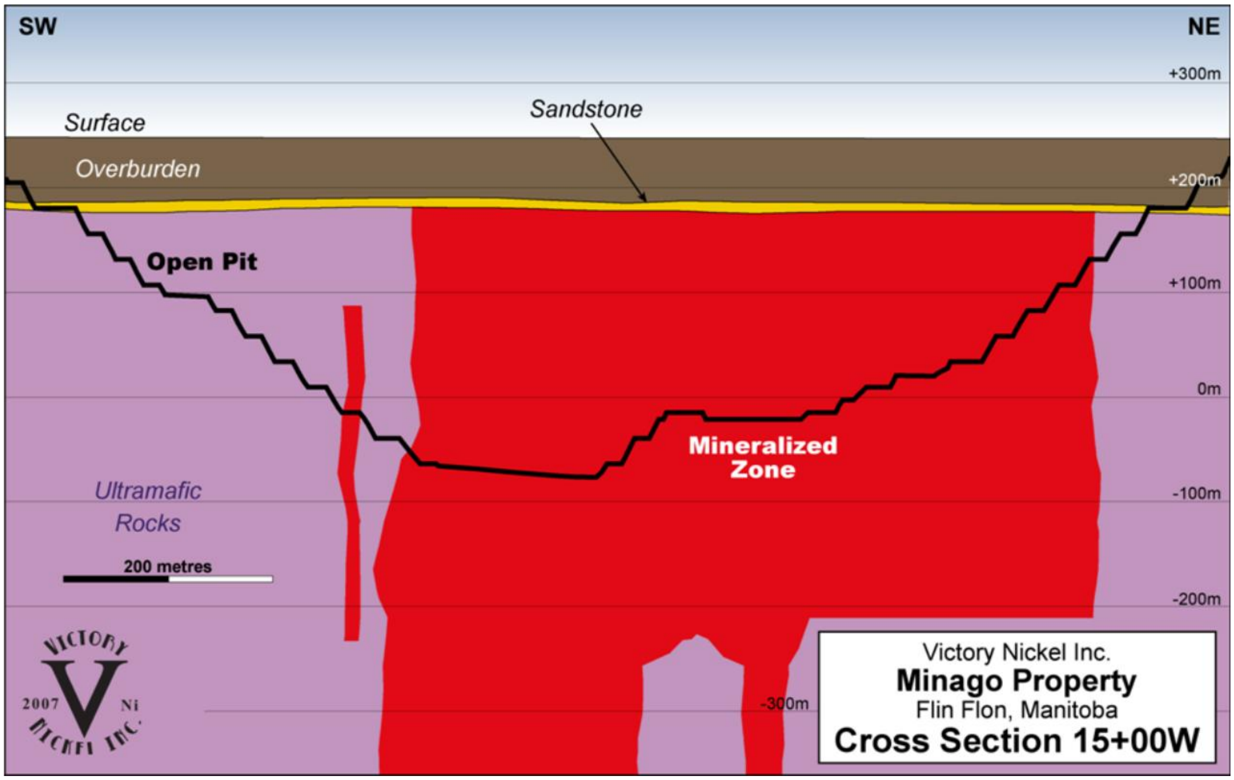


Chapter 7 – Environmental Assessment Findings

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

7. ENVIRONMENTAL ASSESSMENT FINDINGS

7.1 Climate

Golder Associates Ltd. developed a comprehensive database of available climatic data and derived representative climatic characteristics for the Minago Project (Golder Associates, 2009). These characteristics are summarized below.

