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TABLES

FIGURES

19.0 EFFECTS OF THE PHYSICAL ENVIRONMENT ON THE DEVELOPMENT

19.1 Introduction

19.1.1 Context

This section of the Developer's Assessment Report (DAR) for the NICO Cobalt-Gold-Copper-Bismuth Project (NICO Project) consists solely of the potential impacts of the physical environment on the development. In the Terms of Reference (TOR) for the NICO Project's DAR issued on 30 November 2009, the Mackenzie Valley Review Board (MVRB) identified the effects of the environment on the development as one of the issues requiring consideration by the developer (MVRB 2009).

19.1.2 Purpose, Scope, and Content

The purpose of the Effects of the Physical Environment on the Development Section is to identify and assess the potential impact, herein referred to as effects, of the environment on the NICO Project and to meet the TOR issued by the MVRB. The TOR for the Effects of the Environment on the Development Section are shown in Table 19.1-1. The entire TOR document is included in Appendix 1.I, and the complete table of concordance for the DAR is included in Appendix 1.II.

Information from other components of the DAR, including air quality, water quantity, terrain and soils, closure and reclamation, and accidents and malfunctions are summarized in this section. More detailed information on the requirements of the DAR Terms of Reference for this Section can be found in Table 19.1-1.

Table 19.1-1: Concordance with the Terms of Reference

Section in Terms of Reference	Requirement	Section in Developer's Assessment Report
3.1.3	Potential impacts of the physical environment on the development, such as changes in the permafrost regime, other climate change impacts, seasonal flooding and melt patterns, seismic events, geological instability, and extreme precipitation must be considered in each of the applicable items of this *Terms of Reference*. Any changes to the design or management of the NICO Project as a result of considering potential impacts of the environment should be noted in the relevant sections.	Sections 19.0, 2.0

The general organization of this Section is outlined in Table 19.1-2.

Table 19.1-2: Effects of the Physical Environment on the Development Organization

Section	Content
Section 19.1	**Introduction -** Provides an introduction to the effects of thephysical environment on the development chapter by defining the context, purpose, and scope
Section 19.2	**Effects of the Physical Environment on the Development** - Provides a summary of the potential effects of the physical environment on the proposed NICO Project

The sub-sections below are summaries of information provided in other components of the DAR. Table 19.1-3 lists the DAR section associated with each sub-section.

Table 19.1 3: Developer's Assessment Report Associated with Each Sub-Section of Section 19

Developer's Assessment Report Section	Developer's Assessment Report Section Title	Sub-section in Section 19
13	Subject of Note: Terrain and Soils	19.2.1 Permafrost
9	Key Line of Inquiry: Closure and Reclamation	19.2.2 Climate Change
11	Subject of Note: Water Quantity	19.2.3 Seasonal Flooding
10 17	Subject of Note: Air Quality Subject of Note: Accidents and Malfunctions	19.2.4 Precipitation
17	Subject of Note: Accidents and Malfunctions	19.2.5 Seismic Events
3	Project Description	19.2.6 Geological Instability

19.2 Effects of the Physical Environment on the Development

The existing physical environment of the NICO Project area can impact various phases of the NICO Project and to varying degrees depending on the susceptibility of the infrastructure in question and the nature of the activity being undertaken. In previous sections (e.g., Key Line of Inquiry: Water Quality), the effect the NICO Project has on the existing environment was assessed. Below is an assessment of how the NICO Project may be affected by existing environmental factors in the area of the NICO Project.

The response of the NICO Project to environmental factors (i.e., permafrost regime, climate change, seasonal flooding and melt patterns, seismic events, geological instability, and extreme precipitation) and mitigation measures to offset the predicted response are presented below.

19.2.1 Permafrost

Permafrost across the landscape that contains the NICO Project footprint has been described as extensive discontinuous permafrost (Natural Resources Canada 1993). The ice content of the upper 10 to 20 metres (m) of the ground is described as having low to moderate ice content with sparse areas that contain ice wedges and pingo ice (i.e., ice-rich permafrost) (Natural Resources Canada 1993). Though most bogs typically contain permafrost, many fens are free of permafrost (Zoltai 1995). Within the terrestrial Regional Study Area (RSA), soils with high potential to contain permafrost are typically poorly-drained organic soils within treed bogs and poorly-drained low-lying mineral soils associated with wetlands (Section 13.2.2) The distribution of permafrost across the landscape is highly variable, with variations in ice content occurring over small scales (i.e., within several metres).

The majority of the terrestrial RSA has been characterized as having a moderate or low potential for permafrost occurrence. Areas rated as having a high permafrost potential tend to be scattered in isolated pockets throughout the terrestrial RSA, as they are almost exclusively associated with poorly drained organic soils within treed bogs.

Permafrost in the terrestrial local study area (LSA) is associated with poorly-drained organic soils within treed bogs and low-lying mineral soils associated with wetlands. Frozen ground (potential permafrost) was observed at depths of 22 to 45 centimetres (cm) within the mine LSA, with an average thaw depth of 34 cm. Frozen ground was observed at depths between 32 to 100 cm along the NICO Project Access Road (NPAR), with an average thaw depth of 62 cm. Of the 8 boreholes installed with thermistors that were drilled in the LSA, 4 of the boreholes had permafrost present at depth, and all 4 were located centrally in low-lying valleys (Golder 2010).

