GAHCHO KUÉ PROJECT

ENVIRONMENTAL IMPACT STATEMENT

SECTION 11.13

SUBJECT OF NOTE: CLIMATE CHANGE IMPACTS

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11.13.1 Introduction

11.13.1.1 Context

This section of the Environmental Impact Statement (EIS) for the Gahcho Kué Project (Project) consists solely of the Subject of Note: Climate Change Impacts. In the *Terms of Reference for the Gahcho Kué Environmental Impact Statement* (Terms of Reference) issued on October 5, 2007, the Gahcho Kué Panel (2007) requested that climate change impacts be a specific subject of note and provided the following reason:

> *"The scientific consensus is that the North is particularly vulnerable to impacts from a changing climate."*

The Subject of Note: Climate Change Impacts is closely related to air quality. Although greenhouse gas (GHG) emissions associated with the Project were estimated as part of the Subject of Note: Air Quality (Section 11.4), they are summarized and presented here to meet the Gahcho Kué Panel (2007) Terms of Reference requirements. This subject of note also contains an evaluation of the effects of climate change on the Project, including how it may alter Project impacts.

Climate change may not be relevant to some key lines of inquiry and subjects of note, if climate change is not expected to affect the pathways considered in those sections of the EIS. It is relevant to the key lines of inquiry and subjects of note where climate change could alter the Project in a manner that changes the Project's predicted effects on a valued component (VC). An assessment of those potential changes to predicted effects has been completed and is outlined herein. Key lines of inquiry and subjects of note closely linked to this subject of note include the following:

- Key Line of Inquiry: Water Quality and Fish in Kennady Lake (Section 8);
- Subject of Note: Alternative Energy Sources (Section 11.3);
- Subject of Note: Mine Rock and Processed Kimberlite Storage (Section 11.5); and
- Subject of Note: Permafrost, Groundwater, and Hydrogeology (Section 11.6).

11.13.1.2 Purpose and Scope

The purpose of the Subject of Note: Climate Change Impacts is to meet the Terms of Reference for the EIS issued by the Gahcho Kué Panel. The Terms of Reference for this subject of note are shown in Table 11.13-1 together with the locations where they are addressed in the EIS. The Terms of Reference document is included in Section 1, Appendix 1.I, and the complete table of concordance for the EIS is in Section 1, Appendix 1.II of the EIS.

The assessment of climate change follows the approach outlined in the report, *Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners* (Climate Change Assessment Guide), which was prepared by The Federal-Provincial-Territorial Committee on Climate Change and Environmental Assessment (FPTCCCEA 2003). As recommended in that document, the assessment of climate change in this subject of note includes two components:

- the Project's contribution to climate change in the form of GHG emissions; and
- the potential impact of climate change on the Project.

Greenhouse gas emission estimates are presented and summarized here in Section 11.13 and are evaluated following the process recommended in the climate change assessment guide. As required in the Terms of Reference, this subject of note also examines the use of alternative energies, energy conservation initiatives, and linkages between greenhouse gas (GHG) prevention and other environmental opportunities.

The potential impacts of climate change on the Project include an evaluation of how climate change could directly affect the Project and how it may alter predicted Project effects to VCs. Where climate change has the potential to alter predicted effects to VCs, the potential effect pathways by which this change could occur are identified and evaluated to determine how climate change may influence the Project effects outlined elsewhere in the EIS. Alternatives for transporting goods via the Tibbitt-to-Contwoyto winter road are also considered.

Although the influences from climate change on altering environmental residual effects (those remaining after consideration of environmental design features and mitigation) from the Project are assessed and summarized, a formal classification of residual effects is not provided in this subject of note. The analysis of effects of climate change on the Project and related environmental effects is an uncertainty analysis, and it would not be appropriate to classify impacts related to uncertain future climate conditions. Impact predictions based on known climate conditions are provided and classified in the subject of notes and key lines of inquiry that involve VCs.

Table 11.13-1 Terms of Reference Pertaining to Climate Change Impacts

Final Terms of Reference Requirements		Applicable EIS Sub-section
Section	**Description**	
5.2.7 Biophysical Subjects of Note: Climate Change Impacts	General requirements pertaining to climate change impacts include:	
	- the EIS must examine and evaluate the development (Project) as a potential greenhouse gas contributor	11.13.3
	- it (the EIS) must also examine potential climate change effects on the proposed development (Project)	11.13.4
	- the EIS must examine quantity of greenhouse gas emissions, the use of alternative energies, energy conservation initiatives, and linkages between greenhouse gas prevention and other environmental opportunities	11.13.3, 11.13.6
	- climate change scenarios and their impacts on the development, as well as climate variability and its impacts (e.g., on the operation of the ice road). This analysis must include the effect of changing extremes, such as 100-year rainfall events)	11.13.4
	- the EIS must include an evaluation of the potential for the development to create a local change in climate at the mine site	11.13.4
	- the EIS must address climate change impacts in combination with development related impacts on any of the valued components	11.13.4
	- the EIS must outline any specific adaptations of the development to climate change, as well as management options for a variety of future climate change effect scenarios	11.13.4, 11.13.6
	- the EIS must provide a detailed analysis of alternatives to transporting goods via road to the development site (as the ice road and the traffic on it contribute to greenhouse gas emissions and are vulnerable to climate change at the same time)	11.8, 11.13.4
	- the EIS must provide a detailed account of energy conservation initiatives on-site, addressing subjects such as vehicle idling policies, use of waste oil for heating, etc. Describe how this compares to energy conservation plans at other diamond mines	11.13.4, 11.13.6
	Specific requirements pertaining to climate change impacts include:	
	- describe the quantity of emissions (in absolute terms, as proportion of NWT industrial emissions, and as proportion of NWT total emissions)	11.13.3
	- describe project alternatives, including greenhouse gases offsetting options and technology innovations (including descriptions of alternative energy initiatives on-site)	11.3
	- describe linkages between greenhouse gas prevention and other environmental opportunities (e.g., air and water pollution reduction, sustainable development)	11.13.6
7 (Table 7-4) Other Issues	Other issues pertaining to climate change include:	
	- impact on project design	11.13.4
	- transportation alternatives	11.13.4, 11.13.6
	- energy alternatives	11.3
	- creation of microclimate at the mine site	11.13.4

Source: *Terms of Reference for the Gahcho Kué Environmental Impact Statement* (Gahcho Kué Panel 2007).

