Table of Contents

TABLES

FIGURES

11.0 SUBJECT OF NOTE: WATER QUANTITY

11.1 Introduction

11.1.1 Context

This section of the Developer's Assessment Report (DAR) for the NICO Cobalt-Gold-Copper-Bismuth Project (NICO Project) consists solely of the Subject of Note (SON) for water quantity. In the Terms of Reference (TOR) for the NICO Project's DAR issued on 30 November 2009, the Mackenzie Valley Review Board (MVRB) identified water quantity as one of 7 top priority valued components requiring a high level of consideration by the developer (MVRB 2009).

As identified within the TOR, this SON for water quantity details any effects the NICO Project may have on the surface water in the watershed and downstream of the watershed.

All effects on water quantity are assessed in detail in this SON; however, issues addressed in the following other Key Lines of Inquiry (KLOI) and SON may overlap with this SON:

- KLOI: Water Quality (Section 7);
- KLOI: Caribou and Caribou Habitat (Section 8);
- KLOI: Closure and Reclamation (Section 9);
- SON: Fish and Aquatic Habitat (Section 12);
- SON: Terrain and Soils (Section 13);
- SON: Vegetation (Section 14);
- SON: Wildlife (Section 15); and
- Section 18: Biophysical Environment Monitoring and Management Plans.

11.1.2 Purpose and Scope

The purpose of the SON Water Quantity is to assess the effects of the NICO Project and meet the TOR issued by the MVRB. The terms for the SON: Water Quantity are shown in Table 11.1-1. The entire TOR document is included in Appendix 1.I and the complete table of concordance for the DAR is in Appendix 1.II of Section 1.

The SON: Water Quantity includes an assessment of direct effects on the quantity of surface water within the study area and downstream of the watershed. This assessment includes potential changes resulting from NICO Project-related components and associated activities, including groundwater withdrawal, surface water withdrawal, and effluent discharge.

The effects assessment will evaluate all NICO Project phases, including construction, operation, and closure. Indirect and cumulative effects have been considered throughout this section, where applicable. Given the NICO Project is proposed to be constructed at the upstream end of the watershed, the effects from the NICO Project must be considered in combination with other developments, activities, and natural factors that influence water quantity within the watershed.

Table 11.1-1: Water Quantity Concordance with the Terms of Reference

Section in Terms of Reference	Requirement	Section in Developer's Assessment Report
3.2.3	An overall environmental assessment study area and the rationale for its boundaries;	11.1.3
	Fortune's chosen spatial boundaries for the assessment of potential impacts for each of the valued components considered; and	11.1.3
	The temporal boundaries chosen for the assessment of impacts on each valued component.	11.2
3.2.4	**Description of the Existing Environment**	
	The developer is encouraged to provide a description of the methods used to acquire the information used to describe baseline conditions.	11.2
3.3.1	**Impact Assessment Steps and Significance Determination Factors** In assessing impacts on the biophysical environment, the *Developer's Assessment Report* will for each subsection:	
	• Identify any valued components used and how they were determined;	11.1.2
	• For each valued component, identify and provide a rationale for the criteria and indicators used;	11.1.2
	• Identify the sources, timelines and methods used for data collection;	11.2
	• Identify natural range of background conditions (where historic data are available), and current baseline conditions, and analyze for discernible trends over time in each valued component, where appropriate, in light of the natural variability for each;	11.2
	• Identify any potential direct and indirect impacts on the valued components that may occur as a result of the proposed development, identifying all analytical assumptions;	11.3
	o Predict the likelihood of each impact occurring prior to mitigation measures being implemented, providing a rationale for the confidence held in the prediction;	11.3.2
	o Describe any plans, strategies or commitments to avoid, reduce or otherwise manage the identified potential adverse impacts, with consideration of best management practices in relation to the valued component or development component in question;	11.3.2
	o Describe techniques, such as models utilized in impact prediction including techniques used where any uncertainty in impact prediction was identified;	11.3.2
	• Assess and provide an opinion on the significance of any residual adverse impacts predicted to remain after mitigation measures; and	11.3.2.3
	• Identify any monitoring, evaluation and adaptive management plans required to ensure that predictions are accurate and if not, to proactively manage against adverse impacts when they are encountered.	11.5
	The developer will characterize each predicted impact. These criteria will be used by the developer as a basis for its opinions on the significance of impacts on the biophysical environment.	

Table 11.1-1: Water Quantity Concordance with the Terms of Reference (continued)

Section in Terms of Reference	Requirement	Section in Developer's Assessment Report
3.3.5	**Water Quantity** The developer will:	
	• Describe the potential impacts of the NICO Project on upstream and downstream water quantity, with a particular emphasis on changes in:	11.3.2
	o Lou, Peanut, Nico and Burke Lakes;	11.3.2.1, 11.3.2.2
	o Connecting waterways (including any streams from Burke Lake feeding Marian River) and ephemeral springs that form during freshet; and	11.3.2.1, 11.3.2.2
	o groundwater flows.	11.2.3.1, 11.3.2.2
	Provide a water balance for the project (with proposed water recycling).	11.2.2.2, Appendix 3.III
	• Discuss potential effect of pit dewatering on groundwater levels and water table drawdown.	Appendix 11.I
	• Discuss potential changes to groundwater-surface water interactions resulting from project activities.	11.3.2.2
	• Discuss how potential changes to permafrost resulting from Project activities may affect groundwater quantity.	11.3.2.2, Appendix 11.I
	• Describe potential impacts of water withdrawals and the loss of littoral habitat.	11.3.2.2
	• Describe potential effects of changes in water quantity on the Marian River and Marian Lake.	11.3.2.2
	• Describe mitigation measures to minimize impacts to water quantity.	11.3.2
Appendix A	**Existing Environment**	
	Biophysical environment Describe the biophysical environment within the relevant environmental assessment study areas. The following description should be at a level of detail sufficient to allow for a thorough assessment of project effects. Describe the following:	
	Hydrology and hydrogeology, including surface water and groundwater amounts, direction of flow, likely surfacing points/discharge area (for groundwater and shallow subsurface water), and maps and descriptions of associated watersheds. Discussion should focus in particular on:	
	a. the NICO Project mine site with sufficient data to capture spatial and temporal variations in water quality;	11.2
	b. seasonal and annual variation in groundwater and surface water quantity around the mine site; including trends over time related to climatic change and extreme events (e.g. high flows);	11.2.1
	c. the relative contribution of water from the NICO Project mine site to the volume of Burke Lake and the Marian River;	Appendix 11.III

Table 11.1-1: Water Quantity Concordance with the Terms of Reference (continued)

Section in Terms of Reference	Requirement	Section in Developer's Assessment Report
Appendix A (continued)	d. surface water and groundwater flow regimes associated with the plateau on which the mine site is located including groundwater flow from the mine itself;	11.2.2.3, 11.2.3.4
	e. relationship between the groundwater regime and permafrost conditions and how permafrost influences on-site hydrogeology;	11.2.3.3
	f. description of the methodology used to derive the components of the water balance and characterization of flow regimes including a discussion of any uncertainty;	11.2.2.2
	g. provide a map indicating the location with rationale of all existing and planned wells, and seeps within the study area and other monitoring locations;	Appendix 11.I
	h. provide location of seepage meters, if any, and evaporation pans installed in the study area; and	Not applicable
	i. provide a water table elevation map and a map detailing drainage patterns for surface and groundwater for the mine site and mine workings.	Appendix 11.I, Appendix 3.III

Valued components (VCs) represent physical, biological, cultural, social, and economic properties of the environment that are considered to be important by society. Hydrology was selected as one of the VCs for this effects assessment. Hydrology is a fundamental component of the natural ecosystem because of its importance of water availability to all living organisms including fish, vegetation, wildlife, and people.

Assessment endpoints represent the key properties of the VC that should be protected for their use by future human generations, while measurement endpoints are quantifiable (i.e., measurable) expressions of changes to assessment endpoints. Hydrology, geology, and hydrogeology do not have assessment endpoints (Section 6.2). Instead, these VCs have measurement endpoints that are linked to changes in other VCs (e.g., fish and fish habitat) that are more directly associated with an assessment endpoint (e.g., persistence of fish and fish habitat). Measurement endpoints for water quantity, geology, and hydrogeology are presented in Table 11.1-2.

Table11.1-2: Summary of the Valued Components and Measurement Endpoints for Water Quantity

Valued Component	Assessment Endpoints	Measurement Endpoints
Hydrology	Not Applicable	• Flow rate and the spatial and temporal distribution of water • Surface topography, drainage boundaries, and waterbodies (e.g., streams, lakes, and drainages)
Hydrogeology		• Groundwater flows and levels

11.1.3 Study Areas

11.1.3.1 General Setting

The NICO Project is approximately 160 kilometres (km) northwest of Yellowknife in the Northwest Territories (NWT) and is located within the Marian River drainage basin, approximately 10 km east of Hislop Lake at a latitude of 63° 33' North and a longitude of 116° 45' West (Figure 11.1-1). The NICO Project is located approximately 50 km northeast of Whatì and 70 km south of Gamètì, the nearest communities. Other communities include Behchokǫ̀, approximately 85 km southeast of the NICO Project, and Wekweètì, located approximately 140 km northeast of the NICO Project. All of these communities are within Tłįchǫ Land Claim. The NICO Project is surrounded by the Tłįchǫ Land Claim. The mean annual temperature for this region is -4.6 degrees Celsius (°C) (Environment Canada; Yellowknife A Weather Station 2011). July is the warmest month with a mean temperature of 16.8°C, whereas January is typically the coldest month with a mean temperature of -26.8 °C.

The NICO Project is a contributor within the sub-sub-drainage area known as the Marian – Mouth, the sub-drainage area known as Marian, and the major drainage area identified as the Great Slave Lake Drainage Area. The NICO Project intersects watershed areas identified as the Lou Lake and Burke Lake watersheds and both systems discharge southwest to the Marian River. The Marian River generally flows towards the south joining first with the Emile River and second with the La Martre River. The Marian River drains into Marian Lake, which drains into the North Arm of Great Slave Lake. Great Slave Lake is drained by the MacKenzie River, which discharges to the Beaufort Sea.

To facilitate the assessment and interpretation of potential effects associated with the NICO Project, it is necessary to define appropriate spatial boundaries. Study area boundaries were delineated based on the predicted spatial extent of the NICO Project-related effects.

11.1.3.2 Regional Study Area

The regional study area (RSA) was selected to encompass the maximum predicted spatial extent of direct and indirect effects from the NICO Project. The RSA includes the local study area (LSA) and extends along the Marian River from its connection to the NICO Project to its junction with the Emile River. The boundary of the RSA exterior to the LSA, which follows the Marian River, includes the Marian River channel and floodplain width up to 100 metres (m) on either side of the channel to encompass possible flooded areas during peak flow conditions (Figure 11.1-2).

11.1.3.3 Local Study Area

The NICO Project is expected to directly affect the Lou Lake and Burke Lake watersheds, as well as the Marian River. The LSA for hydrology includes portions of the Burke Lake and Lou Lake watersheds draining to the Marian River (Figure 11.1-3). These portions are anticipated to reflect the areas of the drainage that may be directly affected by the NICO Project. The LSA covers an approximate area of 56.9 square kilometres (km^2). In comparison, the Burke Lake and Lou Lake watersheds, including contributing upstream drainage areas, are approximately 90.8 and 58.5 km^2, respectively.