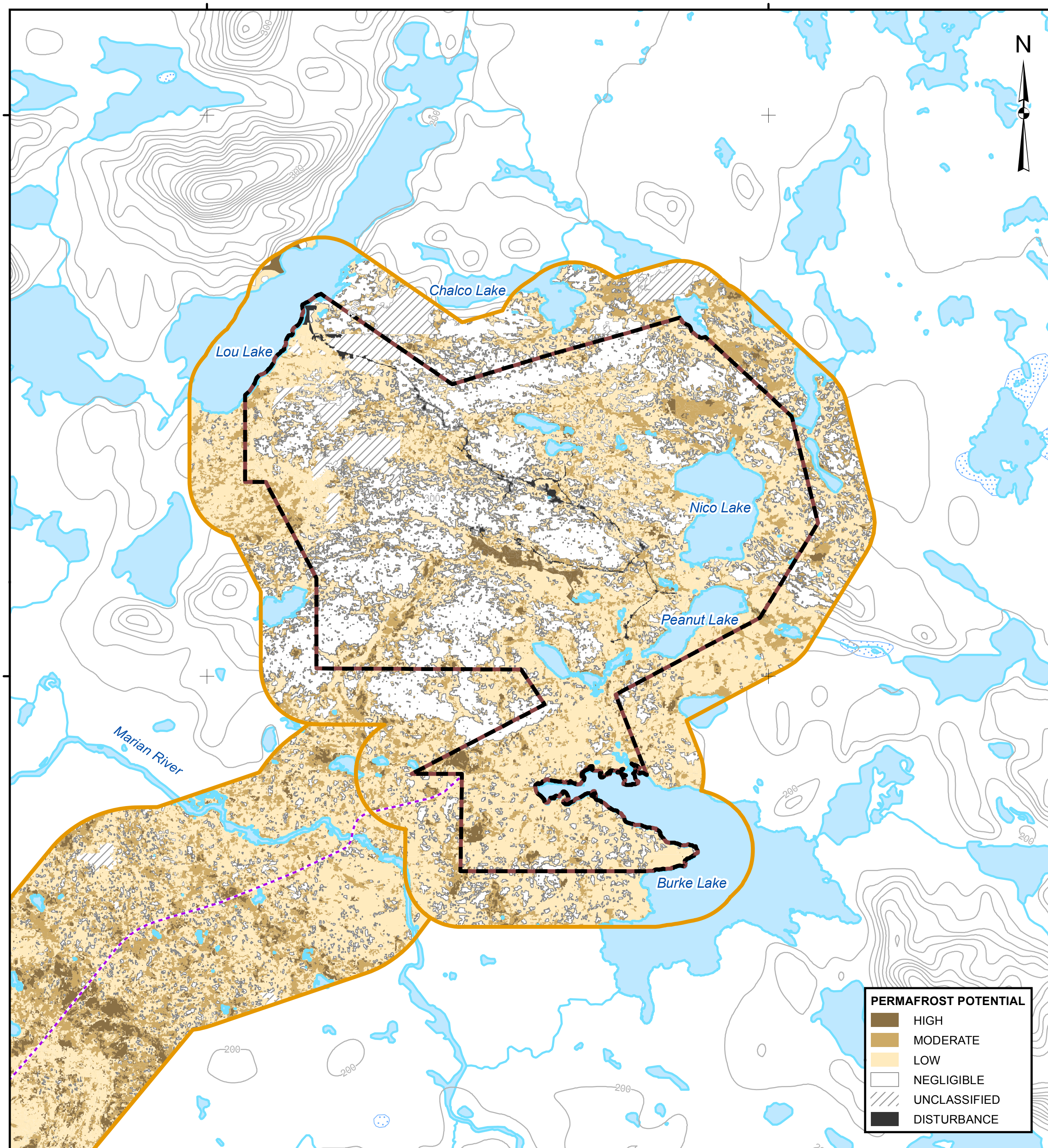
The majority of the terrestrial LSA (i.e. 56.3%) is classified as having a low potential for permafrost (Section 13.2.2, Table 13.2-6). Approximately 421 ha (5.0%) of the terrestrial LSA is classified as high permafrost potential, with the majority of this area occurring along the NPAR (Figures 19.2-1a and 19.2-1b). The predominant permafrost potential under the footprint of the main NICO Project facilities is as follows:

- Co-Disposal Facility (CDF): negligible to low permafrost potential;
- Mineral Process Plant (Plant) and camp: negligible to low permafrost potential;
- Open Pit: negligible to low permafrost potential; and
- Airstrip: low to moderate permafrost potential.

The effects of changes in permafrost to soils and terrain and the effects of terrain instability due to changes in the ground thermal conditions to the NICO Project were assessed in the Subject of Note: Terrain and Soils (Section 13.3.2).

19.2.1.1 Predicted Response of Permafrost

Permafrost that occurs within the NICO Project footprint is described as having low ice content, and is limited in spatial extent and thickness (Golder 2010). The amount of ground ice present within the permafrost is important for assessing the response of permafrost to clearing, construction, and subsequent recovery of ice conditions following disturbance (Jorgenson et al. 2010). The magnitude of changes to permafrost thermal regimes and potential thaw settlement is directly related to the nature and abundance of ground ice and the type and severity of disturbance at the surface (Lawson 1986; Pullman et al. 2007). Knowledge of the potential magnitude of thaw settlement is important for assessing placement and construction of NICO Project components, the long-term recovery of disturbed areas, and developing reclamation and rehabilitation plans. Warmer permafrost, as in the discontinuous permafrost zone, is susceptible to long-term degradation as a result of surface disturbances (Nolte et al. 1998). Clearing of an area and subsequent construction activities are anticipated to cause permafrost to slowly degrade due to ground thermal changes resulting from removal and disturbance of vegetation.



LEGEND

- PROJECT LEASE BOUNDARY
- CONTOUR (10 METRE INTERVAL)
- PROPOSED NICO PROJECT ACCESS ROAD
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA

1 0 1

SCALE 1:50,000 KILOMETRES

NOTE: Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

Base data obtained from GeoGratis.
Projection: UTM Zone 11 Datum: NAD 83

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

PERMAFROST POTENTIAL OF SOILS IN THE LOCAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE NO. E-EnvEffects-001				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	FIGURE: 19.2-1a	
GIS	SK	01 Feb. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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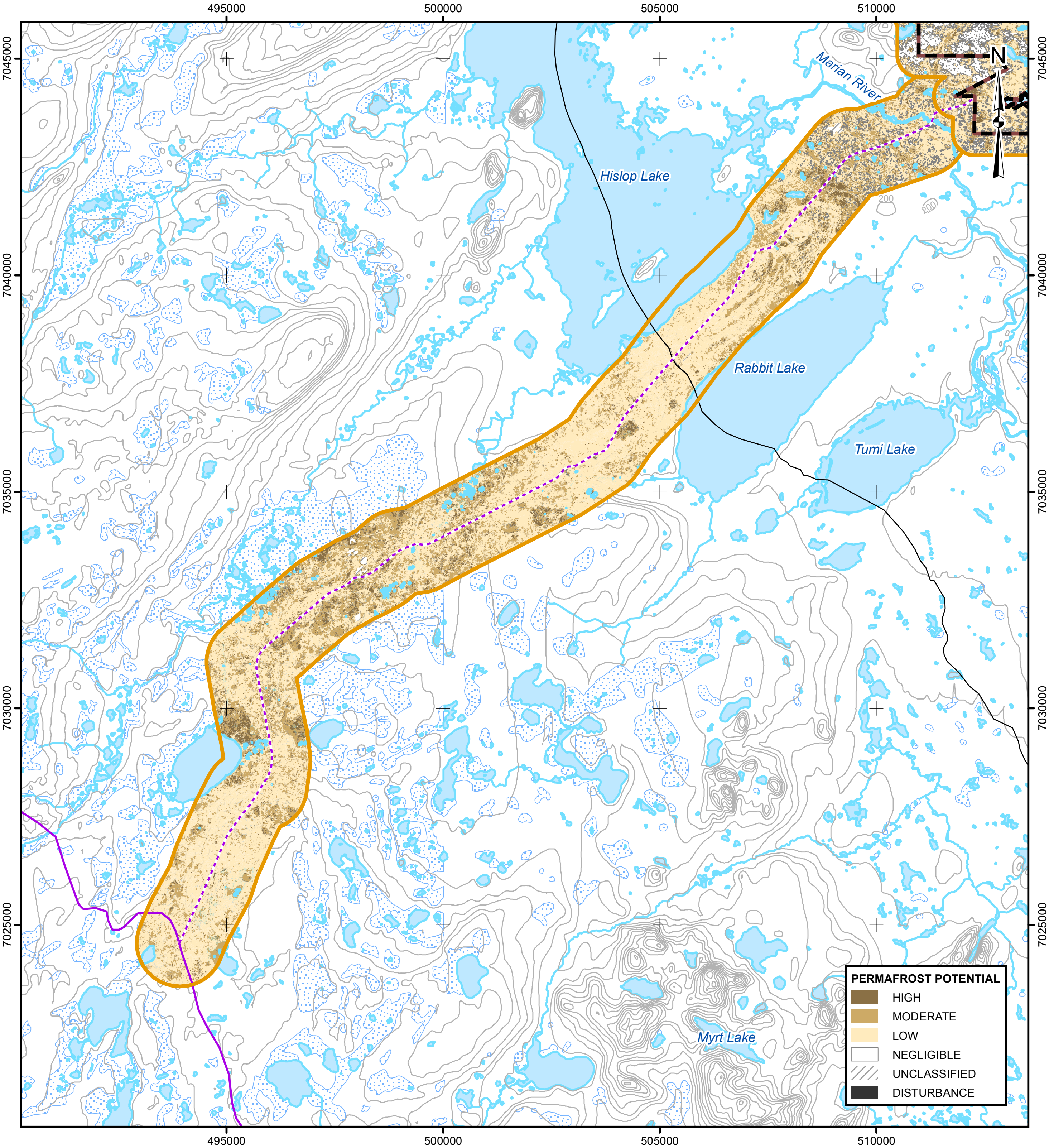

3 0 3

SCALE 1:125,000 KILOMETRES

LEGEND

- PROJECT LEASE BOUNDARY
- CONTOUR (10 METRE INTERVAL)
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁĮCHQ ROAD ROUTE
- WATERCOURSE
- WATERBODY
- WETLAND
- LOCAL STUDY AREA

NOTE: Unclassified areas are portions of the LSA for which an ELC vegetation class could not be assigned due to satellite interference.

REFERENCE

Base data obtained from GeoGratis.
Projection: UTM Zone 11 Datum: NAD 83

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

PERMAFROST POTENTIAL OF SOILS IN THE LOCAL STUDY AREA

Golder Associates
Edmonton, Alberta

FILE No. E-EnvEffects-002				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	LV	12 Dec. 2008	FIGURE: 19.2-2b	
GIS	SK	01 Feb. 2011		
CHECK	GRA	03 Apr. 2011		
REVIEW	GRA	03 Apr. 2011		

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Numerous factors affect the magnitude of changes to permafrost areas and influence recovery of an area following disturbance; these include type of construction activities, site infrastructure, vegetation, soil type, soil texture, density, water content, and snow depth (Lawson 1986; Nolte et al. 1998; Jorgenson et al. 2010). For example, soil type influences the thermal regime of permafrost because heat loss tends to be more rapid from mineral soils as the thermal conductivity of a mineral soil is usually higher than in an organic soil (Woo and Winter 1993). Thaw settlement caused by disturbance and subsequent melting of permafrost can initially lead to water impoundment, decreased albedo, and an increase in heat flux, which in turn causes more thaw settlement (Jorgenson et al. 2010). This can result in a change in surface hydrology that shifts recovery patterns towards new plant communities, further influencing permafrost. The depth of the active layer may continue to increase as a result of disturbance (Burgess and Harry 1990; Burn and Smith 1993; Hayhoe and Tarnocai 1993). Jorgenson et al. (2010) found that the thaw depth continued to increase for 3 to 8 years after disturbance prior to stabilizing and recovering. Stabilization or re-establishment of equilibrium between climate and permafrost will eventually occur but may take decades, depending on the severity of the disturbance (Nolte et al. 1998; Jorgenson et al. 2010).