Note: EIS = Environmental Impact Statement.

11.13.1.3 Study Area

General Location

The Project is situated north of East Arm of Great Slave Lake in the Northwest Territories (NWT) at Longitude 63° 26’ North and Latitude 109° 12’ West. The Project site is about 140 kilometres (km) northeast of the nearest community, Łutselk’e, and 280 km northeast of Yellowknife (Figure 11.11-1).

Study Area Selection

The Study Area for the evaluation of climate change on the Project includes the mine site and associated infrastructure, which are collectively referred to as the Project footprint, and the Tibbitt-to-Contwoyto Winter Road and Winter Access Road. The locations of the winter roads are shown in Figure 11.1-1. The Project footprint is shown in Figure 11.1-2.

11.13.1.4 Content

Section 11.13 provides details of the impact analysis and assessment related to climate change. The headings in this section are arranged according to the sequence of steps in the assessment. The following briefly describes the content under each heading of this subject of note:

- **Potential Changes in Climate** presents a summary of the current climate, the methods used to predict the extent of climate change and the results of the future climate projections (Section 11.13.2).
- **Greenhouse Gas Emissions Assessment** summarizes, presents, and assesses the amount of GHG the Project is expected to contribute to the environment (Section 11.13.3).
- **Pathway Analysis** identifies the potential pathways by which climate change could affect Project activities or alter environmental effects of the Project, summarizes the environmental design features and mitigation that will eliminate these pathways or reduce associated effects, and assesses the linkages of each identified pathway (Section 11.13.4.1).
- **Effects Analysis** presents the methods used to evaluate primary pathways and the results of the analysis (Section 11.13.4.2).
- **Residual Effects Summary** presents a summary of how climate change could alter the Project or the predicted impacts of the Project (Section 11.13.5).
- **Uncertainty, Monitoring, and Follow-up** discusses sources of uncertainty surrounding the evaluation of how climate change may alter

the Project or the predicted impacts of the Project, and describes recommended monitoring programs, contingency plans and adaptive management strategies related to climate change (Section 11.13.6).

- **References** lists all documents and other material used in the preparation of this section (Section 11.13.7).
- **Glossary, Acronyms, and Units** explains the meaning of scientific, technical, or other uncommon terms used in this section. In addition, acronyms and abbreviated units are defined (Section 11.13.8).

11.13.2 Potential Changes in Climate

11.13.2.1 Methods

An evaluation of the potential effects of climate change on impact predictions requires an understanding of how the climate has been changing and how it may change in the future. Current climate conditions for the Study Area were evaluated using recent climate normals (e.g., 30 years) available for Yellowknife. Future climate conditions in the Study Area were estimated using applicable climate projection data from the Canadian Climate Change Scenarios Network (CCCSN) website (CCCSN 2010, internet site), which is operated by Environment Canada. Further detail about the methods used to evaluate how climate in the Study Area may change is provided below.

11.13.2.1.1 Climate Projection Models

Projections of future climate conditions are based on sophisticated mathematical computer programs called General Circulation Models (GCMs). These models simulate the interactions of airborne emissions, the atmosphere, land surfaces and oceans. Due to their complexity, it can take several months to complete a single model simulation.

The Intergovernmental Panel on Climate Change (IPCC) provides regular reviews of climate change science and uses several different GCMs. The 24 models presented in Table 11.13-2 were used in the IPCC's Fourth Assessment Report (IPCC 2007). Canadian projected data from these models were made available from CCCSN (2010, internet site).

Table 11.13-2 General Circulation Models Considered in the Assessment

Organization	Model	Country	Emission Scenarios[(a)]
Bjerknes Centre for Climate Research	BCM2.0	Norway	A2, A1B, B1
Canadian Centre for Climate Modelling and Analysis	CGCM3T47 (T47 resolution)	Canada	A2, A1B, B1
Canadian Centre for Climate Modelling and Analysis	CGCM3T63 (T63 resolution)	Canada	A2, A1B, B1
Centre National de Recherches Météorologiques	CNRMCM3	France	A2, A1B, B1
Commonwealth Scientific and Industrial Research Organization	CSIROMk3.0	Australia	A2, A1B, B1
Commonwealth Scientific and Industrial Research Organization	CSIROMk3.5	Australia	A2, A1B, B1
Max Planck Institute for Meteorology	ECHAM5OM	Germany	A2, A1B, B1
Meteorological Institute, University of Bonn Meteorological Research Institute of KMA Model and Data Groupe at MPI-M	ECHO-G	Germany	A2, A1B, B1
Institute of Atmospheric Physics, Chinese Academy of Sciences	FGOALS-g1.0	China	A1B, B1
Geophysical Fluid Dynamics Laboratory	GFDLCM2.0	United States	A2, A1B, B1
Geophysical Fluid Dynamics Laboratory	GFDLCM2.1	United States	A2, A1B, B1
Goddard Institute for Space Studies	GISS-AOM	United States	A1B, B1
Goddard Institute for Space Studies	GISS-EH	United States	A1B
Goddard Institute for Space Studies	GISSE-ER	United States	A2, A1B, B1
UK Met Office	HADCM3	United Kingdom	A2, A1B, B1
UK Met Office	HADGEM1	United Kingdom	A2, A1B
National Institute of Geophysics and Volcanology	INGV-SXG	Italy	A2, A1B
Institute of Numerical Mathematics, Russian Academy of Science	INMCM3.0	Russia	A2, A1B, B1
Institut Pierre Simon Laplace	IPSLCM4	France	A2, A1B, B1
National Institute for Environmental Studies, University of Tokyo	MIROC3.2 hires	Japan	A1B, B1
National Institute for Environmental Studies, University of Tokyo	MIROC3.2 medres	Japan	A2, A1B, B1
Meteorological Research Institute, Japan Meteorological Agency	MRI-CGCM2.3.2	Japan	A2, A1B, B1
National Centre for Atmospheric Research	NCAR CCSM3	United States	A2, A1B, B1
National Centre for Atmospheric Research	NCAR PCM	United States	A2, A1B, B1