LEGEND

- NICO PROJECT
- TERRITORIAL CAPITAL
- POPULATED PLACE
- HIGHWAY
- EXISTING ALL-WEATHER ROAD
- EXISTING WINTER ROAD
- PROPOSED NICO PROJECT ACCESS ROAD
- PROPOSED TŁĮCHǪ ROAD ROUTE
- RAILROAD
- TERRITORIAL/PROVINCIAL BOUNDARY
- WATERCOURSE
- WATERBODY

100 0 100

SCALE 1:3,000,000 KILOMETRES

REFERENCE

Base data obtained from Atlas of Canada, DMTI, and ESRI.
Projection: Canada Lambert Conformal Conic

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

LOCATION OF THE NICO PROJECT

Golder Associates
Edmonton, Alberta

FILE No. E-Section1-002-GIS

PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	JG	17 Jan. 2011	**FIGURE: 11.1-1**	
GIS	CW	17 Jan. 2011		
CHECK	GRA	04 May 2011		
REVIEW	GRA	04 May 2011		

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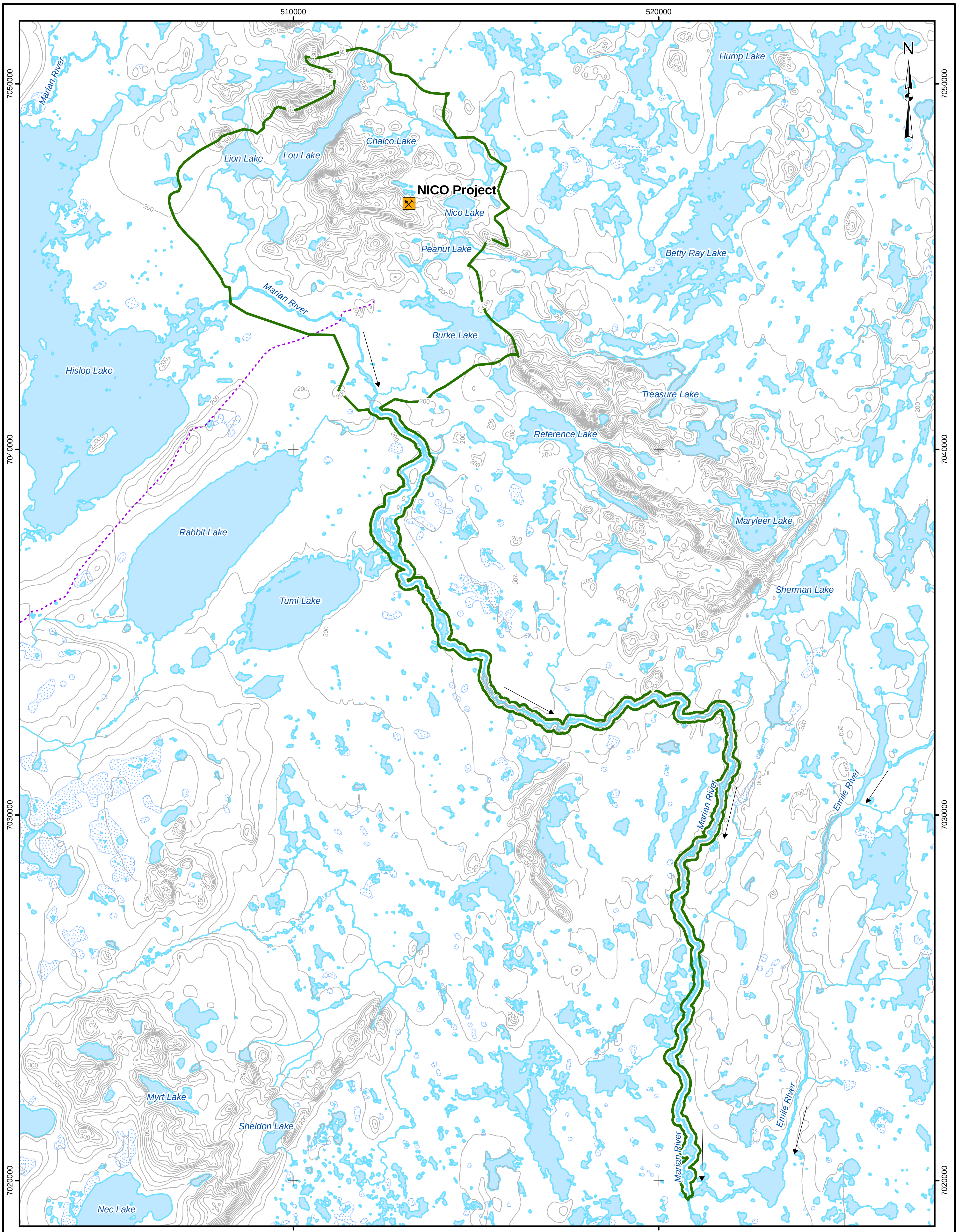

LEGEND

- NICO PROJECT
- CONTOUR (10 METRE INTERVAL)
- PROPOSED NICO PROJECT ACCESS ROAD
- WATERCOURSE
- WATERBODY
- WETLAND
- FLOW DIRECTION
- REGIONAL STUDY AREA BOUNDARY

3 0 3

SCALE 1:100,000 KILOMETRES

REFERENCE

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

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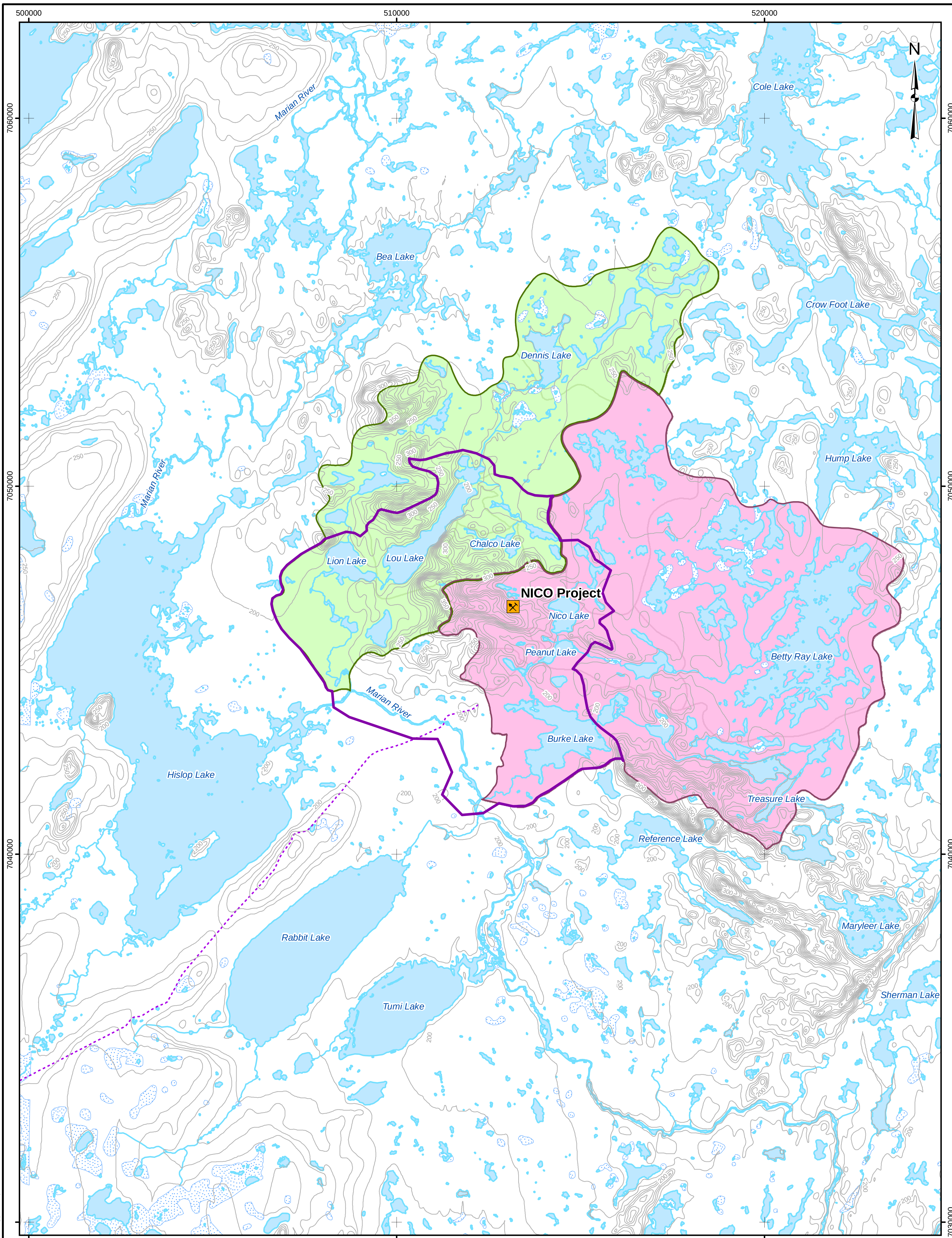
FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

HYDROLOGY REGIONAL STUDY AREA
FOR THE NICO PROJECT

Golder Associates
Edmonton, Alberta

FILE No. E-Hydrol-001-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	TL	01 Jan. 2009	FIGURE: 11.1-2	
GIS	RLP	08 Feb. 2011		
CHECK	GRA	4 May. 2011		
REVIEW	GRA	4 May. 2011		



LEGEND

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

WATERSHED

- BURKE LAKE
- LOU LAKE

Waterbody	Area (ha)
Burke Lake	231.00
Chalco Lake	32.80
Lion Lake	82.40
Lou Lake	199.00
Nico Lake	50.60
Peanut Lake	20.90

3 0 3

SCALE 1:100,000 KILOMETRES

REFERENCE

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

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NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

HYDROLOGY LOCAL STUDY AREA
FOR THE NICO PROJECT

Golder Associates
Edmonton, Alberta

FILE No. E-Hydrol-002-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	TL	01 Jan. 2009	FIGURE: 11.1-3	
GIS	RLP	08 Feb. 2011		
CHECK	GRA	04 May 2011		
REVIEW	GRA	04 May 2011		

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11.1.4 Content

The general organization of this SON is outlined in Table 11.1-3. To verify that the contents of the TOR are addressed in this report, a table of concordance that cross-references the TOR to the information and location in this DAR is contained in Table 11.1-1.

Table 11.1-3: Subject of Note: Water Quantity Organization

Section	Content
Section 11.1	**Introduction -** Provides an introduction to the Water Quantity Subject of Note by defining the context, purpose, scope, and study areas, and providing an overview of the Subject of Note organization
Section 11.2	**Existing Environment** - Provides a summary of baseline methods and results for ground and surface water quantity
Section 11.3	**Pathway Analyses** - Provides a screening level assessment of all potential pathways by which the NICO Project may influence ground and surface water quantity after applying environmental design features and mitigation that reduce or eliminate NICO Project-related effects
Section 11.6	**Uncertainty** - Provides a discussion of the uncertainty related to the effects on water quantity
Section 11.7	**Monitoring and Follow-up** - Provides a summary of the proposed monitoring and follow-up programs that will be implemented to evaluate the predicted effects on water quantity

In addition to the content included in this SON, the following Appendices and Annex are included to provide additional detailed information.

- Appendix 11.I: Report on NICO Fortune Minerals Groundwater Modelling
- Appendix 11.II: Effects of Freshwater Extraction on Lou Lake
- Appendix 11.III: Effects of Fortune Minerals NICO Project on Surface Water Quantity
- Appendix 11.IV: Results of Flooded Open Pit Filling Scenarios
- Annex G: Hydrology Baseline Report

11.2 Existing Environment

Hydrological data includes estimated streamflow volumes, temporal and spatial distribution of runoff, flow directions, and identification of watershed boundaries in the vicinity of the NICO Project. Climate parameters derived from regional data have been used to estimate actual evapotranspiration and evaporation from free water surface for water balance calculations, along with prediction of normal ranges and extreme precipitation potential.

Local streamflow and water level data were collected at 13 streams and 7 waterbodies from 2005 through 2008. In the spring of 2005, the approximate extents of the watershed boundaries and flow directions in the vicinity of the NICO Project were verified during an initial reconnaissance survey. Surface water hydrology data collected in the LSA included the following:

- watershed drainage boundary delineation and verification;

- lake water level measurement;
- continuous stream water level (stage) measurement at 3 stations;
- instantaneous stream discharge and stream stage measurement; and
- winter discharge measurement.

The NICO Project occurs within both the Lou Lake and Burke Lake watersheds. Both drainage systems discharge water to the southwest towards the Marian River. The Marian River generally flows towards the south joining with the Emile River and then with the La Martre River. The Marian River drains into Marian Lake, which drains to the North Arm of Great Slave Lake. Great Slave Lake is drained by the MacKenzie River, which discharges to the Beaufort Sea.