19.2.1.2 Mitigation Measures

Mitigation and environmental design features to reduce the potential for permafrost melting, and subsequent thaw subsidence of areas include the following:

- all mine infrastructure will be designed to be physically stable, even if existing permafrost thaws;
- infrastructure (buildings) foundations will be built on bedrock not susceptible to frost heave, where possible;
- clear areas for construction from a snow packed surface during winter months;
- re-vegetate disturbed areas as soon as possible;
- use culverts to maintain surface drainage and reduce pooling of water at the surface;
- limit the mine footprint disturbance area;
- limit the road footprint disturbance area, while maintaining safe construction and operation practices;
- insulate infrastructure, where possible;
- build the foundations of buildings on bedrock not susceptible to frost heave to minimize thawing of permafrost in sensitive areas; and
- do not strip organic and/or topsoil horizons in areas containing ice-rich permafrost to reduce potential for an increase in thaw depth and related thaw subsidence.

Mitigation and environmental design features to reduce the potential effects on the NICO Project from permafrost melting include the following:

- all mine infrastructure will be designed to be physically stable, even if existing permafrost thaws;
- infrastructure (buildings) foundations will be built on bedrock not susceptible to frost heave, where possible; and

- during operations of the Open Pit, instability due to settlement or thawing would be managed by flattening slopes, buttressing, covering with rip-rap, or other method as required, to maintain safe conditions. Post-closure, significant deformations and erosion would not be expected because of remedial measures during operations.

19.2.1.3 Effects to Project Infrastructure

19.2.1.3.1 Co-Disposal Facility

The CDF and the dams associated with the Seepage Collection Ponds (SCPs) are not expected to be affected by changes to ground thermal conditions and permafrost as these structures do not rely on permafrost to operate correctly. They are designed to be physically stable even if the existing permafrost beneath the foundations of the structures thaws.

The creation of permanent SCPs will change the local thermal regime and thaw any permafrost in the soils below them. Geotechnical investigations within the NICO Project footprint indicate that the presence of permafrost is limited in spatial extent, and thickness (Golder 2010). The resulting differential settlements or subsidence due to the thawing of permafrost are expected to be minor and are not expected to affect the integrity of the dams and infrastructure.

The construction of the CDF will change the thermal regime that pre-existed in the area of the Grid Ponds. After closure, the active freeze-thaw zone will be at the surface of the raised CDF structure. Permafrost may eventually form and accumulate within the CDF, which would result in decreased water infiltration and oxygen influx into the tailings and mine rock materials.

19.2.1.3.2 Open Pit/Underground Workings

Shallow overburden slopes (less than 20 m before bedrock is exposed) may occur on the north wall of the Open Pit in the Bowl Zone (Bowl Zone is described in Section 3.4.3). The area may contain discontinuous permafrost. Ground settlement due to thawing of overburden could cause localized deformation of the overburden pit slopes, and localized ravelling, sloughing, or instability. The Open Pit slopes are designed to be stable under operating conditions. Given the competent character of the wall rocks, for which overall slope failure is not a concern, the slopes were designed to control the expected failure mechanism, and bench widths are designed to capture most sliding blocks and wedges of rock at the bench scale.

Permafrost is not expected to be of concern in the portal or underground workings based on the absence of permafrost in the decline.

19.2.1.3.3 NICO Project Access Road

The proposed NPAR transverses terrain with variable sub-grade and drainage conditions, permafrost characteristics, and compressed peat. Thaw-related settlement of the sub-grade is expected and maintenance will be required. Embankment cross sections based on the peat cover, presence or absence of permafrost, and drainage conditions are proposed. Side-slopes no steeper than 2 horizontal to 1 vertical (2H:1V) were recommended by EBA (2005) for terrain units 1 and 4 and 4H:1V for all other terrain units (Table 19.2-1). Selective use of geotextile will enhance the roadway performance over soft, natural foundation soil. In particular, Terrain Units 2 and 3 (Table 19.2-1) will be underlain by geotextile. Terrain Unit 2 is poorly drained with standing water and grasses at many places and characterized by highly compressible peat greater than 200 mm in thickness (EBA 2005). Terrain Unit 3 is defined as Waterbodies, including streams, ponds, and stagnant water in hollows between peat hummocks. Permafrost is likely present under peat hummocks (EBA 2005).

Table 19.2-1: Terrain Units along the NICO Project Access Road

Terrain Unit	Terrain Name	Permafrost Conditions
1	Level or Undulating Terrain	Sporadic permafrost
2	Level or Gently Undulating Terrain	Widespread permafrost
3	Waterbodies	Permafrost or nonpermafrost
4	Undulating Sedimentary, Igneous, or Meta-Sedimentary Bedrock	Sporadic permafrost or nonpermafrost
5	Complex Terrain	Widespread permafrost (overburden) and nonpermafrost (bedrock

19.2.1.3.4 NICO Project Infrastructure

The NICO Project infrastructure has been designed to withstand minor thaw settlements due to potential permafrost melting. Change in the local thermal regime and permafrost distribution is expected to result in a negligible effect on the NICO Project.

19.2.2 Climate Change

Scientific evidence has suggested that the earth is undergoing a period of climate change. This has implications to the permafrost as well as hydrology, soil moisture, and nutrient availability, affecting vegetation, and influencing ecology. Predictions for climate change in northern environments include increased temperatures, increase precipitation in winter months and drought conditions in summer months (Stewart et al. 1997).

19.2.2.1 Predicted Response

Climate change issues need to be considered when mine planning and for long-term sustainable reclamation of the environment. Freeze induced displacement of soil (i.e., frost jacking) and thaw induced displacement (i.e., subsidence) of soil are the main issues related to permafrost degradation (i.e., loss or alteration). Changes to thaw penetration and thickness of the active layer can influence surface stability through thaw settlement, frost heave, and bearing capacity, as well as slope stability (Tarnoicai et al. 2004).

As discussed in Section 19.2.1.3.1 above, the CDF and the dams associated with the Water Management Ponds do not rely on permafrost to operate correctly. They are designed to be physically stable even if any existing ground ice in the foundations of the structures thaws. The environmental performance of the CDF does not rely on freezing of the waste materials or the cover materials. The rate of infiltration assumes that the cover is thawed; frozen conditions would reduce the rate of infiltration. Similarly, the rate of oxygen influx into the CDF assumes that the cover and the Co-disposed Tailings and Mine Rock are thawed. The possible development of frozen horizons would reduce oxygen influx.