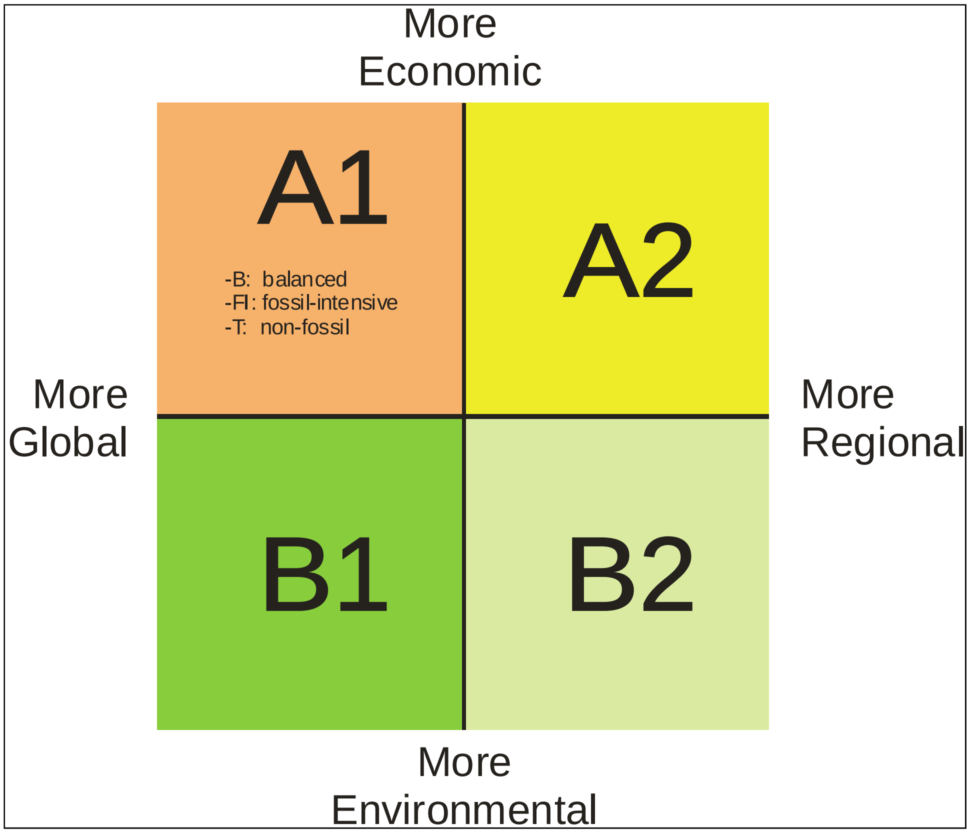
Source: CCCSN 2010, internet site.

[(a)] A1 and A2 scenarios focus on economic growth, while B1 and B2 scenarios consider more environmentally focused growth.

11.13.2.1.2 Projection Scenarios

Given the range of inputs available to the GCMs, the IPCC has established a series of global GHG emission scenarios based on four potential socio-economic development paths. The Fourth Assessment Report (IPCC 2007) identifies these scenarios as A1, B1, A2, and B2. The A1 and A2 scenarios focus on economic growth, while the B1 and B2 scenarios shift towards more environmentally sustainable solutions to growth. Scenarios A1 and B1 shift towards global solutions, while the A2 and B2 scenarios focus on growth-based regional approaches. Figure 11.13-1 provides an illustrative summary of the four emission scenarios, which are described more fully in the IPCC Special Report on Emissions Scenarios (SRES) (IPCC 2000).

Figure 11.13-1 Intergovernmental Panel on Climate Change Emission Scenarios



Although the IPCC has not stated which of the emission scenarios is most likely to occur, the A2 scenario appears to most closely reflects the current global socio-economic situation, and is closely related to the IS92a scenario that was used by IPCC historically in its climate assessments. In relation to the A2 scenario, scenarios A1, B1, and B2 result in lower long-term GHG emissions over the next century. Of the A1 scenario family, scenario A1FI yields high emissions in the first half of the 21st century, because of increasing population and high dependence on fossil fuels for energy. Scenario A1T emphasizes the use of non-fossil fuels. Scenario A1B represents a balance with a mix of fossil and non-fossil fuels. The SRES scenarios so far evaluated with each GCM are summarized in Table 11.13-2.

11.13.2.1.3 Baseline Climate

Climate change analysis not only depends on future conditions but also on the baseline climate to which the predictions are compared. Baseline climate information is important for describing average conditions, spatial and temporal variability, anomalous events, and calibrating and testing climate models (CCCSN 2010, internet site).

The baseline period used for this assessment was 1980 to 2009, which is the most recent 30-year period. This period was selected because it is considered to:

- be representative of the present-day or recent average climate;
- be of a sufficient duration to encompass a range of climatic variations, including several weather anomalies;
- cover a period for which data on all major climatological variables are abundant, adequately distributed over the Earth, and readily available; and
- include data of sufficiently high quality for use in evaluating impacts.

Establishing baseline climatic conditions in the Study Area provides context when evaluating projections of future changes in climate. The baseline climate is described using climate data from an appropriate nearby station. For the purposes of this Project, the data from the Yellowknife station operated by the Meteorological Service of Canada is considered to be the most appropriate given the long period of record and data coverage. This assessment of baseline climate focuses on temperature and precipitation, as these parameters are the most widely assessed and available. The assessment also focuses on expected, or average, conditions as this information is consistent with the data available for future climate projections.