11.2.1 Climate

11.2.1.1 Methods

Climatic parameters for the NICO Project (temperature, relative humidity, wind speed, and wind direction) were characterized using data from the nearest long-term climate station (1953-2008) located at the Yellowknife Airport, which is operated by Environment Canada (Yellowknife A meteorological station). Net radiation data used in the assessment of actual evapotranspiration was taken from the Norman Wells A meteorological station. This is the nearest station providing net radiation data. Yellowknife Airport precipitation and temperature data were visually compared to coincident data from Snare Rapids (located 39 km east of the NICO Project) and Gamètì Airport (located 68 km northwest of the NICO Project). The visual inspection involves the monthly mean value and calculation of the normal 95 percent (%) confidence interval based on the sample size of the variable of interest from the locations being compared (Smith 2008, internet site). When a confidence interval for either mean overlaps the other mean, the means were assumed to be equal. Based on this assessment, it was concluded that the Yellowknife Airport data would be suitable for use as a representation of climate at the NICO Project. Local climate data were collected at the NICO Project's meteorological station from 2004 through 2008; however, winter precipitation data were not collected. Due to the brevity of the data and the lack of winter precipitation measurements, these data were not incorporated into the assessment.

Yellowknife Airport is the only local climate station that remains active with a full suite of measured parameters. In addition, precipitation data from the Yellowknife Airport are available with corrections that account for snow gauge undercatch to provide a more accurate measurement for precipitation.

11.2.1.2 Results

Climatic parameters are used for numerous NICO Project development purposes. These include calculation of water balance, extreme precipitation events, and the average monthly and annual precipitation and temperature. Water balance calculations require the estimates of lake evaporation and actual evapotranspiration.

Monthly and annual means of selected climatic parameters are provided in Table 11.2-1. Long-term mean precipitation for the LSA over the 55 year period of record was 343.5 millimetres (mm). The twenty-fifth and seventy-fifth percentiles, which would be indicative of a dry or wet year, were 299 mm and 395 mm, respectively. The wettest year on record was 1974 (506.4 mm), whereas the driest was 1949 (194.9 mm). Most rainfall occurs in July, August, and September whereas maximum snowfall occurs in late fall and early winter (Table 11.2-1). On an annual basis, slightly more precipitation occurs as rain rather than snow. The maximum monthly rainfall was 152.4 mm (August 1969), whereas the highest snowfall in one month is 95 mm (water equivalent), which occurred in November 2006. 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 mm of rain.

Climatic parameters used for water balance calculations are also provided in Table 11.2-1. 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).

Actual evapotranspiration was calculated using the method of Granger and Gray (1989) and was limited to an 11 year period as net radiation was the limiting input variable. Net radiation from Norman Wells was used for actual evapotranspiration calculations.

Table 11.2-1: Summary of Monthly and Annual Mean Climatic Parameters for the Local Study Area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	Total
Rainfall (mm)	0.3	0.3	0.2	2.8	15.7	25.0	40.1	44.1	32.1	15.2	1.6	0.4	n/a	177.9
Snowfall (water equivalent) (mm)	21.2	19.3	18.8	11.6	4.8	0.2	0.0	0.1	3.9	23.6	35.5	26.6	n/a	165.5
Total Precipitation (mm)	21.5	19.5	19.0	14.5	20.5	25.2	40.1	44.1	36.0	38.8	37.1	27.1	n/a	343.5
Actual Evapotranspiration (mm)	0.0	0.0	0.0	0.0	45.3	58.5	53.3	34.2	12.9	2.1	3.0	0.0	n/a	209.3
Lake Evaporation (mm)	0.0	0.0	0.0	0.0	0.0	118.6	154.4	120.7	66.8	18.0	0.0	0.0	n/a	478.5
Temperature (°C)	-27.0	-23.8	-17.6	-5.9	4.7	13.2	16.6	14.0	6.8	-1.5	-13.7	-22.8	-4.7	n/a
Relative Humidity (%)	69.2	68.8	66.6	65.6	59.2	55.9	59.6	68.1	75.2	82.4	80.3	72.5	68.6	n/a
Wind Speed (km/h)	12.4	12.9	14.0	15.3	15.7	15.5	14.5	14.4	15.4	15.9	14.5	12.4	14.4	n/a
Net Radiation (MJ/m^2)	-1.41	-1.69	2.50	-1.49	9.49	11.02	9.25	6.01	2.45	-0.81	-1.43	-1.27	n/a	n/a

MJ/m^2 = megajoules per square metre; mm = millimetres; °C = degrees Celsius; % = percent; km/h = kilometres per hour

11.2.2 NICO Project Hydrology

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. The majority of the monitoring sites occurred within the LSA; however, there are other sites included in the monitoring program that flow into the RSA.

11.2.2.1 Local Drainage

Two local drainage areas collect runoff from the LSA and both flow south to the Marian River. These drainages are referred to as the Burke Lake and Lou Lake watersheds and they drain areas of 90.8 km^2 and 58.5 km^2, respectively. Flow from the Lou Lake and Burke Lake drainages contribute a very small portion of the Marian River discharge. The Burke Lake and Lou Lake watersheds have been further divided into sub-basins based on topographic divides, with the smallest divisions in the area where NICO Project facilities are expected to be constructed.

11.2.2.2 Water Balance

11.2.2.2.1 Methods

A climatic water balance was calculated to predict the mean annual discharges from each of the basins. This approach uses total precipitation, actual evapotranspiration, lake evaporation, and spatial parameters including land and lake surface areas to estimate mean annual discharge from each sub-basin. The approach assumes that seepage losses to (or gains from) groundwater are negligible and that water storage in soils is relatively static.

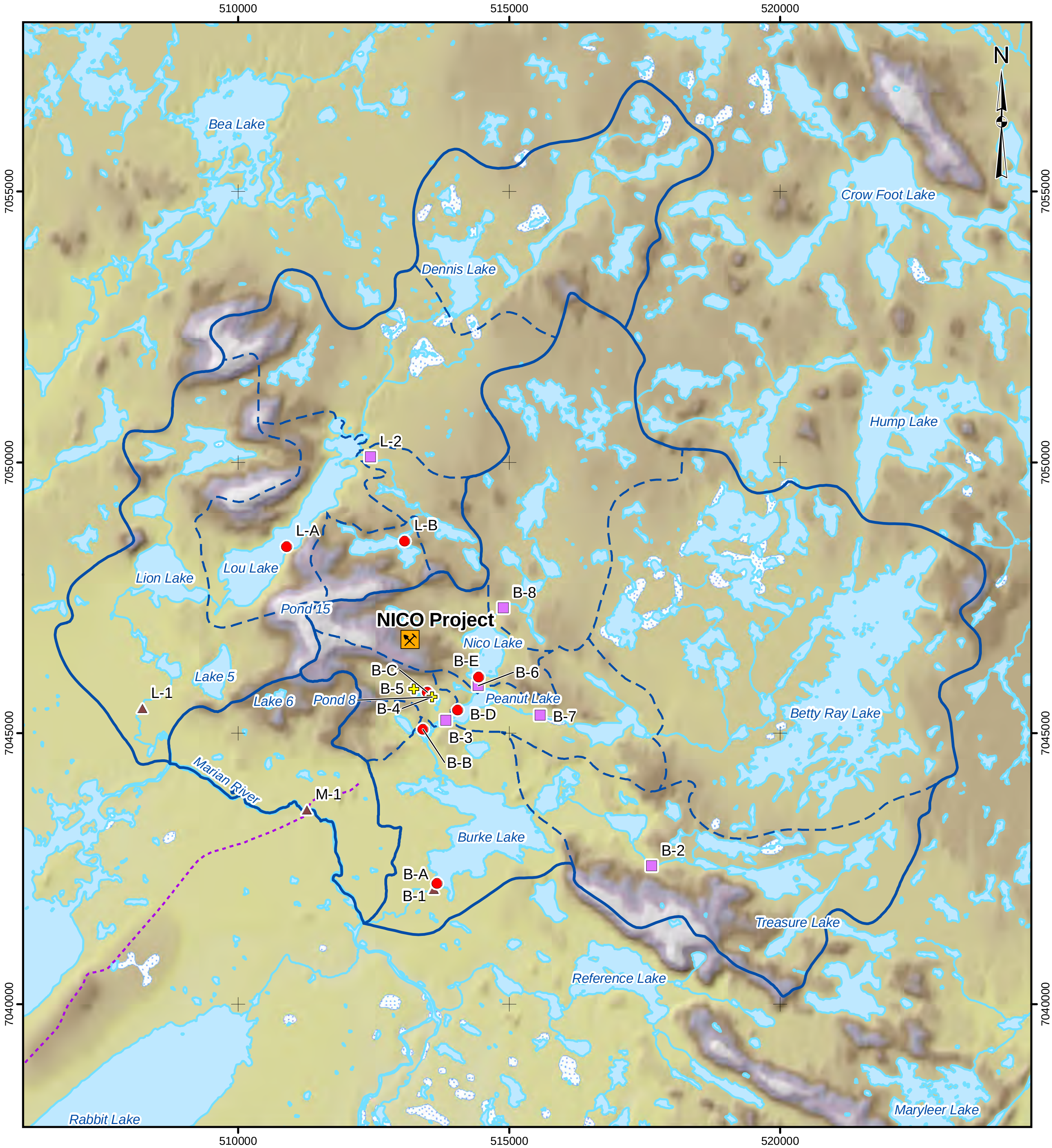
11.2.2.2.2 Results

The calculated mean annual discharge from the Lou Lake drainage to the Marian River is 0.260 cubic metres per second (m^3/s) and the discharge from the Burke Lake drainage is 0.362 m^3/s. On a per unit area runoff basis, this translates to 0.0045 $m^3/s/km^2$ (cubic metres per second per square kilometre in watershed) from the Lou Lake drainage and 0.0040 $m^3/s/km^2$ from the Burke Lake drainage. These results are similar to unit area runoff results for long-term regional hydrometric stations. For example, the unit area runoff for the Indin River hydrometric station, located 125 km northeast of the LSA, is 0.0052 $m^3/s/km^2$, and the unit area runoff for the Emile River, located 42 km east of the LSA, is 0.0033 $m^3/s/km^2$.

11.2.2.3 Baseline Flow Monitoring and Long-Term Record Derivation

11.2.2.3.1 Methods

Hydrometric monitoring field investigations occurred mainly during the open-water seasons from 2005 through 2008; however, one field investigation occurred during the winter of 2008. Lake levels were surveyed from 2005 to 2008 at 7 waterbodies. Hydrometric monitoring at up to 11 streamflow monitoring stations involved taking coincident measurements of stage and discharge during each field visit (Figure 11.2-1). An additional 2 stations along the corridor of the proposed access road were also observed and measured one time in 2005.



LEGEND

NICO PROJECT
PROPOSED NICO PROJECT ACCESS ROAD
WATERCOURSE
WATERBODY
WETLAND

MONITORING STATION

CROSS-SECTION LOCATION
STAFF GAUGE LOCATION
STAFF GAUGE AND CROSS-SECTION LOCATION
STAFF GAUGE, CROSS-SECTION, AND DATALOGGER LOCATION
MAJOR DRAINAGE BOUNDARY
SUB-DRAINAGE BOUNDARY

2.5 0 2.5

SCALE 1:100,000 KILOMETRES

REFERENCE

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

FORTUNE MINERALS LIMITED
NICO DEVELOPER'S ASSESSMENT REPORT

TITLE

HYDROMETRIC MONITORING LOCATIONS AT THE NICO PROJECT

Golder Associates
Edmonton, Alberta

FILE No. E-Hydrol-004-GIS				
PROJECT No. 09-1373-1004			SCALE AS SHOWN	REV. 0
DESIGN	TL	18 Apr. 2011	FIGURE: 11.2-1	
GIS	ANK	19 Apr. 2011		
CHECK	GRA	04 May 2011		
REVIEW	GRA	04 May 2011		

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Stage (water level) was measured using staff gauges installed in the streams, and these were re-surveyed once each year relative to local benchmarks at each site. Continuous stage recording using water level sensors (Leveloggers) occurred during the open water season in streams draining Burke Lake, downstream of Lou Lake, and in the Marian River. Stage data from the Leveloggers were converted to discharge using the stage-discharge data pairs (i.e., rating curves) so that a daily flow record was developed for each monitoring station.