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 NICO Project site on existing winter roads. The NICO Project requires an all-weather road to operate the mine, and specifically to transport concentrate to Hay River for processing in Saskatchewan. Therefore, winter access roads are not feasible. The NICO Project has been designed to operate with all-weather roads from the mine site to the territorial highways. Therefore, if the winter road season is reduced, this will not have impact on the NICO Project.

19.2.3 Seasonal Flooding and Drought Conditions

Surface water hydrology was characterized for the basins located in the LSA (i.e., Burke Lake, Lou Lake, and Marian River watersheds). As part of the hydrology study, basin drainage areas were delineated, flow from the basins was estimated using a water balance method, hydrometric and lake level monitoring was completed for the years 2005 to 2008, and flood magnitudes and frequencies were estimated for the basins (Section 11.2.2).

Data collected between 2005 and 2008 were correlated to long-term data at Baker Creek for the smaller drainages and the Cameron River for the Marian River. The correlation provided estimates of long-term daily average discharge at the watersheds delineated around the NICO Project.

Based on 2005 to 2008 monitoring results, the Marian River had the largest flows, followed by Burke Creek and Lou Creek (Section 11.2.2.3.2, Figures 11.2-2 to 11.2-4). Burke Creek drains Burke Lake to the Marian River, and Lou Creek drains Lou Lake via Lion Lake to the Marian River. Flows in 2006 were higher than in other years, likely due a large amount of snowfall over the previous winter. The discharge peak for 2006 may not have been measured because the hydrographs were receding when the first measurements were collected that year. Flows were lower in 2007 and 2008 than the other years measured, and reflect dry conditions in the area. The early summer of 2008 was particularly dry and forest fires were widespread, including areas in the vicinity of the NICO Project.

Although discharge measurements have been taken regularly from 2005 through 2008, the stage-discharge relationships should still be considered preliminary. The majority of the discharge through the stations occurs as a function of snowmelt rather than high rainfall volumes throughout the year.

The long-term data correlated to the site indicates that discharges at the outlet of the Burke (BL8) and Lou (LL6) drainages could exceed 5.0 and 4.0 cubic metres per second (m^3/s), respectively. The long-term data for the Marian River indicates that discharges in the system could exceed the 43.0 m^3/s discharge recorded in 2006; however, the correlation to the Cameron River may over estimate discharge in larger flood events. All long-term data are presented in Annex G.

Water levels receded in Peanut Lake beginning in 2006 and continuing through 2008, but they increased in Burke Lake over the same time period. Burke Lake is located immediately downstream of Peanut Lake (Section 11.2.2.3.2, Figure 11.2-5). The most probable reason for these water level patterns was failure in a beaver dam that was controlling the water level in Peanut Lake, combined with the construction of a new beaver dam at the outlet of Burke Lake. In general, extensive beaver activity in the area has a strong influence on water levels and subsequently stream discharges.

19.2.3.1 Predicted Response and Mitigation Measures

Annual peak daily discharges for each of the watersheds in the LSA were estimated and fit to a probability distribution (Log-Pearson III) to calculate flood magnitude and frequency. Annual long-term peak data were derived based the flow relationship between site flow data and regional flow data. The flood magnitudes and frequencies can be used in evaluation of structural design for stream crossings and other engineered structures.

Results of the flood magnitude and frequency analysis for streamflow monitoring stations at all of the watershed outlets are provided in Section 11, Table 11.2-2. The 1 in 2 year peak flow is near the average peak flow value and there is a 50% chance that peak flows would equal or exceed that value in any given year. Similarly, the 1 in 20 year flood is the average length of time between 2 floods of a given size or larger, but there is a 5% chance of that flood level or greater occurring in any given year. Flooding was considered as part of the NICO Project design.

The data above, as well as extreme precipitation and drought, were taken into consideration for the NICO Project design. For example, the CDF and Water Management Ponds have been designed for flood events or extreme precipitation, The CDF is designed to store the Inflow Design Flood in addition to the Environmental Design Flood during operations. The Inflow Design Flood is a rainfall storm of 1/3 between the 1000-year return period precipitation and the probable maximum precipitation, and the Environmental Design Flood is the 100-year return period 30-day rainfall-plus-snowmelt event. Water Management Ponds will be designed to store the Environmental Design Flood of 100 year, 24-hour storm. The dams will include spillways to prevent dam overtopping and failure in case of a flood event of a longer return period (Section 17.3.3).

In addition the CDF was selected as the preferred tailings and Mine Rock management option for the following reasons related to water management:

- **Consolidated water management:** Use of the CDF allows for water management related to the mine to be concentrated into a single watershed.
- **More efficient water collection (maximizing the rate of consolidation of the tailings):** The coarse mine rock will act as a drainage path for tailings consolidation water.

The Water Management Plan (Appendix 3.III) outlines the lakes that the Water Management Ponds can be built to manage for flood conditions during construction. Failure of the Water Management Ponds' dams is collectively classified as "Low Consequence" (Appendix 3.III). Canadian Dam Association (2007) recommends that low consequence dams be designed to safely convey the inflow design flood resulting from 1 in 100 year storm events to avoid overtopping. The guideline also suggests that the dams should be designed to withstand the 1 in 500 year earthquake event.

The water management system has been optimized in terms of internal recycling within the plant, thickening of the tailings, and high level of reclaim water from the CDF back to the plant to minimize freshwater requirements. Modelling freshwater withdrawal in a 1:25 dry year predicted that the maximum change in water level in Lou Lake relative to the natural (modelled baseline) conditions is approximately 4.7 cm in a 1:25 year dry period coinciding with the maximum required water withdrawal, which occurs during the beginning of operations. In general, it is anticipated that the average fresh water withdrawal condition in Lou Lake would not exceed 3.7% of the mean annual discharge relative to baseline conditions, which is expected to have negligible residual effect on water level in Lou Lake and downstream flow to the Marian River. It is anticipated that both seasonal flooding and drought conditions should have minimal effect on the construction, operation and closure of the NICO Project.