Baseline climate conditions (or “climate normals”) refer to arithmetic calculations based on observed climate values for a given location over a specified period. The World Meteorological Organization recommends that climate normals be prepared at the end of every decade for the official 30-year period. The latest official climate normals cover the period 1971 to 2000; however, in order to incorporate the most recent observations, a 30-year average was calculated for Yellowknife using 1980 to 2009 observations.

11.13.2.2 Baseline Climate

A summary of the annual and seasonal climate data (1980 to 2009) for the Yellowknife station is provided in Table 11.13-3. The 1971 to 2000 climate normals are shown for comparison. The seasonal averages are represented by the following:

- spring – March, April, and May;
- summer – June, July, and August;
- fall – September, October, and November; and
- winter – December, January, and February.

Table 11.13-3 Observed Climate Normals for Yellowknife

Period	Season	Observed Normals	
		Temperature (°C)	Precipitation (mm)
1971-2000[a]	annual	-4.6	280.7
	spring	-5.7	43.3
	summer	14.8	102.8
	fall	-2.8	91.4
	winter	-24.6	43.3
1980-2009[b]	annual	-4.2	285.2
	spring	-5.8	44.4
	summer	14.8	107.0
	fall	-2.5	89.9
	winter	-23.6	43.8

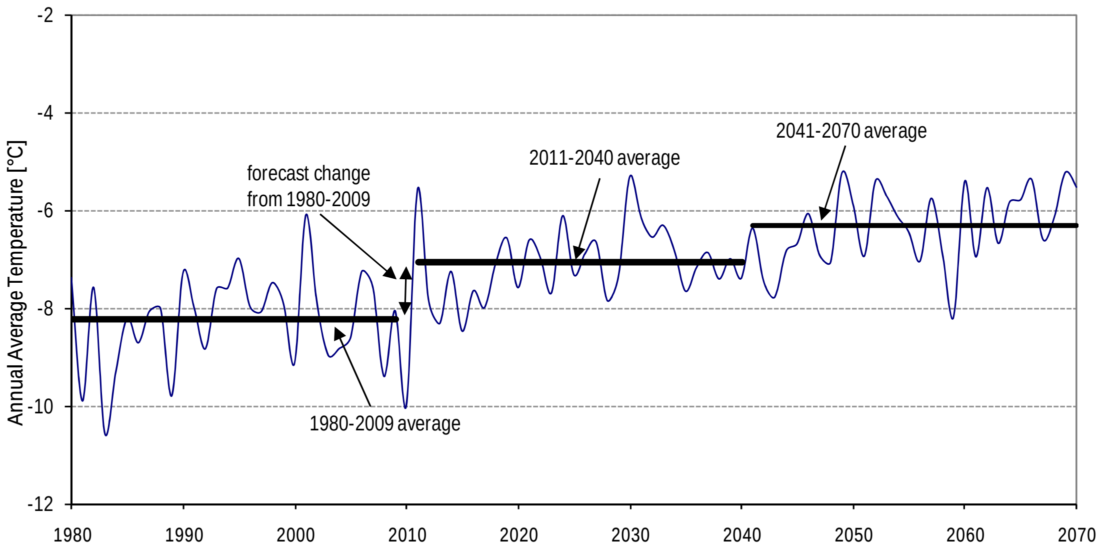
[a] Source: Environment Canada (2010a, internet site).
[b] Calculated based on data from Environment Canada (2010b, internet site).
°C = degrees Celsius; mm = millimetres.

11.13.2.3 Future Climate

Climate projection data from various models and emissions scenarios were analyzed to estimate possible climate change in the region. Because the models are susceptible to inter-decadal variability, the analysis used the average of 30 years of data, centred on the decade of interest. The future conditions have been represented by the 30-year period between 2011 and 2040, representative of the mid-2020s. This period is near the end of the life of the Project and incorporates the post-operations management and closure period of the Project.

The projected change in climate relative to the 1980 to 2009 baseline represents the total change projected between the modelled 30-year average for 1980 to 2009 and the modelled future conditions, as represented by the 30-year period between 2011 and 2040. This concept is illustrated in Figure 11.13-2.

Figure 11.13-2 Evaluating Climate Change Relative to the 1980 to 2009 Baseline



°C = degrees Celsius.

The projected changes in temperature and precipitation relative to the 1980 to 2009 baseline were determined for all 65 of the models/scenarios available on the CCCSN website for the corresponding model grid cell covering the Study Area. While all of the climate projection information is valuable, it is not practical to evaluate the potential impacts for every possible scenario. The challenge of selecting the appropriate scenarios to be evaluated can be addressed using Burn's approach (Burn 2003). Burn (2003) recommended using the 86th percentile projections in environmental assessments in the Mackenzie Valley. This percentile incorporates all the model results falling within approximately one standard deviation of the median annual average temperature.

For this assessment, model projections were initially ranked by annual and seasonal average temperatures and by annual and seasonal precipitation. The predicted temperature and precipitation changes for the "low" (9th highest or 86th percentile), "mid" (33rd highest or median) and "high" (56th highest or 14th percentile) scenarios were then determined.

Based on this analysis, the annual average temperature in the Study Area is projected to increase by 0.7 degrees Celsius (°C) to 1.6°C through the 2011 to 2041 period (Table 11.13-4. The largest increase is expected to occur in the winter season, wherein temperatures may increase by 3.6°C to 8.0°C. Annual precipitation is projected to change by -0.2 percent (%) to +9.0% by 2011 to 2040 (Table 11.13-5). In Yellowknife and, by extension, the Study Area, this change would result in annual precipitation ranging from approximately 285 to 311 millimetres (mm). As with temperature, the largest changes in precipitation are projected to occur in winter, with increases in precipitation ranging from 5.3% to 22.4%. In Yellowknife and in the Study Area, this change would result in winter precipitation ranging from approximately 46 to 54 mm.