The data collected were then 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.

11.2.2.3.2 Results

The Marian River had the largest flows, followed by Burke Creek and Lou Creek (Figures 11.2-2 to 11.2-4). Burke Creek drains Burke Lake to the Marian River and Lou Creek flows from Lou 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 year 2008 was particularly dry and forest fires were widespread in the early summer, 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 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.

Figure 11.2-5 provides the results of lake level monitoring in the LSA over the period 2005 to 2008. 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. 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.

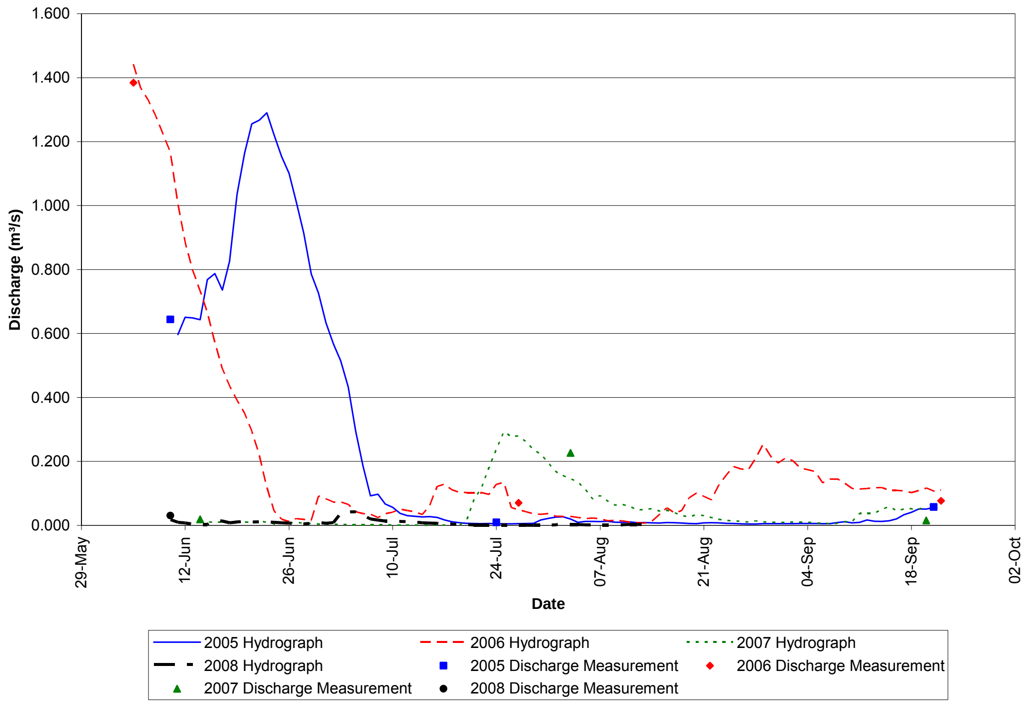

Figure 11.2-2: Burke Creek Measured Hydrograph from 2005 to 2008

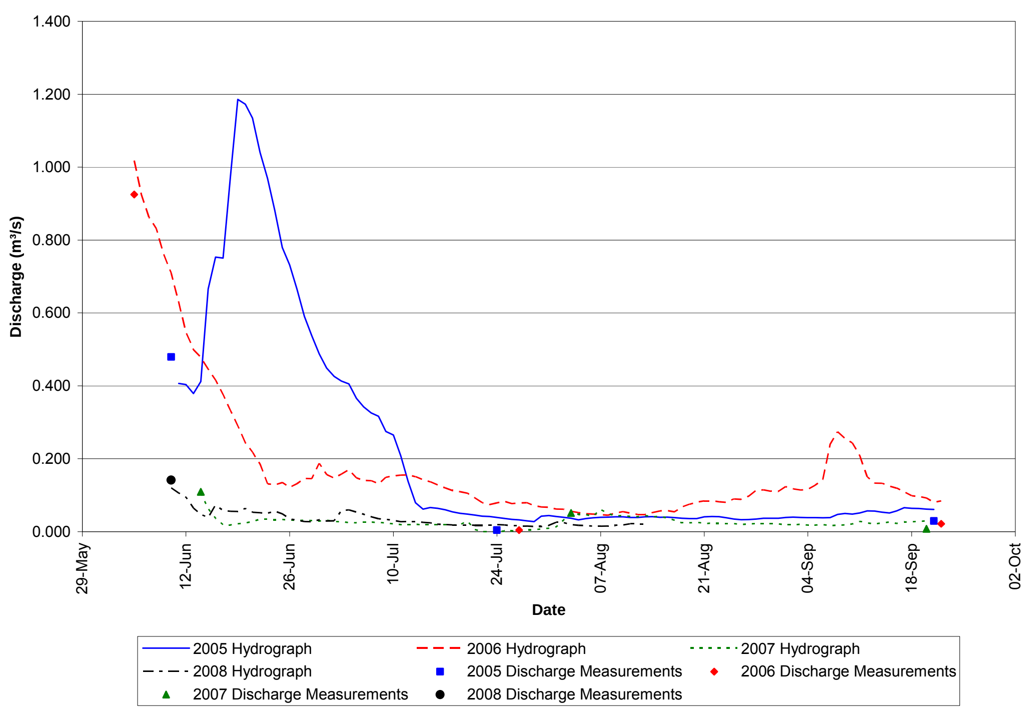

Figure 11.2-3: Lou Creek Measured Hydrograph from 2005 to 2008

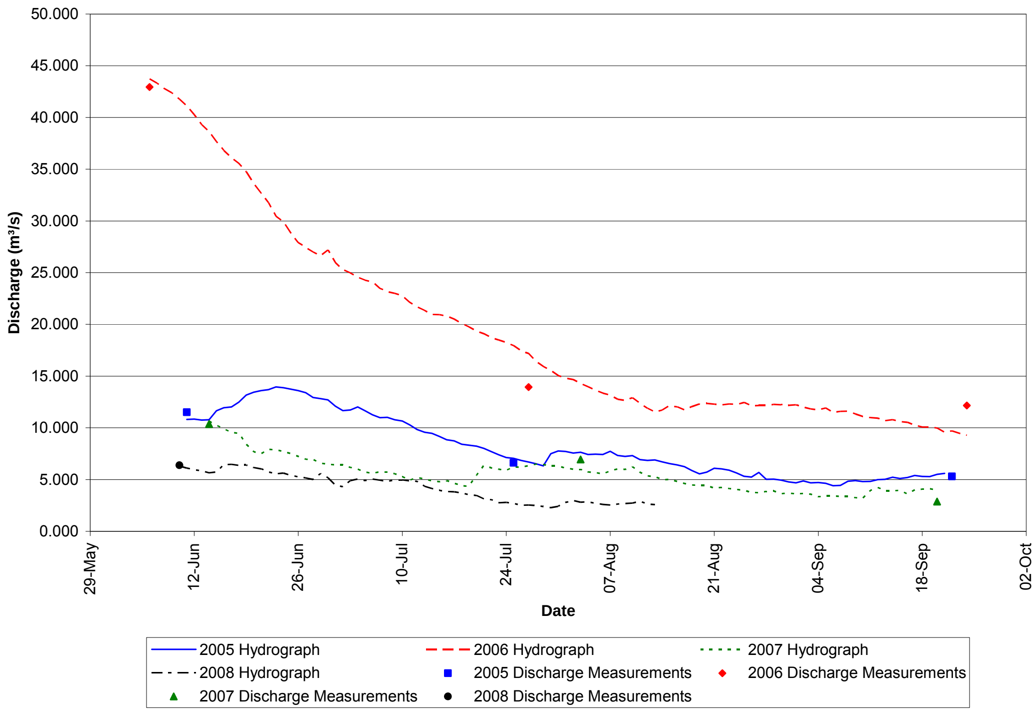

Figure 11.2-4: Marian River Measured Hydrograph from 2005 to 2008

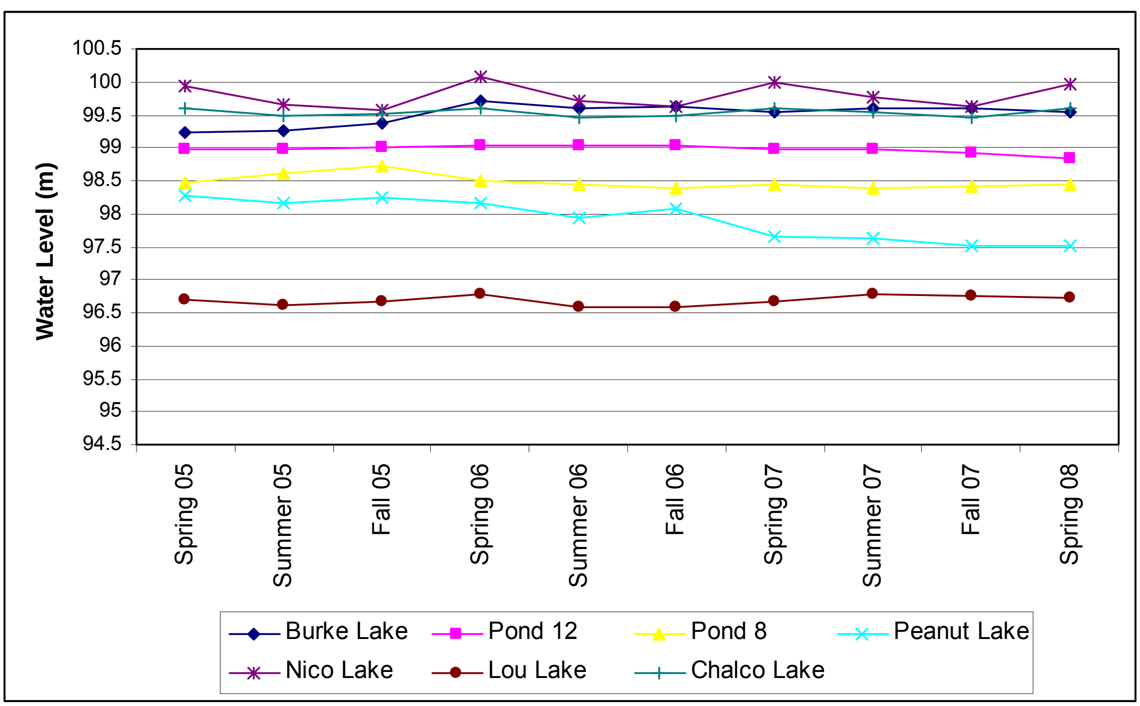

Figure 11.2-5: Water Level Measurements for Lakes and Ponds in the Local Study Area

11.2.2.4 Flood Magnitude and Frequency

11.2.2.4.1 Methods

Annual peak daily discharges for each of the watersheds in the LSA were estimated and fit to a probability distrubtion (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.

11.2.2.4.2 Results

Results of the flood magnitude and frequency analysis for streamflow monitoring stations at all of the watershed outlets are provided in 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.

Table 11.2-2: Annual Maximum Flood (m^3/s) at Specific Return Intervals (year)

Return Period (years)	BL1	BL2	BL3	BL4	BL5	BL6	BL7	BL8	LL1	LL2	LL3	LL4	LL5	LL6	M1
2	0.09	0.15	0.50	0.64	0.09	0.02	0.01	1.15	0.10	0.23	0.10	0.02	0.59	0.87	9.84
5	0.18	0.29	1.02	1.24	0.19	0.05	0.02	2.35	0.20	0.45	0.20	0.03	1.21	1.78	31.09
10	0.25	0.40	1.45	1.76	0.27	0.07	0.02	3.34	0.28	0.63	0.28	0.04	1.72	2.53	55.28
20	0.33	0.53	1.92	2.33	0.36	0.10	0.03	4.42	0.37	0.84	0.37	0.06	2.27	3.34	87.73
50	0.45	0.73	2.59	3.20	0.49	0.13	0.04	5.97	0.50	1.15	0.51	0.08	3.07	4.52	145.47
100	0.55	0.91	3.14	3.94	0.59	0.16	0.05	7.25	0.60	1.42	0.62	0.10	3.72	5.48	202.13

11.2.3 Hydrogeological Conditions

This section provides a description of key aspects of the hydrogeologic system and data used in the construction and calibration of the groundwater model for the NICO Project. A complete description and a full discussion of hydrogeological investigations and modelling results are found in Appendix 11.I.