19.2.4 Precipitation

Fortune operates a meteorological station near the proposed NICO Project. It is located at the height of land north of the proposed mine at UTM 511931 East and 7047508 North (NAD 83). Meteorological data has been collected near the NICO Project since October 2004. Data was logged year-round on an hourly basis. Maximum, average, and total values were collected for wind, temperature, rainfall, relative humidity, and solar radiation. There were several periods in which data was lost. Details on the equipment and methodology used to obtain the data, as well as the subsequent measurements, are presented in Annex F: Air Quality and Meteorology Baseline Report.

Thirty-year normals observed at the Environment Canada Yellowknife airport station between the years of 1971 and 2000 were also included for comparison (Environment Canada 2011).

19.2.4.1 Rainfall

The monthly rainfall measurements at the NICO Project are shown in Figure 19.2-2 for 2005 to 2007. The data were compared to the monthly rainfall for Yellowknife for the same years and were also compared to the 1971 to 2000 long-term climate normals for Yellowknife. The figure indicates that the majority of rainfall occurs between April and October.

For extreme precipitation, intensity-duration-frequency analysis using data from the Yellowknife Airport indicates that a 1:100 year, 24 hour storm would yield 83.6 millimetres of rain.

Climatic parameters used for water balance calculations are also provided in Table 11.2-1 in Section 11.2.1.2. Parameters derived from Yellowknife Airport for the years 1953 to 2007 included: precipitation adjusted for undercatch, air temperature, relative humidity, and wind speed. Lake evaporation was calculated using the modified Meyer formula (PFRA 2002).

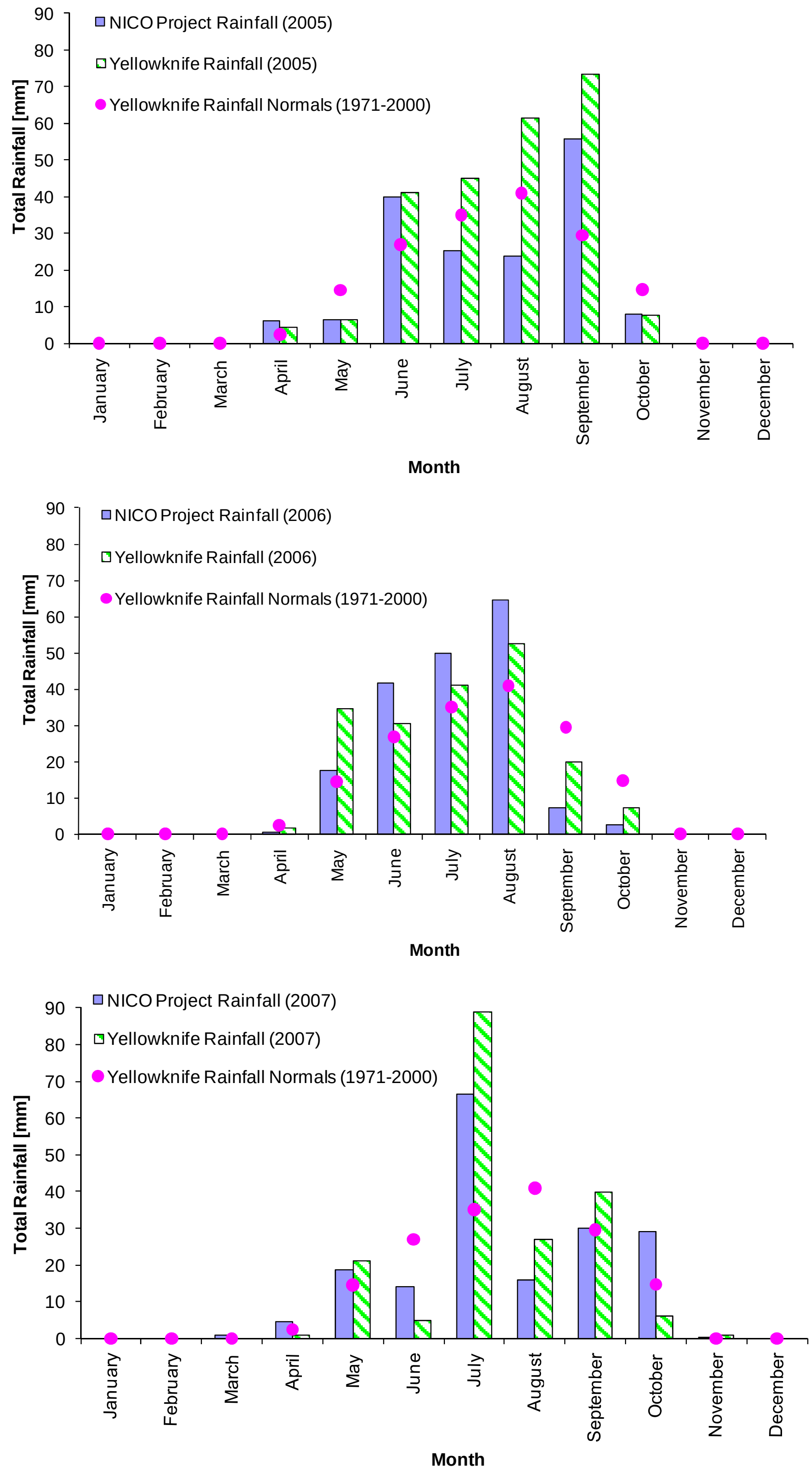

Figure 19.2-2: Monthly Rainfall Summary (2005 to 2007)

19.2.4.2 Predicted Response and Mitigation Measures

The assessment methods for precipitation related to facility failure were based on the Systems Failure Modes and Effects Criticality Analysis approach, which is a standard risk assessment method (Canadian Standards Association 1997; International Organization for Standardization 2009 a, b). This system is outlined in Subject of Note: Accidents and Malfunctions (Section 17). Failure modes and their associated consequences (i.e., hazard scenarios) were first identified for each component of the NICO Project facility using an assessment protocol and the knowledge base of the risk assessment team. Planned mitigation measures for the NICO Project were also identified. Information presented in Section 17 was used to determine the effects of the physical environment on the NICO Project.