Table 11.13-4 Climate Change Scenario Temperature Projections

Season	Yellowknife 1980 to 2009 Average[a] (°C)	Projected Change for 2011 to 2040 Relative to the 1980 to 2009 Baseline (°C)		
		Low [b]	Mid [c]	High [d]
Annual	-4.2	+0.7	+1.2	+1.6
Summer	14.8	+1.5	+2.5	+3.8
Winter	-23.6	+3.6	+5.9	+8.0

[a] Yellowknife average temperature calculated based on data from Environment Canada (2010b, internet site).
[b] The "low" projection is based on the 14th percentile (i.e., 9th highest) prediction.
[c] The "mid" projection is based on the 50th percentile (i.e., 33rd highest) prediction.
[d] The "high" projection is based on the 86th percentile (i.e., 56th highest) prediction.
°C = degrees Celsius.

Table 11.13-5 Climate Change Scenario Precipitation Projections

Season	Yellowknife 1980 to 2009 Average[a] [mm]	Projected Change for 2011 to 2040 Relative to the 1980 to 2009 Baseline (%)		
		Low [b]	Mid [c]	High [d]
Annual	285.2	-0.2	+4.0	+9.0
Summer	107.0	-2.8	+4.4	+11.0
Winter	43.8	+5.3	+15.0	+22.4

[a] Yellowknife average precipitation calculated based on data from Environment Canada (2010b, internet site).
[b] The "low" projection is based on the 14th percentile (i.e., 9th highest) prediction.
[c] The "mid" projection is based on the 50th percentile (i.e., 33rd highest) prediction.
[d] The "high" projection is based on the 86th percentile (i.e., 56th highest) prediction.
mm = millimetres; % = percent.

11.13.3 Greenhouse Gas Emissions Assessment

11.13.3.1 Methods

The GHG assessment followed the methods outlined in the guidance document prepared by The Federal-Provincial-Territorial Committee on Climate Change and Environmental Assessment (FPTCCCEA 2003). The methods included the following steps:

- identifying and assessing GHG considerations;
- developing GHG management plans, if required; and

- identifying the need for monitoring, follow-up and/or adaptive management.

The first step in identifying and assessing GHG considerations was to describe estimated GHG emissions from the Project and to put these emissions into context with those of other diamond mines and total emissions for the Northwest Territories and Canada.

Estimates of Project emissions of GHG were calculated for all stationary and mobile equipment that will generate GHG emissions using their rated capacity or fuel consumption rate and emission factors from the Environment Canada National Inventory 1990-2008 (Environment Canada 2010c). Greenhouse gases that will be emitted by the Project include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Estimates of total GHG emissions are expressed as CO_2 equivalent (tonnes of CO_2 eq units), which were calculated using the following formula, where all values are expresses in kilotonnes (kt):

$$CO_2 \text{ equivalent} = CO_2 + (21 \times CH_4) + (310 \times N_2O)$$

Estimates of GHG emissions for the NWT and Canada originated from Environment Canada (Environment Canada 2010c). Estimates of GHG emissions from other diamond mines in the NWT were taken from published reports (e.g., Diavik 2007, BHP Billiton 2007).

11.13.3.2 Results

The average annual total GHG emissions from the Project are projected to be 104 kt CO_2 eq units (Table 11.13-6). Total GHG emissions for the Project and the other diamond mines in the NWT are summarized in Table 11.13-7.

Table 11.13-6 Summary of Average Annual Estimates of Greenhouse Gas Emissions for the Project

Source	CO_2 Emissions (kt CO_2 eq)	N_2O Emissions (kt CO_2 eq)	CH_4 Emissions (kt CO_2 eq)	Total CO_2 eq (kt CO_2 eq)
Mining equipment	42.20	5.40	0.05	47.7
Generator stacks	49.80	2.32	0.05	52.2
Boiler stack	2.91	0.14	0.00	3.1
Incinerator	1.41	0.07	0.00	1.5
Total	96.33	7.92	0.11	104.4

kt CO_2 eq = kilotonnes of carbon dioxide equivalent; CO_2 = carbon dioxide; N_2O = nitrous oxide; CH_4 = methane.

Table 11.13-7 Annual Greenhouse Gas Emissions Summary for Producing Diamond Mines in the Northwest Territories

Project	Total Annual GHG Emissions (kt CO_2 eq)	Year and Comments
Gahcho Kué Project	104	annual average during operation
Snap Lake Mine	63	2008 actual
Diavik Diamond Mine	159 161	2006 actual 2007 estimate
Ekati Diamond Mine	210	2006 actual

Sources: Diavik (2007); BHP Billiton (2007).
GHG = greenhouse gas; kt CO_2 eq units = kilotonnes of carbon dioxide equivalent units.

Estimates of GHG emissions for the Project are similar to those of the other diamond mines in the NWT (Table 11.13-7). It is equivalent to about 7% of the estimated total for the Northwest Territories (1,450 kilotonnes of carbon dioxide equivalent [kt CO_2 eq] units in 2008) and about 0.01% of the estimated national total (734,000 kt CO_2 eq units in 2008) (Environment Canada 2010c).

The Project will be a small contributor to GHG emissions. During construction efforts will focus on monitoring fuel consumption and employee awareness of the need to minimize emissions. To the extent possible, a centralized power supply will be provided in order to minimize the need for independent generators. Once in operation, the focus will shift to attaining the performance standards set out in the Mining Association of Canada's Towards Sustainable Mining Energy Use and Green House Gas Emission Management Protocol."

The footprint of the Project is small and will not have any large-scale effects on carbon sinks. Therefore, the Project does not have any indirect effects on carbon emissions.

11.13.4 Climate Change Assessment

11.13.4.1 Pathway Analysis

11.13.4.1.1 Methods

Pathway analysis is used to identify and assess mechanisms by which climate change could alter the Project in a manner that changes the predicted effects on VCs. It involves a three-step process for initially identifying and then assessing linkages among Project activities, associated potential environmental effects and climate change. Potential pathways through which climate change could influence the Project and potentially alter the predicted effect on the environment were identified from a number of sources, including the following:

- the guidance document, *Incorporating Climate Change Considerations in Environment Assessment: General Guidance for Practitioners* (FPTCCCEA 2003);
- the Terms of Reference for the Gahcho Kué Environmental Impact Statement (Gahcho Kué Panel 2007) and the Report of Environmental Assessment (MVEIRB 2006);
- a review of the Project Description and scoping of potential effects by the environmental assessment and Project engineering teams for the Project; and
- consideration of potential effects identified for the other diamond mines in the Northwest Territories and Nunavut.