11.2.3.1 Surface Terrain and Drainage

Ground elevations within the LSA range from 190 to 370 metres above sea level (masl). The majority of the study area consists of low-lying, densely wooded swampy terrain with numerous small to large lakes and streams ("lowlands areas"). In addition, the landscape features a number of distinct hills or "upland" areas. Most of these upland areas, scoured by the action of glaciers, have bedrock at surface and are sparsely vegetated. The proposed mine site is located on one of these upland features.

11.2.3.2 Geology

The geological data are generally confined to the proposed Open Pit area. Therefore, much of the geologic interpretation implemented in the model is inferred from site data and applied at a regional scale. To simplify the regional interpretation, the geology within the model domain is divided based on the following distinct topographic settings: upland areas and lowland areas.

Upland Areas

The upland areas (defined herein as those areas with elevations greater than 230 masl) are generally comprised of fractured rock outcrop at surface, low permeability bedrock at depth, and an absence of permafrost throughout (Appendix 11.I). The NICO deposit is situated in Snare Group meta-sedimentary rocks comprised of siltstone, impure dolomite, subarkosic wacke, and arenite. These strata are interpreted to dip 50 degrees (°) to 80º towards an azimuth of 030º. The sedimentary rocks are overlain by Faber Lake Group volcanic rocks of rhyolitic to rhyodacitic composition. Further, the sedimentary rocks are intruded by quartz-feldspar and quartz-porphyritic dykes. The ore itself is found mainly in the sedimentary units that have been subject to “Black Rock Alteration.” Geotechnical logging indicates that the site is typically comprised of Good Quality rock, with localized exceptions including Fair and Very Good rock intervals, based on the Q-System.

Lowland Areas

The lowland areas are defined as regions with elevations less than 230 masl (Appendix 11.I). The defining geologic characteristics of the lowland areas are variable thicknesses of overburden at surface and discontinuous permafrost at depth (where lakes are not present). The overburden consists of peat, topsoil, and organics followed by silty clay to clayey silt, and then glacial till. Measured thicknesses of overburden vary from 0.5 to 9.4 m.

The shallow bedrock geology beneath the overburden in the lowland areas depends on the drilled area; siltstone, rhyolite, or wacke have been identified in the lowland cores. Regardless of the rock type, the bedrock material is usually described as slightly weathered at shallow depths, becoming increasingly strong to very strong with depth, and containing moderate to widely spaced fractures. From a hydraulic perspective it is thought that the shallow bedrock in the lowlands is in essence an extension of that found in the upland areas.

11.2.3.3 Permafrost

Based on field measurements, areas of discontinuous permafrost are inferred to be present in the lowland areas (Appendix 11.I). Thermistor measurements in 3 lowland wells indicate a permafrost thickness ranging from 29 to 76 m (average of about 50 m) with an active zone in the overburden ranging from 2 to 4 m.

11.2.3.4 Groundwater Flow

Generally, groundwater flows radially outward from the topographic highs (considered recharge zones) to the lowland areas, where shallow groundwater likely reports to streams and lakes (considered discharge zones). The majority of the measured water levels used to produce the inferred groundwater flow map are limited to the anticipated mine site (Appendix 11.I). The measured water levels indicated that groundwater levels in the upland area range from 1 to 37 m below ground surface (average 17 m below ground), follow topography, and thus flow is roughly radial from the hill itself. As most of these water levels were measured in open exploratory boreholes, they are considered to be generally indicative of the water table elevation. It should be noted that the upper fractured zone is often not saturated.

The groundwater elevation map has been extrapolated beyond the existing site data (Appendix 11.I). This extended regional interpretation was based on topographic elevations of the numerous lakes and streams in the lowland areas, which are considered to be hydraulically connected to the groundwater system. Topographic maps are considered to provide a reasonable estimation of lake levels. In addition, the groundwater elevations in the remaining off-site upland areas were assigned to be 17 m below ground, based on the average measured water levels. Therefore, the water table elevations for the off-site upland areas are inferred based on a generalized average condition.

Lakes and streams in the lowland areas around the site are considered locations of groundwater discharge. Groundwater that discharges to waterbodies and thus becomes surface water is referred to as “baseflow” in this report. As mentioned above, groundwater is generally considered to discharge to the lakes and streams within the lowland areas, however, seeps have been observed along the sides of the NICO Project hill “bowl” areas at elevations of roughly 240 to 250 masl (Appendix 11.I).

11.2.3.5 Recharge

Meteorological data have been collected in the LSA from October 2004 to August 2008; however, the monitoring does not provide winter precipitation data. Consequently, regional data have been used to assess the precipitation conditions at the site. The closest meteorological station to the site is at Yellowknife. Average annual precipitation based on 30-year climate normals in the Yellowknife area is about 281 mm (Environment Canada 2011). Based on the precipitation inputs recorded at Yellowknife and the surficial soils in the LSA, it is estimated that about 10 to 50 mm per year infiltrates the ground and reaches the water table (Appendix 11.I).

11.2.3.6 Hydraulic Conductivity

In general, the bedrock is relatively low hydraulic conductivity material, ranging from approximately 5E-6 metres per second (m/s) to 1E-10 m/s with a geometric mean of 3E-8 m/s. While the correlation between hydraulic conductivity and test interval is not particularly strong, there does appear to be some decrease in permeability with depth.

The overburden material is generally silty till material with occasional pockets of sand. Shepherd’s Method may be used to estimate the hydraulic conductivity of the overburden based on available grain size. Shepherd’s Method correlates grain size to permeability as follows:

$$K = a(D_{50})^b$$

where D_{50} is the diameter of the 50 percentile grain size in mm, and a and b are empirical constants based on the soil type, considered to be 100 feet per day and 1.5, respectively, for this analysis. Based on an analysis of the grain size curves the hydraulic conductivity of the overburden ranges from 5E-4 to 3E-8 m/s, with a geometric mean of 3E-6 m/s.

11.2.3.7 Hydrogeologic Conceptual Model

The conceptual model is the synthesis of the hydrogeologic information provided above, and forms the generalized framework behind the construction of the numerical model (Appendix 11.I). The model conceptualization has been divided into 2 main areas: upland and lowland. In summary, water recharges the system in the upland area and flows outwards to the lowland areas where it may exit from seeps in the hillside, travel farther and discharge into lakes or streams, or continue in a deeper flow system and discharge at another lake or stream further down the gradient. The recharge rates used in the model are derived from the climate data and fine-tuned during calibration. The geology in the upland area consists of relatively high permeability fractured rock at surface and increasingly lower permeability rock with depth. No attempt has been made to differentiate among the different rock types in the model conceptualization (and, ultimately, the numerical model); this is because, in general, the bedrock hydraulic conductivity testing results only appears to be related to depth and not actual geologic material. The hydraulic conductivity assignments of the rock layering with depth are derived from the testing data and fine-tuned during calibration.

The geology in the lowland area consists of relatively high permeability silt till at surface underlain by discontinuous permafrost, which is underlain by relatively low hydraulic conductivity bedrock. The lowland bedrock is considered an extension of the bedrock material found in the upland areas. The majority of the overburden thickness is frozen; however, there is an active zone through which groundwater flow is possible.

Exceptions to the configuration described above are lowland areas overlain by lakes. Here permafrost is not considered to exist because of thermal convection currents emanating from the lake. Mackay (1962) has developed a series of analytical equations that relate lake radius to depth of unfrozen material below the lake. For a lake of radius 200 m or greater (over 80% of waterbodies within the model domain are greater than this dimension), a ground temperature of -10 °C (twice as cold as the average air temperature at Yellowknife), a lake temperature of 2 °C and geothermal gradient of about 1 °C per 50 m, permafrost would be absent at depths of greater than 50 m (the ultimate depth of permafrost in the model).

11.3 Pathway Analyses

11.3.1 Methods

Pathway analysis identifies and assesses the linkages between NICO Project components or activities, and the correspondent potential residual effects to ground and surface water quantity. Potential pathways through which the NICO Project could affect water quantity were identified from a number of sources including:

- a review of the development description and scoping of potential effects by the environmental and engineering teams for the NICO Project;
- scientific knowledge, and experience with other mines in the NWT;
- engagement with the public, Aboriginal people, communities, and government; and
- consideration of potential effects identified from the TOR for the NICO Project.

The first part of the analysis is to produce a list of all potential effects pathways for the NICO Project (Section 6.3). Each pathway is initially considered to have a linkage to potential effects on water quantity. This step is followed by the development of environmental design features and mitigation that can be incorporated into the development description to remove a pathway or limit (mitigate) the effects to water quantity. Environmental design features and mitigation include NICO Project design elements, environmental best practices, management policies and procedures, and social programs. Environmental design features are developed through an iterative process between the NICO Project's engineering and environmental teams to avoid or mitigate effects.

Knowledge of the environmental design features and mitigation is then applied to each of the pathways to determine the expected amount of NICO Project-related changes to the environment and the associated residual effects (i.e., effects after mitigation) on ground and surface water quantity. Changes to the environment can alter physical measurement endpoints (e.g., surface water flows and levels) (Section 6.2). For an effect to occur there has to be a source (NICO Project component or activity) that results in a measurable environmental change (pathway) and a correspondent effect on a water quantity.

Project activity → change in environment → effect on water quantity

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 NICO 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 on water quantity. 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 so that the NICO Project results in no detectable environmental change and residual effects to water quantity relative to baseline or guideline values;
- secondary – pathway could result in a minor environmental change, but would have a negligible residual effect on water quantity relative to baseline or guideline values; or
- primary – pathway is likely to result in a measurable environmental change that could contribute to residual effects on a water quantity relative to baseline or guideline values.

Primary pathways require further effects analysis from the NICO Project on water quantity. Pathways with no linkage to water quantity or that are considered minor (secondary) are not analyzed further or classified in the DAR because environmental design features will remove the pathway (no linkage) or residual effects to water quantity can be determined to be negligible through a simple qualitative evaluation of the pathway. Pathways determined to have no linkage to water quantity or those that are considered secondary are not predicted to result in environmentally significant effects on ground and surface water quantity. All primary pathways are assessed in the DAR.

11.3.2 Results

Potential pathways through which the NICO Project could affect water quantity are presented in Table 11.3-1. Environmental design features and mitigation incorporated into the NICO Project Description to remove a pathway or limit (mitigate) the effects to water quantity are listed, and pathways are determined to be primary, secondary, or as having no linkage. The following section discusses the potential pathways relevant to water quantity.