19.2.4.3 Effects to NICO Project Infrastructure

19.2.4.3.1 Failure of Surface Runoff Collection

Failure of the surface runoff collection system during operation could result from high precipitation. However, the surface runoff collection system, including the SCPs, will be designed to contain an Environmental Design Flood equal to the greater of a 100-year return period 24 hour precipitation event or a 100-year return period 30 day duration rainfall plus snowmelt event. Inspection and maintenance of the collection system will be performed as part of the operating and closure procedures. The risk of the surface runoff collection system failing is possible (i.e., likelihood is 1 in 10 to 1 in 100 years), but the environmental consequences would be low (Section 17.3.2).

19.2.4.3.2 Overflow of the Tailings Reclaim Ponds

Overflow of the tailings reclaim ponds during operation could result from precipitation exceeding design criteria. It could lead to the release of tailings and contact water to the environment. Depending on the scale of the hypothetical failure, the tailings will report to and may be contained within the SCPs.

As stated in Section 19.2.3.1, the CDF is designed to store the Inflow Design Flood in addition to the Environmental Design Flood during operations. The Inflow Design Flood is a rainfall storm of 1/3 between the 1000-year return period precipitation and the probable maximum precipitation. The Environmental Design Flood is the 100-year return period 30-day rainfall-plus-snowmelt event. During final years of operation and post-closure, an Emergency Spillway will be constructed to safely convey the Inflow Design Flood into the Open Pit. The Co-disposed Tailings and Mine Rock leads to an inherently more stable slope to prevent slope failure. Furthermore, construction quality control and material testing will be performed as the CDF Perimeter Dyke is progressively constructed, to meet specifications. Slope inspection and monitoring will also be performed. In the case of a failure, the effects are at most medium-term. The estimated likelihood of a perimeter dyke failure impacting the off-site environment is rare (i.e., likelihood is 1 in 1000 years or less) (Section 17.3.2).

19.2.4.4 Mitigation for Large Precipitation Events

During Operations

The design is such that the SCPs will be able to contain the runoff from events up to the selected Environmental Design Flood, which is the 30-day, 100 year rainfall plus snowmelt event (215 mm). Larger events could result in a discharge through the spillways of SCP No. 2 or 3 into Nico Lake. Strategies available to prevent or reduce spillway discharges are to:

- pump down the water level in SCP No. 1, 2, and 3 below their normal operating water levels prior to an anticipated event such as a large spring melt;

- accelerate the rate of treatment in the ETF;
- pump excess water from SCP No. 1, 2, and 3 into the Reclaim Pond for temporary holding; or
- pump excess water from SCP No. 1, 2, and 3 into the Open Pit for temporary holding.

The water held temporarily in the Reclaim Pond or in the Open Pit will have to be subsequently eliminated by treating in the ETF.

Post- Closure

The base case for water management after closure is to passively treat water in SCP No. 1, 2, 3, and 5, and the Surge Pond by allowing it to drain by gravity through Wetland Treatment Systems No. 1, 2, and 3 into Nico Lake. The water levels in these ponds will be raised to the spillway invert level to enable gravity drainage.

The ETF and the pumping systems will be left in place for about 10 years after closure, and after that they will be demolished. In the first 10 years after closure, the following actions are available as a contingency in response to anticipated events such as a heavy spring snow melt:

- pump down the water level in SCP No. 1, 2, and 3 below the spillway inverts prior to the heavy spring melt;
- pump water out of the ponds for treatment in the ETF; or
- pump water from the ponds into the Open Pit, which will be slowly flooding.

After the ETF and pumps are decommissioned, the ponds and the Wetland Treatment Systems will operate passively, without active intervention to manage high flow events. If active management appeared necessary, the pumping capacity would have to be brought to site.

19.2.5 Seismic Events

The impact of seismic events on the NICO Project is evaluated in the Subject of Note: Accidents and Malfunctions (Section 17). For the purpose of the discussion on seismic events on the NICO Project, only the potential accidents and malfunctions related to seismic events are discussed below. For the complete discussion on accidents and malfunctions for the NICO Project see the Subject of Note for accidents and malfunctions in Section17.

19.2.5.1 Predicted Response

19.2.5.1.1 Co-Disposal Facility Perimeter Dyke Failure

A CDF Perimeter Dyke failure during operation, closure, or post-closure could result from slope failure due to earthquake. It could lead to tailings being released into the off-site environment, including the surrounding lakes.

The site lies in a region of low seismicity. The CDF Perimeter Dyke will be designed for a peak ground acceleration of 0.059 g (acceleration due to gravity), which corresponds to a 2475-year return period earthquake event. Construction quality control and material testing will be performed as the CDF Perimeter Dyke is progressively constructed, to meet specifications. Slope inspection and monitoring will also be performed to limit the slope to 3:1 (H:V). In the case of a failure, the volume of tailings that could be released to the environment is limited by the Co-Disposed Tailings and Mine Rock cell design, and the effects are at most medium-term. In the worst-case, SCPs would be filled with tailings and Mine Rock with the seepage collection dams acting as a separate barrier. Emergency response measures will be taken, as described in Section 19.2.5.2.

The estimated likelihood of a CDF Perimeter Dyke failure impacting the off-site environment is rare (i.e. likelihood is 1 in 1000 years or less), partially due to the low likelihood of a seismic event.

19.2.5.1.2 Dam Failure at the Water Management Ponds

Dam failure at the Water Management Ponds (i.e., the SCPs, Surge Pond, Contingency Pond (if constructed), and the Plant Runoff Pond) during operation, closure, or post-closure may result in the release of seepage, contact water, or unacceptable effluent into the environment, reaching the surrounding lakes.

Dams will be present at 6 of the Water Management Ponds (SCPs No. 1, 2, and 3, Surge Pond, Contingency Pond (if constructed), and Process Plant Runoff Pond). The site lies in a region of low seismicity and the dams will be designed for a peak ground acceleration of 0.021 g, which corresponds to a 475-year return period earthquake event.