The first part of the analysis involves producing a list of potential effects pathways by which climate change could alter the predicted impacts of the Project. This step is followed by the development and/or identification of environmental design features and mitigation incorporated into the Project to remove the pathway or limit (mitigate) the degree to which climate change could affect the Project or its predicted effects on the environment. These design features are often developed through an iterative process involving the Project's engineering and environmental teams, and they include Project designs and environmental best practices, and management policies and procedures. Knowledge of the ecological system and environmental design features and mitigation is then applied to each of the pathways to determine the degree to which the Project or its predicted effects may change as a result of climate change.

Pathway analysis is a screening step that is used to determine the existence and magnitude of linkages from the initial list of potential effects pathways for the Project. This screening step is largely a qualitative assessment, and is intended to focus the effects analysis on pathways that require a more comprehensive assessment of effects of climate change. Pathways are determined to be primary, secondary (minor), or as having no linkage using scientific and traditional knowledge, logic, and experience with similar developments and environmental design features. Each potential pathway is assessed and described as follows:

- no linkage – pathway is removed by environmental design features and mitigation, and, as a result, climate change is not expected to affect the Project or alter the predicted effects on the environment;

- secondary - pathway by which climate change could result in some change to the Project or its predicted effects, but the change is expected to be small and of negligible consequence in terms of the classification of potential effects to VCs (as completed elsewhere in the EIS); or
- primary - pathway is likely to result in a notable change to the Project or its predicted effects, which could influence the classification of impacts to VCs.

Pathways with no linkage or that are considered minor (secondary) are not analyzed further because no changes to the conclusions of the EIS are expected to result from the consideration of climate change. Primary pathways are assessed in more detail to identify if and how climate change may affect the design of the Project or the conclusions of the EIS.

11.13.4.1.2 Results

Pathways through which climate change could potentially alter the Project and the predicted effects on the environment are outlined in Table 11.13-8. The following sub-section provides the rationale for the “no linkage” and “secondary” pathway determinations outlined in Table 11.13-8.

Table 11.13-8 Description of Potential Effects Pathways by which Climate Change Could Alter the Project and the Predicted Effects on the Environment

Affected Project Component	Effects Pathway	Environmental Design Features and Mitigation	Pathway Assessment
Air strip, winter access road and site roads	Climate change and the resulting increase in air temperature could result in an increase in the size of the active frost layer in areas around the air strip, winter access roads and site roads, which could lead to greater amount of thaw settlement	• exploration of alternative energy sources • use of high efficiency equipment	no linkage
Dykes, rock piles and other constructed structures	Climate change could affect the stability of structures developed as part of the Project, which could lead to effects on aquatic and terrestrial systems if it results in a loss of containment	• designed to include safety factors appropriate for both frozen and thawed conditions	no linkage
Site water balance	Climate change could result in higher rates of precipitation, which could alter surface water runoff volumes and cause changes to surface water quality	• none	secondary
Fine PKC Facility, mine rock piles and coarse PK pile	Warming associated with climate change could delay or prevent permafrost development in the Fine PKC Facility, the mine rock piles and the coarse PK pile, which could alter long-term seepage rates from these structures and affect water quality in Kennady Lake	• none	secondary
Winter Access Road and Tibbitt-to-Contwoyto Winter Road	Climate change and the resulting increase in winter air temperatures could result in a shorter operating season for the Winter Access Road and Tibbitt-to-Contwoyto Winter Road, which could lead to increased traffic on the road when it is open and a subsequent increase in vehicular collisions with wildlife and altered wildlife movements and behaviour	• routine monitoring of winter road conditions • development of contingency plans	secondary
On-site Project Activities	As outlined in the Terms of Reference, the Project could potentially create a local change in climate at the mine site, which could result in altered effects to vegetation and wildlife habitat	• compact development footprint located in an area with a number of other waterbodies	no linkage

PKC = processed kimberlite containment; PK = processed kimberlite.

11.13.4.1.3 Pathways with No Linkage

A pathway may have no linkage if the activity does not occur, or if the pathway is removed by environmental design features and mitigation that result in the Project having no detectable (measurable) change on the environment and/or residual effects to aquatic and terrestrial ecosystems. The pathways outlined below are anticipated to have no linkage by which climate change could alter predicted effects of the Project on VCs. As a result, they are not carried through the effects assessment.

Increased thaw settlement around the airstrip and roads

Climate change and the resulting increase in air temperature could result in an increase in the size of the active frost layer in areas around the air strip, winter access roads and site roads, which could lead to greater amount of thaw settlement. Under current climate conditions the thickness of the active layer is estimated to range from 0.6 to 3.4 metres (m), depending on composition and moisture content of surficial soils (see Section 11.6). With climate change, increases in the thickness of the active layer could range from 0.1 to 0.4 m. The lower active layer depth and amount of increase of the active layer will correspond to organic soils (peat), while the higher active layer depths and amount of increase would be expected to occur in dry sandy deposits. In each case, the potential increase in the size of the active layer is small in relation to the overall depth of the active layer. As such, climate change is expected to have a negligible effect on thaw settlement.

Structural stability

The mine rock piles, the Coarse PK Pile and the Fine PKC Facility have been designed to incorporate a 1.5 factor of safety, meaning that the shear strength available to resist slope failure exceeds the shear stresses in place to drive slope failure by at least 50%. This factor of safety applies to both frozen ground and thawed ground conditions, and is consistent with the recommendations of the Canadian Dam Association guidelines (CDA 2007). Therefore, stability of the mine rock piles, the Coarse PK Pile and the Fine PKC Facility would not be sensitive to climate change; hence, this pathway has no linkage.