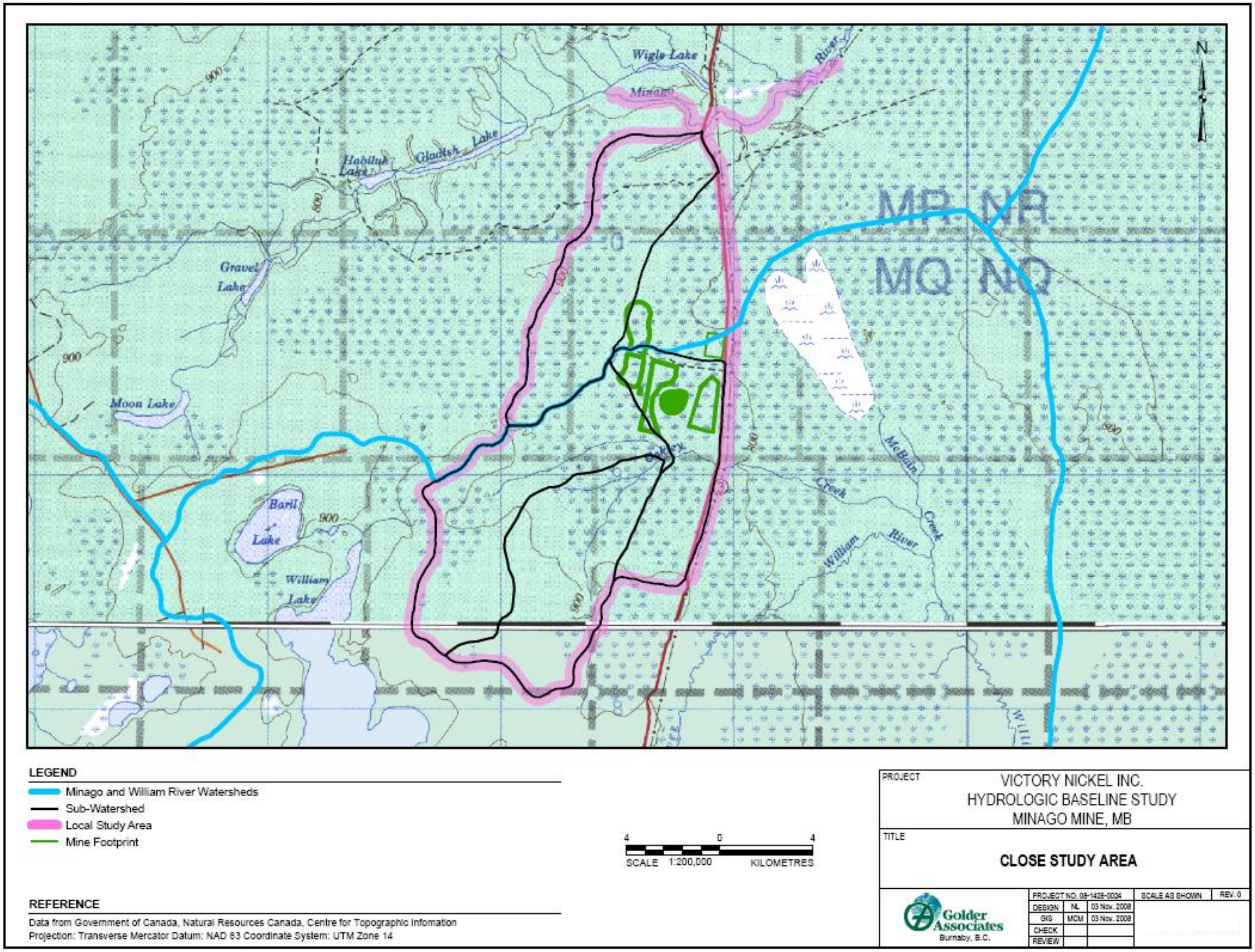
Two regions were identified for the climatic baseline study: a close study area (CSA) and an extended study area (ESA). The CSA encompasses areas that may be directly impacted by the development project. The ESA includes the CSA within a larger geographic and ecological context that may be considered in subsequent impact assessments. The ESA is defined as the region within which any effect from the development project would become negligible. Figures 7.1-1 and 7.1-2, which were developed using topographic maps of the region (NRC, 2008), illustrate the extent of the project CSA and ESA, respectively.

The CSA, (Figure 7.1-1), encompasses the watersheds of the watercourses and surface areas within which the footprint of the proposed mine development is located. Most mine activities are planned within the Oakley Creek watershed west of Highway 6. Oakley Creek is a tributary of the William River. The proposed infrastructure to the west of the mine will include a Tailings and Ultramafic Waste Rock Management Facility (TWRMF), and Waste Rock Dumps. The tailings area is located between Oakley Creek and the Minago River, in an area with no defined surface water runoff channels or streams.