Table 11.3-1: Potential Pathways for Effects to Groundwater and Surface Water Quantity

NICO Project Component/ Activity	Effect Pathways	Environmental Design Features and Mitigation	Pathway Assessment
General construction and operation of mine and supporting infrastructure	Fresh water withdrawal from Lou Lake will decrease water level in Lou Lake and discharge downstream of Lou Lake and within the Marian River	Preliminary assessments of water withdrawal are substantially lower than initially estimated as per the 2007 Class A Water License application submitted by Fortune Minerals. This application identified a withdrawal need of 73 litres per second which is approximately 10 times higher than the current required freshwater withdrawal.	Secondary
	Discharge of processed and/or treated water from the mine site will increase flow rates downstream of Peanut Lake and increase local storage in Peanut Lake, Ponds 11, 12, and 13, and Burke Lake	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 Co-Disposal Facility back to the plant. The outfall for treated effluent release is located in Peanut Lake rather than Nico Lake since the Peanut Lake drainage area is much larger, along with the outflow rate.	Secondary
	Construction and operation of the Co-Disposal Facility will alter the local drainage area reporting to Nico Lake	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 Co-Disposal Facility back to the Plant. Geochemical testing results revealed that a separate Mine Rock Management Area south of the Open Pit would result in long-term poor water quality. The NICO Project Co-Disposal Facility was re-located to the Grid Ponds drainage basin.	Secondary
	Changes to flow rates from Lou Creek and Burke Creek during construction and operations will affect flow rates within the Marian River	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 Co-Disposal Facility back to the plant. This has resulted in reduced demand for fresh water from Lou Lake and lower rates of release of treated effluent to Peanut Lake.	Secondary

Table 11.3-1: Potential Pathways for Effects to Groundwater and Surface Water Quantity (continued)

NICO Project Component/ Activity	Effect Pathways	Environmental Design Features and Mitigation	Pathway Assessment
General construction and operation of mine and supporting infrastructure (continued)	Cross-drainage structures for site roads and NICO Project Access Road will alter stream hydraulics	Cross-drainage structures will be designed and constructed such that structures will not create a hydraulic barrier to fish passage.	Secondary
	Groundwater inflows to Nico Lake and Ponds 8, 9, and 10 will be reduced during operations because seepage will be collected and treated		Secondary
Closure and Post-closure	Closure of the Co-Disposal Facility will alter the local drainage area reporting to Nico Lake		Secondary
	Filling of the Open Pit to the full supply level will decrease discharge from Peanut Lake and waterbodies downstream of Peanut Lake, as well as potentially reduce local storage in Peanut Lake, Nico Lake, and Burke Lake		Secondary
	The Flooded Open Pit at full supply level may be allowed to discharge under natural conditions. This new flow path on the ground surface and resulting increased inflow to Peanut Lake may result in an increase in discharge and increased storage for Peanut Lake, Ponds 11, 12, and 13, and Burke Lake		Secondary
	The Co-Disposal Facility is anticipated to generate seepage during closure and post-closure, which by design will report to Nico Lake	At closure and post-closure, seepage will report to Treatment Wetlands.	No Linkage
Closure and Post-closure	Changes to flow rates from Lou Creek and Burke Creek during closure and post-closure will affect flow rates within the Marian River		Secondary

Table 11.3-1: Potential Pathways for Effects to Groundwater and Surface Water Quantity (continued)

NICO Project Component/ Activity	Effect Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Closure and Post-closure (continued)	Groundwater inflows to Nico Lake and Ponds 8, 9, and 10 will be reduced during closure and post-closure.		Secondary

11.3.2.1 Pathways with No Linkage

A pathway may have no linkage if the pathway is removed by environmental design features and mitigation so that the NICO Project results in no detectable (measurable) environmental change and residual effects to water quantity. The pathway described in the following bullet had no linkage to water quantity and will not be carried through the effects assessment.

- **The Co-Disposal Facility is expected to generate seepage during closure and post-closure, which will report to Nico Lake.**

The construction of the Co-Disposal Facility (CDF) will result in a change to topography, which will direct water to the Open Pit and to Treatment Wetlands and may result in a decrease in flows to Nico Lake. However, discharge from the CDF as seepage (approximately 152 000 m^3/year) will report to the Wetland Treatment System prior to release into Nico Lake, and should not result in a detectable change to flows into Nico Lake relative to baseline conditions. Consequently, this pathway is determined to have no linkage to effects on Nico Lake (Table 11.3-1). A similar pathway discussing alteration of the drainage area reporting from the Grid Pond area is discussed below in Secondary Pathways.

11.3.2.2 Secondary Pathways

In some cases, both a source and a pathway exist, but the change caused by the NICO Project is anticipated to result in a minor environmental change, and would have a negligible residual effect on water quantity relative to baseline values. The pathways described in the following bullets are expected to be secondary and will not be carried through the effects assessment.

- **Fresh water withdrawal from Lou Lake will decrease water level in Lou Lake and discharge downstream of Lou Lake and within the Marian River.**

Lou Lake will be used as a source of freshwater from construction to the end of operations. A fresh water intake structure is proposed to be constructed near the existing exploration camp for the NICO Project. The effect from water withdrawal for the NICO Project was assessed as a second outlet to the lake whereby the rate of drawdown of the water surface has a direct relationship to the flow rate leaving Lou Lake from the primary outlet (the outflow channel downstream). Throughout the life of the NICO Project it is anticipated that fresh water withdrawals during construction and operations will range from 112 000 m^3/year under average climatic conditions up to 146 000 m^3/year during a 1:25 year dry period (Appendix 11.II and 11.III). The maximum potential fresh water withdrawal is 179 000 m^3/year during a 12-month period. These withdrawal requirements correspond to a range of extractions from 0.0036 to 0.0057 m^3/s where it is anticipated that the extractions will be constant over the period of one year. The mean annual discharge from Lou Lake is approximately 0.0971 m^3/s ranging from a low of 0.0297 m^3/s in September to 0.371 m^3/s in June as estimated from long-term flow records (Section 11.2.2.3).

A detailed monthly water balance model was created to investigate the effect of fresh water extraction from Lou Lake on Lou Lake levels under average climatic conditions and under conservative estimates for climate conditions in an estimated 1:25 year dry period (Appendix 11.II). The model took into account hydrological inputs (runoff from the local watershed, inflows from upstream sub-basins, precipitation, snowmelt, and precipitation) and outputs (evaporation and lake outflow). The water balance model also incorporated water withdrawals from Lou Lake for the NICO Project.

A test run of the model was performed using average annual climatic parameters with no fresh water extraction. The lake stage (metres above local datum [mald]), which is the primary driver of outflow, was modeled for the baseline condition and compared against the average stage corresponding to the average monthly discharge. In general, the model correctly accounted for the timing of the peak and magnitude of average annual outflow on a monthly basis (Figure 11.3-1). The model slightly overestimated discharge in the summer, fall, and early winter, and underestimated flows through the late winter months. Over the entire average year, the modelled discharge differed from the average flow record discharge by 159 000 m^3, or approximately 5.1% of annual total outflow.

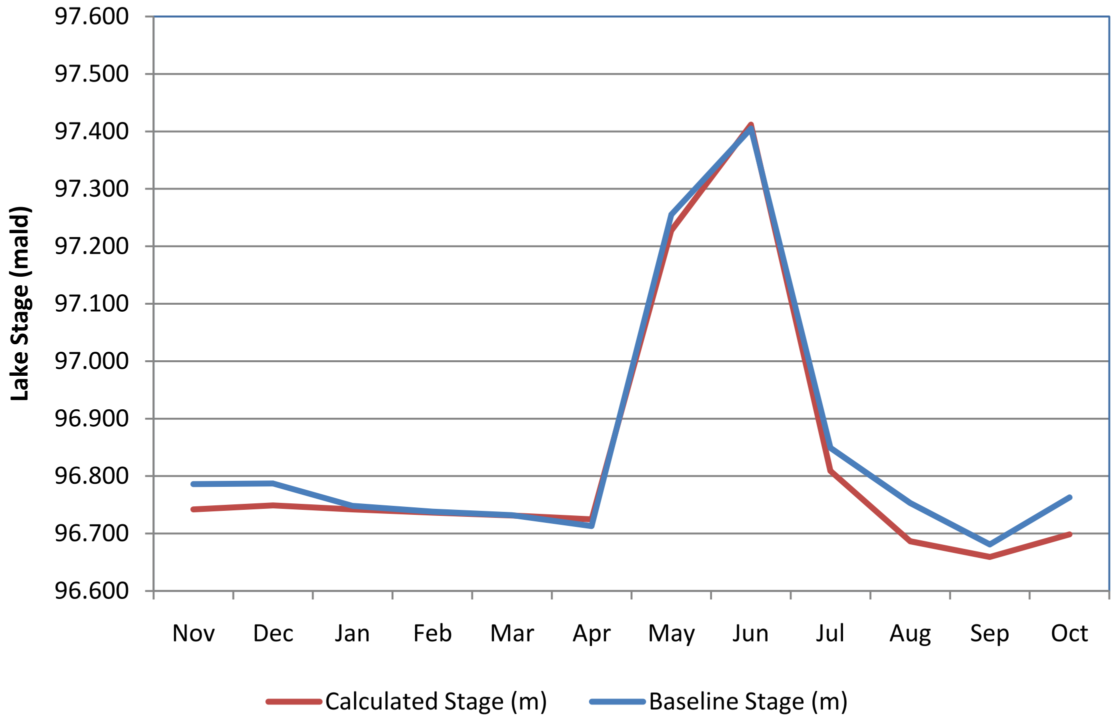

Figure 11.3-1: Modelled and Baseline Monthly Average Lake Stage for Lou Lake

mald = metres above local datum

Average Climate Conditions

Under the average climate conditions, lake stage was modelled for Lou Lake under 3 scenarios: no withdrawal (or the baseline condition), average annual withdrawal, and the maximum annual construction withdrawal. As observed from Figure 11.3-2, the net change to Lou Lake stage as a result of fresh water withdrawal for the NICO Project is approximately 1.9 centimetres (cm) lower relative to baseline values under the maximum withdrawal condition during the construction period.

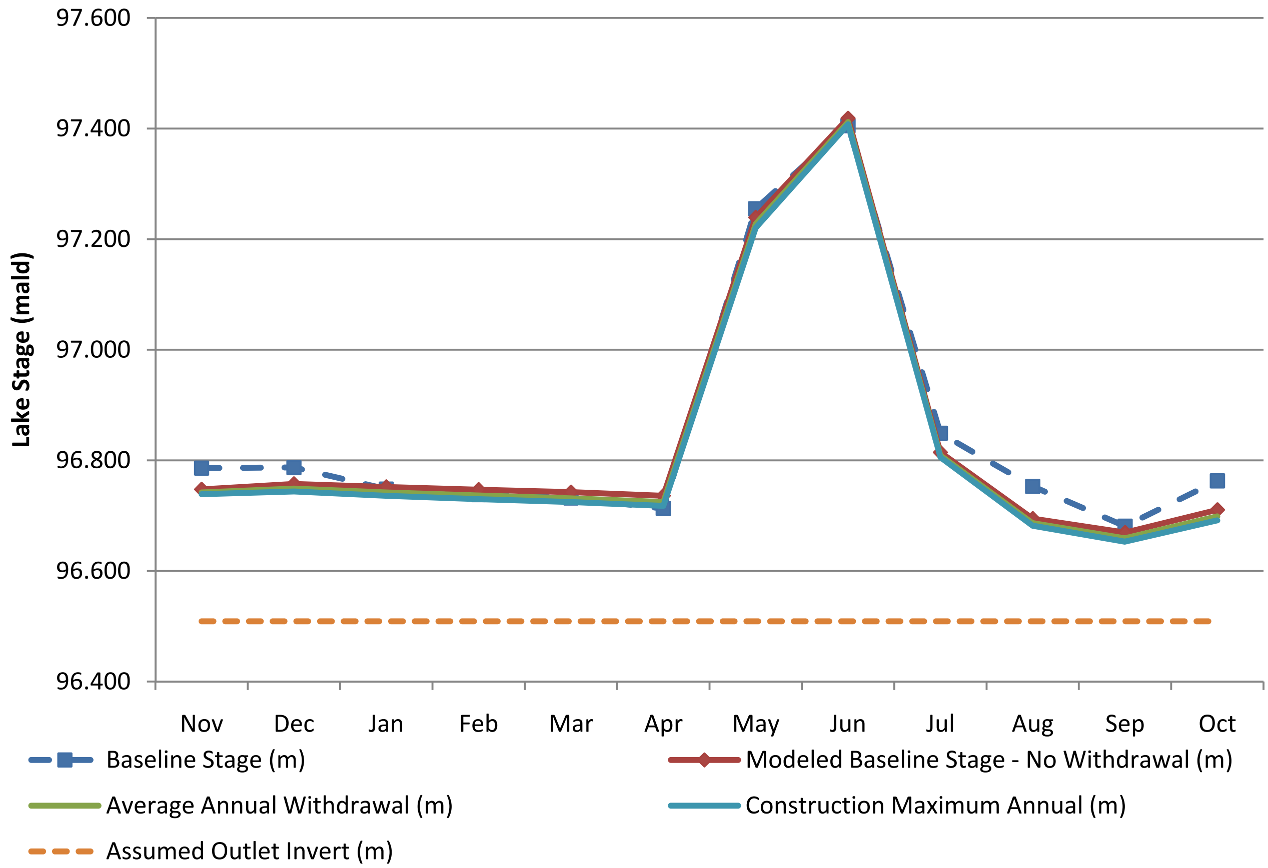

Figure 11.3-2: Average Climate Condition Withdrawal Scenario for Lou Lake

mald = metres above local datum

1:25 Year Dry Climate Conditions

For the 1:25 year dry climate condition, 4 withdrawal scenarios were assessed for the effect on lake stage. As observed in Figure 11.3-3, the baseline condition of the 1:25 year dry period naturally draws the lake level down below the invert elevation of the outlet of the lake. The subsequent 3 withdrawal scenarios further lower the elevation of the water surface by a maximum of 4.7 cm relative to baseline values.

