, increased extremes in both precipitation and runoff are expected with a future warmer climate.

On the South Railway, Baffinland used the 200-year storm event return period, plus an allowance for ice accumulation, to size culverts along the South Railway in the FEIS (Volume 3, Section 2.5.6; Baffinland 2012). The same design return period is deemed adequate to account for the increases in precipitation predicted in the latest climate models.

### 4.6.3 Ore Dock

The ore dock must account for the potential sea level rise due to climate change. As described in Section 3.5.4, it is estimated that the total global sea level rise between 1910 and 2010 has been 0.19 m, with higher rates towards the end of the 20$^{th}$ century and beginning of the 21$^{st}$ century. The dominant contributors to this increasing rate have been ocean thermal expansion and glacier melting. The 20-year average of mean sea-level rise in the period 2081–2100, relative to 1971-2010 are projected to range from between 0.44 m to 0.74 m. Baffinland can confirm that the design of the second ore dock can account for this increase in sea level.

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