The estimated likelihood of dam failure at the Water Management Ponds is unlikely (i.e., 1 in 100 to 1 in 1000 years), given the low potential for seismic activity.

19.2.5.2 Emergency Response Measures

As described above, the 2 NICO Project facilities likely to be impacted by seismic activity are the CDF and the Water Management Ponds. In addition to the design and construction monitoring mitigation measures listed above and to verify preparedness for and response to a catastrophic failure (e.g., due to a seismic event) the CDF, the NICO Project will do the following:

- address responses to catastrophic failures in the Emergency Response and Spill Contingency Plan; and
- include the following procedures to be followed in anticipation of a catastrophic failure:
  - cessation of tails pumping to the facility and flushing out of the tailings lines;
  - implementation of plans to mitigate further loss of tailings from the CDF;
  - notification of the public of the spill and advisement to avoid use of affected areas until further notice;
  - notification of regulatory authorities and maintenance of on-going public and regulatory dialogue throughout the course of remediation;
  - reconstruction of facilities;
  - collection of spilled tailings for return to the CDF;
  - implementation of remediation of affected areas, as identified through testing and monitoring;
  - implementation of the emergency water quality program within the impacted areas and potentially affected downstream areas; and
  - investigation of causes of the failure to develop and implement measures to avoid recurrence.

19.2.6 Geological Instability

Geological instability may affect the proposed NICO Project in the following 4 ways: loss of permafrost, seismic events, open pit rock slope failure, and crown pillar failure. Losses of permafrost and seismic events have been discussed previously in sections 19.2.1 and 19.2.5, respectively.

19.2.6.1 Crown Pillar Failure

The geological instability, from ground subsidence due to presence of voids in the bedrock from underground workings and decline, can be categorized in the following 3 areas of the NICO Project: underground workings, portal, and the decline.

The rock above the underground workings (the crown pillar) may progressively cave upwards. If the progressive failure zone rises to surface, it can result in ground subsidence or collapse. A crown pillar assessment may indicate potential for instability for a certain length of the tunnel down-dip of the portal, until the thickness of rock above the tunnel is such that failure is unlikely to result in subsidence or collapse to surface. A similar condition may exist in the open pit when it mines down to the decline.

Mitigation measures for crown pillar failure will be incorporated into the mine plan. The underground workings, decline and portal will be mined out by the deepening Open Pit. This will remove the hazard. Should any workings not be mined out, and a crown pillar assessment indicates potential risk, the mitigation measures could include the following:

- Isolation: permanent fencing to isolate the potential zone of collapse.
- Removal of hazards: backfill underground workings to prevent collapse.

19.2.6.2 Open Pit Slope Instability

The NICO Open Pit slopes are designed to be stable under operating conditions. Specifically, given the competent character of the wall rocks, for which overall slope failure is not a concern, the slopes were designed to control the expected failure mechanism, and bench widths are designed to capture most sliding blocks and wedges of rock at the bench scale. After closure, there will be changes to the slope conditions. The slopes will become inundated with groundwater as the groundwater recovers. Weathering will continue, which may result in shear strength changes. Additional wedges or blocks of rock may become unstable. The overall effect is that the Open Pit walls may ravel or fail over time.

The potential concerns with slope stability identified for the NICO Project are the following:

- once the Flooded Open Pit filling approaches the overspill point:
  - a wave could occur if a sudden release of Open Pit wall rocks falls into the lake; and/or
  - ravelling rocks on the pit slopes above the pit lake could expose fresh surfaces with potential to change the water quality of the Flooded Open Pit.
- safety for people accessing the Open Pit, whether dry or flooded; and
- enlargement of the top area of the Open Pit over time due to failures.

Once the Flooded Open Pit is formed, the ravelling and small scale block sliding that may occur over time is not expected to generate a wave. Should a wave occur, it would direct water to the Flooded Open Pit outlet where it would travel overland towards the passive treatment wetlands. This travel path would dissipate wave energy. The Open Pit slope rock types that will form both its submerged and exposed portions of the future Flooded Open Pit are similar. The Flooded Open Pit water quality model includes input from the pit-lake catchment, including unsubmerged Open Pit slope rocks.

At closure, access to the Open Pit will be restricted with access control features, such as rock berms. The location of access control will be established based on conservative estimates of the amount of break-back of the slope that could occur and operational experience. Access to the future Flooded Open Pit may be required for post-closure monitoring, therefore grading or recontouring part of the Open Pit wall to allow safe access to the future Flooded Open Pit may also be required.

In summary, Open Pit slope instability is not considered to have a significant potential effect on the NICO Project. Only ravelling, and minor block/rockfalls, are expected, based on the geotechnical character of the rocks that will form the benches. Open Pit access will be restricted by conservatively designed access control structures. Flooded Open Pit water quality considers the impact of the rocks on the walls and the rock outcrops above the Flooded Open Pit. Any post-closure rock fall and ravelling into the future Flooded Open Pit will expose rock already considered in the assessment. A Flooded Open Pit wave due to a sudden rock fall would exit the Open Pit, follow the designed Flooded Open Pit discharge path, and dissipate its energy. The water would eventually drain to Peanut Lake via a constructed wetland.

The potential for geological instability to affect the NICO Project is considered low. Crown pillars on the decline and portal area are comprised of competent rock. The underground workings, decline and portal will be mined out by the deepening Open Pit. Should any workings not be mined out, and a crown pillar assessment indicates potential risk, to ensure that ground collapse into these tunnels does not progress to surface, creating a hole, the shallower portions of the portal area and decline will be back filled with rock. This will prevent collapse. Access to the portal will be prevented by the installation of barriers.

The competent nature of the rocks that comprise the Open Pit slopes and the generally favourable orientation of joints in the rocks are such that slope failures will be limited to ravelling and small rock fall, which will not adversely extend the pit perimeter, affect Flooded Open Pit water quality, or generate a significant Open Pit lake wave.

19.3 References

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