Local change in climate

The Terms of Reference included the requirement to provide "*An evaluation of the potential for the development to create a local change in climate at the mine site*". Greenhouse gas emissions can affect climate on a global scale, not on a local scale; therefore, GHG emissions from the Project will not create a local change in climate at the mine site. Similarly, the dewatering of Kennady Lake is not expected to affect the local climate. There is an abundance of waterbodies in the region, and the temporary loss of one small waterbody is not likely to result in a local climate effect.

There are no other aspects of the Project that have the potential to result in a change to the local climate at the Project site. As such, this pathway was determined to have no linkage by which climate change could alter the predicted effect of the Project on the environment.

11.13.4.1.4 Secondary Pathways

In some cases, both a source and a pathway exist, but the change caused by climate change is not expected to alter the conclusions of the EIS. In other words, although climate change could alter the predicted effects of the Project on the environment, the change in the predicted effects is limited in magnitude and extent and would not alter the results of the impact classifications completed with reference to VCs. Such pathways were determined to be secondary pathways, and were not analyzed further. Secondary pathways relevant to the climate change assessment are discussed below

Alterations to surface water runoff volumes and the site water balance

Changes to the operational and closure drainage site water balance would occur primarily as a result of changes to precipitation and evaporation, which are second-order effects of the changes to air temperature that are projected by GCMs. Walsh et al. (2005, internet site) examined the results of five GCMs for the arctic region for the B2 emissions scenario (Figure 11.13-1), including the Mackenzie River basin, and found that "*the models differ widely in their simulations of baseline*" and that "*the projected changes by 2071-2090 are generally smaller than the range in baseline values simulated by the different models*." This finding is indicative of the high level of uncertainty that is inherent in the modelling of second order effects.

Walsh et al. (2005, internet site) also noted the following:

- "*there is a wider across-model range in projected changes in evaporation than in projected changes in precipitation*";
- "*there is even considerable disagreement among models concerning the sign of the changes in evaporation*"; and
- mean projected increases in net precipitation are modest and well within the range of natural variation, with "*changes considerably smaller than the departures from the means… even during multi-year periods*.".

Because changes in runoff are projected to be modest and well within the range of natural variation, potential changes to the site water balance that may be triggered by climate change are expected to be minor. As a result, this pathway was determined to be a secondary pathway.

Hydrological monitoring during construction and operation will allow site water management systems to be modified as required to adapt to measured flow conditions. As they become available, results of updated climate projections will be used in the final design of a closure drainage system for the Project.

Shorter operating season for the Winter Access Road and Tibbitt-to-Contwoyto Winter Road

Climate change could result in a gradual decrease in the length of the winter road season, which could reduce the number of truck loads that could travel to the Project site. However, the projected increase in average annual temperature for the duration of mine operation is small, ranging from 0.7°C to 1.6°C. The increase would occur gradually over the life of the mine, and changes to the duration of the winter road season resulting from climate change would be difficult to distinguish from the year-to-year variability that is expected to be observed in the duration of the winter road season.

The highest intensity and most schedule-sensitive use of the winter roads for the Project occur during the first two years of the Project (Table 11.13-9) when construction activity is greatest. The effect of climate change on winter road use will be the smallest near the beginning of the Project. The lowest intensity and least schedule-sensitive use of the winter roads for the Project will occur during closure, when potential effects of climate warming would be largest. The lower intensity and schedule sensitivity of winter road use would allow closure activities to be adapted, if required, to accommodate a decrease in the duration of the winter road season.

Table 11.13-9 Project-related Winter Road Traffic Projection by Phase

Project Phase	Number of Years	Loads per Year	
		Average	Maximum
Construction	2	1,500	2,000
Operations	11	1,000	1,200
Closure	2	110	200

During operations, the intensity of use is lower than during construction; however, some requirements (e.g., equipment and fuel) will be schedule sensitive. The adaptations for any decrease in the length of the winter road season resulting from climate change would be the same as the adaptations for current year-to-year variability in the length of the winter road season. Adaptive management actions would include:

- logistical planning, such as increasing fuel storage to allow more flexibility in the transportation of fuel, increased trucking over a shorter season, and long-term planning of loads to be able to take advantage of longer seasons;
- initiating an energy efficiency program and continuing to evaluate alternative energy sources to minimize fuel requirements (see Section 11.3; Subject of Note: Alternative Energy Sources); and
- transporting more equipment to site by air.

Therefore, while climate change may affect the duration of the winter road season, these changes would be difficult to distinguish from previous and existing year-to-year variability. As such, this pathway was determined to be secondary, because the consideration of climate change along this potential effects pathway would not alter the classification of effects of the Project on wildlife.

Delay or prevention of permafrost development in the Fine PKC Facility, the Mine Rock Piles and the Coarse PK Pile

The warmer air temperatures that may result from climate change could prevent the development of permafrost within Mine Rock Piles, Coarse PK Pile and Fine PKC Facility or, more likely, delay its formation. The development of permafrost within the mine rock piles, Coarse PK Pile and the Fine PKC Facility will limit seepage rates from these structures into Kennady Lake. As such, changes to permafrost development that are induced by climate change could alter the predicted effects of the Project on Kennady Lake.

However, the assessment of potential effects to water quality and fish in Kennady Lake has so far been completed without taking the beneficial effects of permafrost into account. In other words, the assessment has been completed to date assuming no permafrost was present within the aforementioned structures. As a result, further analysis of this pathway was not required, and it was classified as a secondary pathway. Potential effects from climate change are not anticipated to alter the classification of effects on the biophysical environment.

11.13.5 Residual Effects Summary

All of the pathways for climate change were determined to have no linkage or minor (secondary) changes to the classification of effects from the Project on the biophysical environment. Therefore, residual effects from these pathways do not require assessment.

11.13.6 Uncertainty, Monitoring, and Follow-up

Climate change predictions are by their nature uncertain. The atmospheric processes involved are complex, as are the models used to develop climate change predictions.