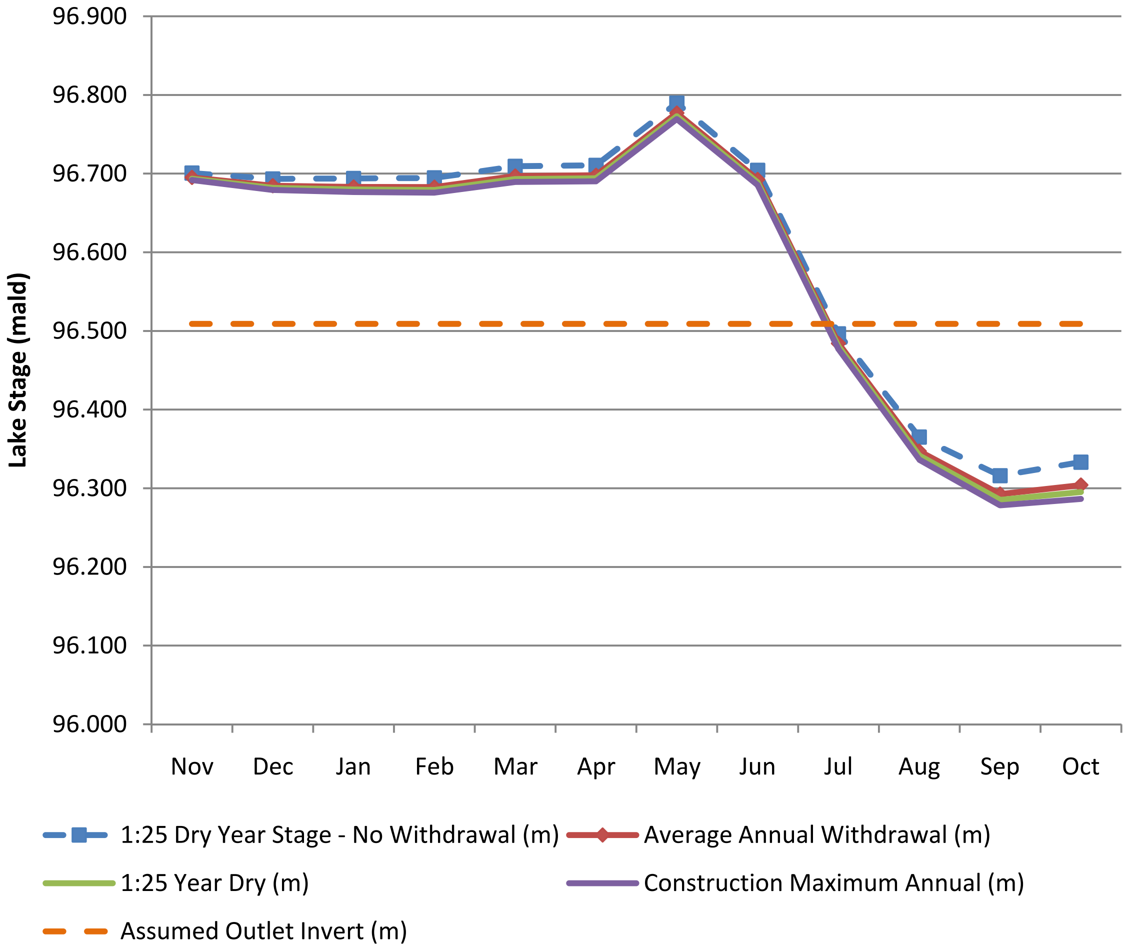

Figure 11.3-3: 1:25 Year Dry Climate Condition Withdrawal Scenario for Lou Lake

mald = metres above local datum

It is expected that the model used in the assessment of the effect to Lou Lake from the NICO Project is conservative due to the low precipitation and high lake evaporation values assumed in the dry year condition. The modelling 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 construction. 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 (secondary pathway; Table 11.3-1).

- **Discharge of processed and/or treated water from the mine site will increase flow rates downstream of Peanut Lake and increase local storage in Peanut Lake, Ponds 11, 12, and 13, and Burke Lake.**

Water will be actively discharged from the NICO Project during the construction and operation phases. Peanut Lake will act as the first receiving waterbody downstream of the NICO Project where the contributing drainage area to the outlet of Peanut Lake is approximately 62.4 km^2 accounting for 69% of the Burke Lake Drainage

Basin (approximately 90.8 km^2). Mean annual discharge from the outlet of Peanut Lake is approximately 0.154 m^3/s and 11 instantaneous measurements of discharge ranged from 0.034 to 0.834 m^3/s. Mean annual discharge from the outlet of the Burke Lake Drainage Basin is approximately 0.207 m^3/s with instantaneous discharge measurements ranging from 0.009 to 1.38 m^3/s at the outlet of Burke Lake, which is approximately 2 km upstream of the outlet of the Burke Lake Drainage Basin. Burke and Peanut lakes are known to be affected by local beaver activity.

Ponds 11, 12, and 13 are essentially the same waterbody with a ‘pinched’ connection between Pond 13 and Pond 12 and a beaver dam at the outlet of Pond 11 between Pond 11 and Pond 12. The ponds reside in the flow path between Peanut Lake and Burke Lake where discharge from Peanut Lake enters Pond 11, flows into Pond 12 and discharges to Burke Lake. Pond 12 is affected by beaver activity and the outflow from Pond 12 is through/over a beaver dam. Discharge measurements were not performed at the outlet of Pond 12; however, stage measurements of Pond 12 fluctuated from a minimum of 98.833 mald to a maximum of 99.043 mald, with an average of 98.981 mald (Annex G).

The NICO Project is expected to discharge approximately 115 000 m^3/year (0.0037 m^3/s) during the start-up year up to 291 000 m^3/year (0.0092 m^3/s) in the final year of operations (Appendix 11.III). Discharge during construction is not expected to exceed the maximum discharge condition in the final year of operations. The anticipated discharge from the NICO Project is expected to occur at a constant rate throughout a given year of construction or operations. The change in outflow from Peanut Lake will be an increase in discharge driven by increased volume to Peanut Lake, which would raise the stage (level) of the lake. However, a more conservative approach to determining the change to Peanut Lake is to sum the mean annual outflow from Peanut Lake and the operations discharge rate to estimate the potential maximum increase in discharge.

This method does not take into account the increase in stage within the lake; however, Peanut Lake is known to be affected by local beaver activity where a dam has been constructed at the outlet of the lake. Observed stage height on Peanut Lake fluctuated between 97.501 mald and 98.272 mald (difference of 0.771 m) with an average stage height of 97.914 mald (Section 11.2.2.3; Figure 11.2-5). The potential change in storage as a result of beaver activity alone is approximately 161 400 m^3, which is nearly half of the NICO Project discharge in the final year of operations.

Similar to Peanut Lake, stage levels on Burke Lake are also influenced by beaver activity at the outlet. Observed stage height on Burke Lake fluctuated between 99.238 mald and 99.702 mald (difference of 0.464 m), with an average stage height of 99.510 mald. The change in storage on Burke Lake from the minimum to the maximum observed stage heights is approximately 1 072 000 m^3. The available storage volume in Burke Lake appeared sufficient to retain the snowmelt discharge in 2007 such that a peak was not detected in the instrumentation on Burke Creek until July of that year (Section 11.2.2.3; Figure 11.2-2); the peak appeared to be a result of a rain event that likely breached the beaver dam allowing the stored water to discharge unrestricted from Burke Lake.

A conservative summation of the mean annual discharge from Peanut Lake with the maximum potential discharge during operations yields a discharge rate of 0.163 m^3/s, representing an increase of approximately 6.0% (Appendix 11.III). In lower flow conditions the increase may be as high as 10 to 20% of the natural flow condition; however, the total discharge during low flow periods would not be much more than 0.040 m^3/s. The uncertainty regarding the low flow prediction is a result of the existence of the beaver dam. The beaver dam at the outlet of Peanut Lake is a ‘living’ structure such that it is regularly maintained and altered, which regularly influences the hydraulics of the feature. It may be possible in very cold years with minimal beaver activity and under natural conditions that discharge may cease in the winter and that influence from the NICO Project may change that regime such that discharge would continue at approximately the same rate as the NICO Project is discharging effluent (up to 0.0092 m^3/s). However, discharge was observed at Peanut Creek in March of 2008 and measured at approximately 0.0359 m^3/s. In general, the influence of discharge from the NICO Project is anticipated to result in a minor increase to peak discharges relative to baseline conditions. In some years, the discharge from the NICO Project will likely maintain a slightly higher level of flow in low flow periods.

Discharge from the NICO Project is also expected to result in a minor change to water level in Burke Lake relative to baseline conditions. A conservative summation of the NICO Project effluent discharge to the natural flow regime would result in an increase to the mean annual discharge from 0.207 m^3/s (baseline) to 0.216 m^3/s, an increase of 4.4% (Appendix 11.III). Discharge in Burke Creek was observed to be as low as 0.009 m^3/s (Summer 2005; Figure 11.2-2) and as with Peanut Lake, it is possible that discharge from Burke Lake would cease given the correct scenario of climate conditions. As such, the additional discharge from the NICO Project would potentially maintain flow within the stream during dry or cold periods.

Minor changes to Peanut Lake from discharges associated with the NICO Project should have little to no effect on water levels in Ponds 11, 12, and 13 relative to baseline conditions, which includes fluctuations generated from beaver activity in the area. The water management system for the NICO Project 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. The implementation of the mitigation practices and environmental design features is expected to result in a minor change (secondary pathway) to the hydrology in the LSA from the NICO Project relative to baseline conditions, which should have a negligible effect on Peanut Lake and downstream waterbodies such as Pond 11, 12, and 13, and Burke Lake (Table 11.3-1).

- **The Co-Disposal Facility will alter the local drainage area reporting to Nico Lake**
- **Closure of the Co-Disposal Facility will alter the local drainage area reporting to Nico Lake**

Implementation of a CDF design in the Grid Pond basin resulted in the elimination of direct changes to Ponds 8, 9, and 10. The Grid Ponds drainage will be directly affected by the anticipated mine footprint. The Open Pit, mine facilities, and CDF occur within the Grid Ponds drainage and will remove a portion of the drainage that reports to Nico Lake. The footprint will constitute a loss of approximately 3km^2 and the entire loss will begin in the early phases of construction as the perimeter dyke for the CDF and the Seepage Collection Ponds are among the first facilities to be constructed. The water reporting from this drainage will be collected, treated as required, and discharged to Peanut Lake. During closure and post-closure the Seepage Collection Ponds No. 1, 2, and 3 at the base of the CDF may be allowed to drain to Nico Lake after passing thru the Wetland Treatment Systems at a rate of approximately 152 000 m^3/year. This will allow for approximately 1.1 km^2 of the drainage area that previously was pumped to Peanut Lake to return to Nico Lake. During closure and post-closure it is expected that this discharge would occur over a 6 month period (May to October) (Appendix 11.III).