The ESA (Figure 7.1-2) extends the CSA to the segments of the Oakley Creek, Minago River and William River watersheds within which any effect for the mine development are expected to become negligible due to a confluence with a significant watercourse or waterbody, and proposed water management planning for the site. The ESA extends to the northeast up to the Hill Lake outlet, where the Minago River joins the Hargrave River. The ESA also extends southeast to include the confluence of Oakley Creek with the William River, as well as the confluence of the latter with Limestone bay.

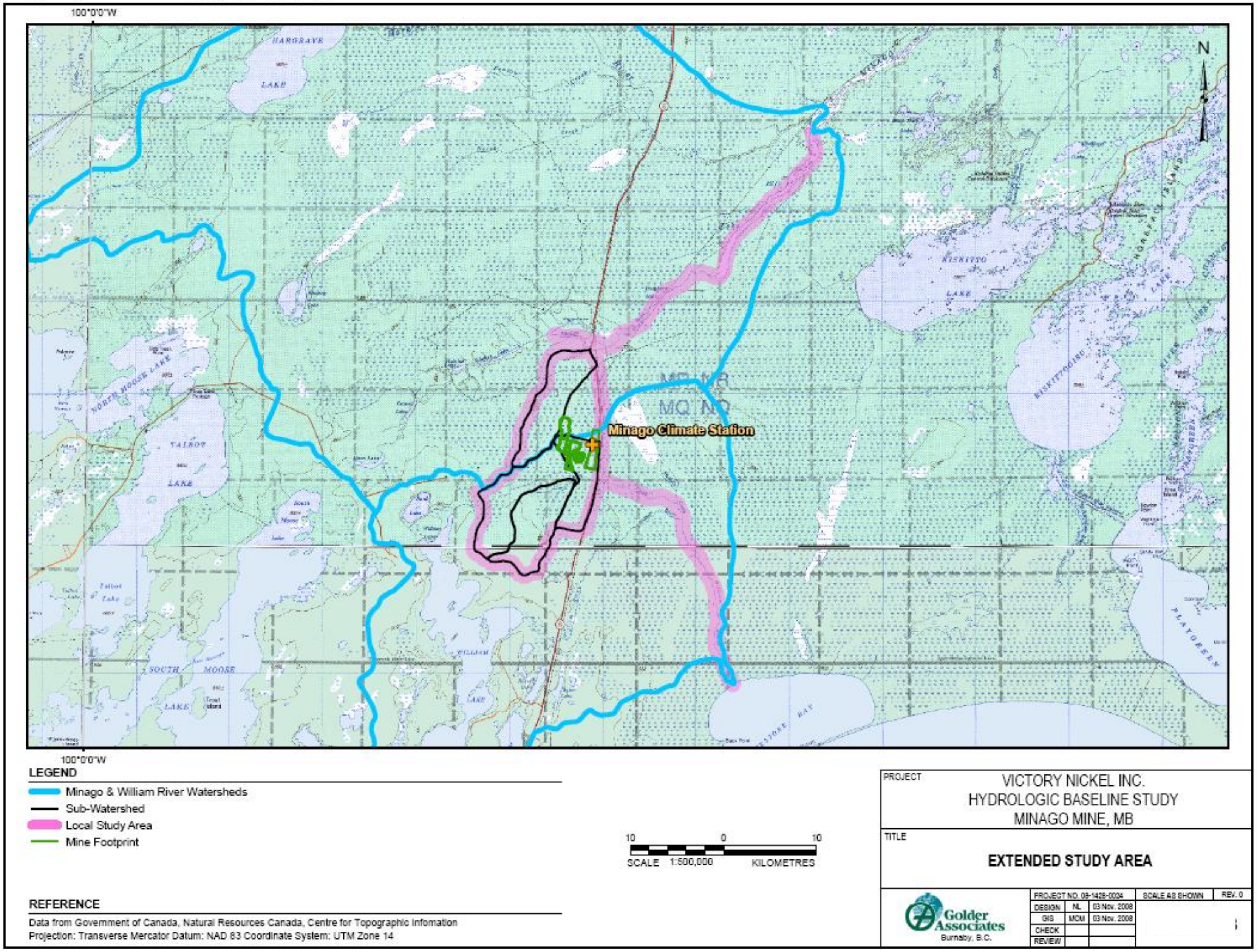
The CSA and ESA (Figures 7.1-1 and 7.1-2) are mostly located within the sub-arctic climate zone (i.e., Dfc zone under the Koppen-Geiger climate classification; Peel et al., 2007). This zone is characterized by a cold climate with relatively humid winters and summers, and less than four months with average monthly temperature above 10 ºC (Kottek et al., 2006). The southern portion of the William River watershed, near Grand Rapids and Lake Winnipeg, is within the humid continental zone (i.e., Dfb zone; Peel et al., 2007). This zone has characteristics similar to those of the sub-arctic zone; however, there is at least four months with average monthly temperatures above 10 ºC (Kottek et al., 2006).