De Beers will monitor for the effects of climate change on the Project. Thermistors will be installed to monitor temperatures within the mine rock piles, the Coarse PK Pile and the Fine PKC Facility. The resulting information will be used to track the development and possible regression of permafrost within these structures. De Beers will also monitor the quality and quantity of the water passing through the operational water management system to verify the conclusions of the analysis outlined herein. Finally, De Beers will periodically review its operating procedures during the life of the Project, and adjust them, if and as required, to account for the influence of climate change.

Linkages between the reduction of GHG emissions and other environmental opportunities will be evaluated and considered as part of monitoring and adaptive management of the Project. Any saving in energy will result in the reduction of diesel fuel consumption, which will result in the reduction of not only GHG emissions, but also nitrogen and sulphur, thereby improving air quality.

The following aspects of the Project potentially affected by climate change or related to GHG emission will be adaptively managed.

- Winter roads — If the hauling season is shortened, then De Beers will develop options for logistical planning (larger storage for fuel and increased trucking over a shorter period). Adaptations for any decrease in the length of the winter road season resulting from climate change would be the same as the adaptations for current year-to-year variability in the length of the winter road season.
- Protection of permafrost — All activities that affect permafrost around the site will be closely planned so that areas not directly affected by the mine and plant site will be preserved.

- Equipment efficiency — During normal regular maintenance refits De Beers will use the most up-to-date, cost effective, and efficient replacement equipment.
- Mine and plant operations — Mining and processing operations will be periodically reviewed with the objective of identifying opportunities for increasing efficiency and acting upon them as appropriate.

11.13.7 References

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11.13.8 Acronyms and Glossary

11.13.8.1 Acronyms and Abbreviations

CCCSN	Canadian Climate Change Scenarios Network
CH_4	methane
CO_2	carbon dioxide
De Beers	De Beers Canada Inc.
EIS	environmental impact statement
FPTCCCEA	Federal-Provincial-Territorial Committee on Climate Change and Environmental Assessment
GCM	General Circulation Model
GHG	greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
N_2O	Nitrous oxide
NWT	Northwest Territories
PK	processed kimberlite
PKC	processed kimberlite containment
Project	Gahcho Kué Project
SRES	Special Report on Emissions Scenarios
Terms of Reference	*Terms of Reference for the Gahcho Kué Environmental Impact Statement*

VC	valued component

11.13.8.2 Units

%	percent
°C	degrees Celsius
e-CO_2	total equivalent carbon dioxide
km	kilometre
kt	kilotonnes
kt CO2 eq	kilotonnes of carbon dioxide equivalent
m	metre
mm	millimetres

11.13.8.3 Glossary

Active Layer — The top layer of ground in permafrost region where temperature fluctuates above and below 0°C during the year.

Carbon Dioxide — A naturally occurring gas, and also a by-product of burning fossil fuels and biomass, as well as land-use changes and other industrial processes. It is the principal anthropogenic greenhouse gas that affects the Earth's radioactive balance. It is the reference gas against which other greenhouse gases are measured and therefore has a Global Warming Potential of 1.

Carbon Sinks — Natural or man-made systems that absorb CO_2 from the atmosphere and store them. Trees, plants, and the oceans all absorb CO_2 and, therefore, are carbon sinks.

Climate Change — Refers to any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer). Climate change may result from:

- natural factors, such as changes in the sun's intensity or slow changes in the Earth's orbit around the sun;
- natural processes within the climate system (e.g. changes in ocean circulation);
- human activities that change the atmosphere's composition (e.g. through burning fossil fuels) and the land surface (e.g. deforestation, reforestation, urbanization, desertification, etc.).

Climate Model — A quantitative way of representing the interactions of the atmosphere, oceans, land surface, and ice. Models can range from relatively simple to quite comprehensive.

General Circulation Model (GCM)	A global, three-dimensional computer model of the climate system which can be used to simulate human-induced climate change. GCMs are highly complex and they represent the effects of such factors as reflective and absorptive properties of atmospheric water vapour, greenhouse gas concentrations, clouds, annual and daily solar heating, ocean temperatures, and ice boundaries. The most recent GCMs include global representations of the atmosphere, oceans, and land surface.
Groundwater	Water that is passing through or standing in the soil and the underlying strata in the zone of saturation. It is free to move by gravity.
Hydrogeology	The scientific study of occurrence and flow of groundwater and its effects on earth materials.
Hydrology	Science that deals with the waters above the land surfaces of the Earth, their occurrence, circulation and distribution, both in time and space, their biological, chemical and physical properties, their reaction with their environment, including their relation to living beings.
Intergovernmental Panel on Climate Change (IPCC)	The IPCC was established jointly by the United Nations Environment Programme and the World Meteorological Organization in 1988. The purpose of the IPCC is to assess information in the scientific and technical literature related to all significant components of the issue of climate change. The IPCC draws upon hundreds of the world's expert scientists as authors and thousands as expert reviewers. Leading experts on climate change and environmental, social, and economic sciences from some 60 nations have helped the IPCC to prepare periodic assessments of the scientific underpinnings for understanding global climate change and its consequences. With its capacity for reporting on climate change, its consequences, and the viability of adaptation and mitigation measures, the IPCC is also looked to as the official advisory body to the world's governments on the state of the science of the climate change issue. For example, the IPCC organized the development of internationally accepted methods for conducting national greenhouse gas emission inventories.
Permafrost	Permanently frozen ground (subsoil). Permafrost areas are divided into more northern areas in which permafrost is continuous, and those more southern areas in which patches of permafrost alternate with unfrozen ground.
Processed Kimberlite	Kimberlite ore which had been screened and washed as part of the processing procedure.
Processed Kimberlite Containment	On-site storage facility for storing processed kimberlite.
Process Water	Water used for processing kimberlite ore to remove diamonds or to carry fine processed kimberlite as a slurry to surface PKC facilities or backfilled mine pits.
Runoff	The portion of water from rain and snow that flows over land to streams, ponds or other surface waterbodies. It is the portion of water from precipitation that does not infiltrate into the ground, or evaporate.
Thermistors	A device whose electrical resistance, or ability to conduct electricity, is controlled by temperature.
Till	Sediments deposited by glacial ice.