The total drainage area reporting to the outlet of Nico Lake is approximately 20.1 km^2. On a unit area basis a decrease of approximately 15% can be expected in the mean annual discharge from Nico Lake during construction and operations. Similarly, a decrease of 9.5% in drainage area can be expected at closure and post-closure due to the allowance of the Seepage Collection Ponds to discharge to Nico Lake (Appendix 11.III). The mean annual discharge from Nico Lake is approximately 0.039 m^3/s and measured discharges ranged from 0.0041 to 0.175 m^3/s.

To determine the effect from the CDF on Nico Lake, an analysis was completed to evaluate the change to the storage and stage level in Nico Lake, which directly affects the outflow to other waterbodies in the LSA. The analysis examined the changes in flow rates as a result of the loss of the Grid Ponds drainage during all phases of the NICO Project, and the additional seepage discharge from the Wetland Treatment System during the closure and post-closure phase of the NICO Project. The magnitude of the changes are based on a modelled inflow and outflow whereby a stage-discharge relationship for Nico Lake was constructed using measured lake stage and downstream discharge, the assumed Seepage Collection Pond discharges at closure to Nico Lake (Appendix 11.III), and the mean annual hydrograph for watershed BL2 constructed from the long-term record (Annex G).

Results predicted that the maximum changes in water level in Nico Lake during construction through post-closure were approximately -1.22% and 2.62% of the daily average hydrograph (Appendix 11.III), which represent minor fluctuations in water level relative to baseline values (i.e., secondary pathway). Subsequently, the CDF is predicted to result in negligible residual effects to Nico Lake and downstream waterbodies (Table 11.3-1).

- **Changes to flow rates from Lou Creek and Burke Creek during construction and operations will affect flow rates within the Marian River**
- **Changes to flow rates from Lou Creek and Burke Creek during closure and post-closure will affect flow rates within the Marian River**

The Marian River is expected to have an augmented flow regime as a result of the NICO Project from construction through post-closure. During construction and operations, the NICO Project is expected to result in a minor decrease in discharge from Lou Lake and a minor increase in flow from Burke Creek relative to baseline conditions (see above analysis of effects from water extraction on Lou Lake and discharge on Peanut Lake). During the closure and post-closure phases, Lou Lake will return to its natural condition while Burke Creek may have a higher discharge relative to natural conditions after the Open Pit fills and overflows (up to 4.4%) (Appendix 11.III). Prior to Open Pit overflow, the change to discharge from Burke Creek will be a negligible decrease as the drainage area lost to the Open Put during filling is small (approximately 3%) relative to the Burke Lake drainage. Lou Creek and Burke Creek contribute to the flow rate in the Marian River.

The influence of the NICO Project on local stream flow hydrology is presented in terms of an average daily stream flow hydrograph (Appendix 11.III). To develop the historic daily average stream flow hydrograph from the flow record, a Julian day calendar, in which a year consists of 365 days, was adopted. The flow record was sorted by Julian day and the daily average stream flow values were averaged for a particular Julian day. The values used for the extractions and discharges from the anticipated mine site originate from the site water balances. The analysis examined the effect on the flow rate in the Marian River due to changes in the hydrology of Lou and Burke creeks from construction through post-closure of the NICO Project.

The analysis estimates that the highest percent change to the Marian River from changes to flow in both Burke and Lou Creeks combined from the NICO Project to the baseline average discharge occurs in May at +0.25%, +0.74%, +0.03%, and +1.14% for construction, end of operation, post-closure prior to Open Pit overflow, and post-closure after Open Pit overflow, respectively (Appendix 11.III). The largest influence to the Marian River occurs early in the year because small tributaries such as Lou Creek and Burke Creek peak while the hydrograph of the Marian River is still rising. For reference, the drainage area reporting to the Marian River in the vicinity of the NICO Project is approximately 2770 km^2 while the Burke Lake and Lou Lake drainage basins make up approximately 149 km^2 (0.56%) of that area. Changes in the hydrology of Lou Creek and Burke Creek due to the NICO Project are not expected to be outside the range of baseline values, which should have a negligible residual effect on flow rates in the Marian River (Table 11.3-1). Similarly, the potential for incremental and cumulative effects from the NICO Project at the confluence of the Emile River, which is in the RSA, is anticipated to be negligible.

- **Cross-drainage structures for roads will alter stream hydraulics**

The installation of cross-drainage structures to prevent roads from impeding water flow can result in the loss and alteration of aquatic habitat and shoreline vegetation, and a constriction of the stream channel, which creates a flow velocity barrier to fish passage. Though the loss of stream habitat and shoreline vegetation may be permanent, the barrier to fish passage can be mitigated through the application of hydraulic design principles. Cross-drainage structures will be implemented in such a way that they will provide sufficiently low flow velocity that the slowest local fish, typically a northern pike, can navigate the structure under a particular design flow condition (usually a 3-day delay; 1:10 year return flood condition). The implementation of appropriate cross-drainage structures is expected to result in minor changes to stream flow velocity in the vicinity of the structures relative to baseline conditions and have negligible residual effects on water quantity. The details of the structures will be evaluated during the construction planning process.

- **Groundwater inflows to Nico Lake will be reduced during operations because seepage will be collected and treated**

- **Groundwater inflows to Nico Lake will be reduced during closure and post-closure because seepage will be collected and treated**

During the construction period, groundwater flows and surface runoff will continue to drain to Nico Lake from the Grid Ponds drainage until the CDF dykes have been completed, therefore, changes to Nico Lake water levels and outflows are not immediately expected. However it is conservative to assume that during late construction, operations, closure, and post-closure flow to Nico Lake from the Grid Ponds will be reduced due to the collection and subsequent treatment of CDF seepage in the Seepage Collection Ponds.

Groundwater inflows to Nico Lake are expected to decrease from baseline levels of 638 to 600 cubic metres per day (m^3/d) during late construction/operations and to 618 m^3/d during closure/post-closure (Appendix 11.I). These changes in flow to Nico Lake constitute a minor decrease in groundwater inflow of 38.0 m^3/d and 19.9 m^3/d for the operations and post-closure scenarios, respectively. Cumulatively, the decrease in discharge from Nico Lake as a result of the loss of runoff to Nico Lake from the Grid Ponds drainage and the decrease in groundwater inflow of a maximum 38.0 m^3/d are expected to result in a minor change in discharge from Nico Lake relative to baseline conditions.

Similarly, it is expected that groundwater inflows to interconnected Ponds 8, 9, and 10 will be reduced by 34 m^3/d from 157 to 123 m^3/d during operations (Appendix 11.I). The average measured discharge was 0.0075 m^3/s (648 m^3/d) (Annex G). Assuming that groundwater inflows are fully reflected in outflow, average outflow may be reduced from 648 to 614 m^3/d (5.2%). The reduction in groundwater inflows during closure and post-closure is about half the decrease during operations (18 m^3/d). Relative to baseline conditions, these minor changes in groundwater flows to Nico Lake and Ponds 8, 9, and 10 from the NICO Project are predicted to have negligible effects on the groundwater and surface water regimes in the LSA.

- **Filling of the Open Pit to the full supply level will decrease discharge from Peanut Lake and waterbodies downstream of Peanut Lake as well as potentially reduce local storage in Peanut Lake, Ponds 11, 12, and 13, and Burke Lake**
- **The Flooded Open Pit at full supply level may be allowed to discharge under natural conditions. This new flow path on the ground surface and resulting increased inflow to Peanut Lake may result in an increase in discharge and increased storage for Peanut Lake, Ponds 11, 12, and 13, and Burke Lake**

At closure, the Open Pit will be allowed to accumulate water under natural climatic conditions and is expected to fill completely. The natural inputs to the Flooded Open Pit will be precipitation, groundwater infiltration, and runoff from the natural ground surface and the top of the CDF. Under natural climatic influence the Open Pit should take approximately 120 years to reach the full supply level of approximately 260 masl. After the Open Pit fills to the full supply level the excess water is anticipated to spill over at the ramp where a constructed channel will carry the water to Peanut Lake via Wetland Treatment System No. 4. If the water in the Open Pit is unsuitable for discharge, it will be treated prior to discharge to Peanut Lake. The Open Pit is expected to discharge approximately 385 000 m^3 annually to a maximum of 601 000 m^3 in a wet year to Peanut Lake (Section 3.9.3).

Climate parameters used to estimate the time at full supply level of the Open Pit included annual precipitation of approximately 343.4 mm and annual lake evaporation of 478.5 mm (Appendix 11.IV). The Open Pit is expected receive runoff from the natural ground surface and the surface of the CDF. Seepage to the Open Pit is controlled by the surface elevation of the water in the Open Pit and an assumed hydraulic conductivity of 5.0 (10^{-9}) m/s was used to characterize the bedrock. A monthly time step was incorporated into the model to account for snow accumulation, snow melt, precipitation onto ground surface, precipitation onto lake surface, and residual outflow after the Open Pit fills (Appendix 11.IV).

After the Open Pit fills, water will flow from the former ramp at approximately 0.0118 m^3/s annually under average conditions to a maximum of 0.0182 m^3/s annually in a wet year. Though these discharges are greater than those discussed for the operations phase the increase in discharge from Peanut Lake will be approximately 7.7% of the annual average discharge and less than 2% of the peak. Similarly for Burke Lake, the annual average discharge will be approximately 5.7% higher and less than 1% higher during peak discharge. As such, the increase in discharge at and downstream of Peanut Lake from the NICO Project is expected to result in a minor change (secondary pathway) to the hydrology in the LSA relative to baseline conditions, which should have a negligible effect on Peanut Lake and downstream waterbodies such as Pond 11, 12, and 13, and Burke Lake (Table 11.3-1).

11.3.2.3 Primary Pathways

No primary pathways were identified for this assessment. Subsequently, there is no comprehensive residual effects analysis (Section 11.3.1).

11.4 Uncertainty

There is a moderate degree of uncertainty in predicting the changes from the NICO Project on surface water flow rates and lake levels, and the correspondent effects to waterbodies in the Lou and Burke lake watersheds, and the Marian River. Most of the uncertainty is related to predicting future climate conditions such as total precipitation and evaporation, which are the primary drivers in the water balance model. At a smaller scale, beaver activity can decrease the confidence in estimating flow rate and water level within and between adjacent streams and lakes (or ponds). For example, the construction of dams at the Peanut Lake outlet and in ponds immediately downstream can obscure any relationship between Peanut Lake stage and discharge out of Peanut Lake. When observing values collected in June, increases in stage correlated to increased discharge (R^2 = 0.98). Following June, increases to stage did not appear to affect discharge. It is expected that at this location beavers increase the elevation of their dams to meet the water levels following the spring flooding. As a result, predictions are affected by uncertainty around the influence of additional inflow to Peanut Lake and Peanut Lake outflow and similarly for Burke Lake and Burke Lake outflow.

Uncertainty was addressed in the assessment by using a conservative approach so that effects are not underestimated. To predict effects from the NICO Project on hydrologic conditions in the LSA the 1:25 year extreme values were used for total precipitation and evaporation in the water balance model. The 1:25 year period corresponds with the anticipated duration of maximum changes to water flow rates and levels from the NICO Project (i.e., from construction to closure). As there is uncertainty in statistically predicting any one climate parameter, there is added uncertainty in the likelihood that these circumstances will coincide. In other words, a minimum total precipitation does not necessarily coincide with an increase in lake evaporation. To be conservative, it was assumed that the 1:25 year minimum precipitation will coincide with the 1:25 year maximum evaporation. Also, it was assumed that all months in the year will experience their 1:25 year extreme values for precipitation and evaporation consecutively.

11.5 Monitoring and Follow-up

It is anticipated that hydrological monitoring at the NICO Project will be continued during construction, operations, and closure as part of the Aquatics Effects Monitoring Program. During construction and operations, monitoring of discharge should include periodic instantaneous discharge measurements as well as stage recorders at Nico, Peanut, Burke, Lou creeks, and the Marian River. Similarly, Nico, Peanut, and Lou lakes should be monitored with stage recorders. At closure and post-closure, the monitoring program can be reduced to Nico Creek, Peanut Creek, and possibly Burke Creek with lake level monitoring at Nico and Peanut Lakes only. These data can then be used to quantify water volume transfers through the local systems, which will assist with decisions for further monitoring of water quality.

11.6 References

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