Based on the above, the annual mean temperature at the Minago Project is expected to be about 0 ºC (Prowse, 1990), with significant seasonal variations. Mean monthly temperatures are expected to be between -20 and -25 ºC in January, and between 15 and 20 ºC in July (EMRC,



Source: Golder Associates, 2009

Figure 7.1-1 Close Study Area (CSA)



Source: Golder Associates, 2009

Figure 7.1-2 Extended Study Area (ESA)

1995). Mean annual total precipitation are expected to be between 400 and 600 mm, with a mean annual snowfall between 1,000 and 2,000 mm (EMRC, 1995).

7.1.1 Available Monitoring Data

The following provides an inventory of available local and regional climate data. The local climate data collection program for the Minago Project is supported by one climate station at the Minago site, which has been in operation since July 2007. The station records ambient air temperature, rainfall, wind speed and direction, relative humidity, and net radiation (Victory Nickel, 2008).

Select regional climate and hydrometric monitoring stations operated by Environment Canada (EC) have systematically collected data that are relevant to the Minago Project, such as air temperature, precipitation, wind, evaporation or streamflow. The sub-sections below provide details on the data at the stations that have been selected to characterize regional climate conditions for the Minago Project. The locations of these stations are shown in Figure 7.1-3. Availability of data over a long-term period and proximity to the proposed Minago project site were the main criteria were used to select the stations.

7.1.1.1 Air Temperature and Precipitation Data

Air temperature affects basin snowmelt, lake ice and water temperature regimes, while precipitation determines basin moisture input and is one of the most important climate parameters in hydrologic studies.

The climate stations selected for the compilation of regional air temperature and precipitation data are Cross Lake, Flin Flon, Grand Rapids, Norway House, The Pas and Thompson (Table 7.1-1 and Figure 7.1-3). These stations effectively cover the CSA and ESA of the proposed Minago project. Temperature and precipitation at these stations can be compared and assessed over a concurrent period of 41 years (1968 to 2008).

The Climate Research Division of Environment Canada has developed a database of long-term homogeneous precipitation data, specifically designed for climate change analysis in Canada. The Adjusted Historical Canadian Climate Data (AHCCD) database can be accessed for research purposes, and includes 495 stations where archived rainfall and snowfall data have been adjusted on a daily level for rain and snow separately (EC, 2008a). Flin Flon, Grand Rapids, Norway House, The Pas and Thompson stations are included in the AHCCD database.

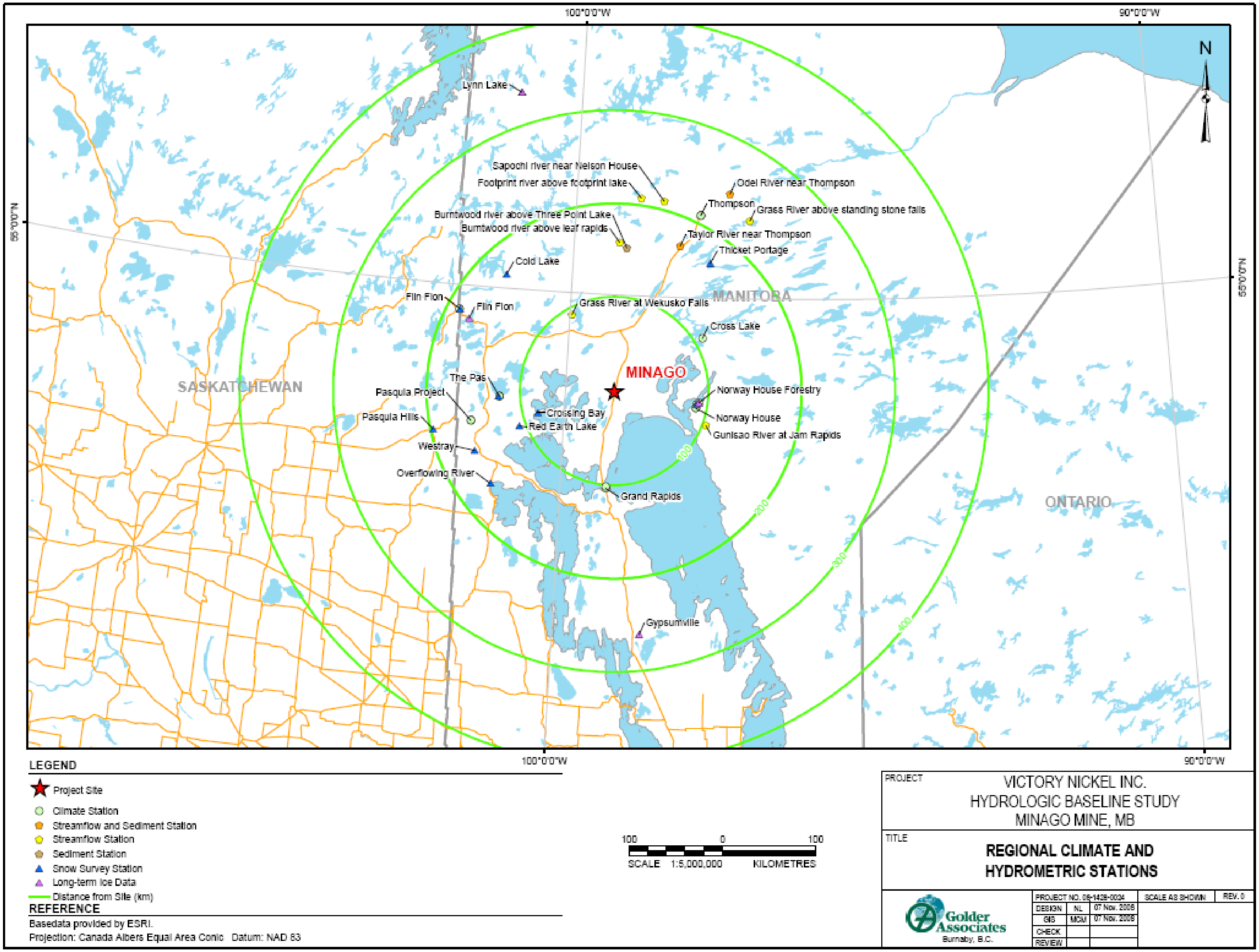
7.1.1.2 Humidity Data

Humidity impacts lake evaporation and inland evapotranspiration. The regional stations near the Minago Project with available records of relative humidity data are summarized in Table 7.1-1, and include the Norway House, The Pas and Thompson stations.

Table 7.1-1 Regional Climate Stations

Station Name	Environment Canada Station ID	Distance from Site (km)	Station Location		Elevation (m)	Recorded Data [1]		
			Latitude North	Longitude West		Data Type	Period of Record	Years of Record
Cross Lake	5060623	100 km to the North East	54° 37'	97° 46'	218.8	Temperature and Precipitation	1972 to 2008	37
Flin Flon	5050920	200 km to the North West	54° 46'	101° 52'	320	Temperature and Precipitation	1927 to 2008	82
						Snow on the Ground	1961 to 2008	60
Grand Rapids	5031111	100 km to the South	53° 09'	99° 16'	222.5	Temperature and Precipitation	1966 to 2008	43
						Evaporation (Pan and Lake)	1966 to 1967	2
	5031110		53° 10'	99° 16'	222.5	Evaporation (Pan and Lake)	1970 to 1978	9
Norway House	506B047	90 km to the East	53° 57'	97° 51'	223.7	Temperature and Precipitation	1970 to 2007	38
						Snow on the Ground	1973 to 2005	23
						Humidity	1975 to 2005	31
						Wind	1973 to 2005	33
	506B0M7		54° 00'	97° 48'	217	Evaporation (Pan and Lake)	1971 to 2000	30
The Pas	5052880	130 km to the West	53° 58'	101° 05'	270.4	Temperature and Precipitation	1944 to 2008	65
						Snow on the Ground	1955 to 2008	62
						Humidity and Wind	1953 to 2008	56
						Global Radiation	1972 to 1998	27
Pasquia Project	5052060	160 km to the West	53° 43'	101° 31'	262.1	Temperature	1960 to 2005	46
						Precipitation	1956 to 2005	50
						Snow on the Ground	1977 to 2005	29
						Evaporation (Pan and Lake)	1969 to 1985	17
Thompson	5062922	200 km to the North	55° 47'	97° 51'	223.1	Temperature, Precipitation, Snow on the Ground, Humidity and Wind	1967 to 2008	42

1. Source: Golder Associates, 2009 (Secondary source: Meteorological Service of Environment Canada (EC, 2008b and c)).



Source: Golder Associates, 2009

Figure 7.1-3 Regional Climate and Hydrometric Stations

7.1.1.3 Wind Data

Wind affects lake circulation patterns, lake currents, wave heights, wave runup, wind setup, and potential lakeshore ice ride-up and pile-up. Wind also affects sensible heat transfer between the air and the earth surface. This in turns affects lake evaporation, basin evapotranspiration, sublimation, snowmelt rate, lake ice freeze-up and break-up, and lake water temperature.

Wind directions usually vary spatially and stations located further away from the study area would be less relevant for derivation of local wind characteristics at Minago. The regional stations near the Minago Project with available records of wind data are summarized in Table 7.1-1, and include the Norway House, The Pas and Thompson stations.

7.1.1.4 Evaporation Data

Historic pan evaporation data are available from three regional Environment Canada stations as indicated in Table 7.1-1 (Grand Rapids, Norway House and Pasquia Project). Calculated lake evaporation amounts are also available for the same stations and periods of record.

7.1.1.5 Radiation Data

Short and long wave radiation from the sun and ground affects basin snowmelt, lake ice, and water temperature regimes. Radiation is recorded only at a few stations in Manitoba. Only data from the region were collected (i.e., The Pas; Table 7.1-1), since radiation varies with latitude. The regional radiation data available is global radiation (i.e., incident from the sun).

7.1.1.6 Snow Survey Data

Snow depth (or snow on the ground) is observed at the Flin Flon, Norway House, Pasquia Project, The Pas and Thompson stations. However, the snow water equivalent (SWE) is not measured at these stations.

Snow depth and SWE data from across Canada have been compiled in a database by the Meteorological Service of Canada, a branch of Environment Canada (EC, 2007). This database is available for research purposes and contains historic snow survey measurements taken by various organizations, in paper and digital formats, for point, bi-weekly and monthly sampling.

Table 7.1-2 lists the snow survey stations found in the region surrounding the study area. The compilation was restricted to the stations between latitude 52º and 56º north and longitude 97º and 101º west, with at least 10 years of snow survey data.

Table 7.1-2 Regional Snow Survey Stations

Station Name[1]	Station Identification	Distance from Site (km)	Latitude (North)	Longitude (West)	Elevation (m)	Period of Record	Years of Record
Flin Flon	SCD-MB049	200 km to the North West	54°46'	101°51'	320	1962 to 1985	24
Norway House	SCD-MB099	90 km to the East	53°59'	97°50'	220	1962 to 1977	16
The Pas	SCD-MB158	130 km to the West	53°58'	101°06'	271	1962 to 1997	36
Westray	SCD-MB185	160 km to the West	53°26'	101°25'	280	1962 to1985	24
Overflowing River	SCD-MB102	160 km to the West	53° 08'	101° 07'	259	1962 to 1985	24
Crossing Bay	SCD-MB037	90 km to the West	53°50'	100°26'	265	1966 to 1985	20
Pasquia Hills	SCD-SK116	200 km to the West	53°36'	102°07'	274	1962 to 1985	24
Red Earth Lake	SCD-MB120	105 km to the West	53°42'	100°43'	258	1965 to 1985	21
Thicket Portage	SCD-MB163	170 km to the North East	55°20'	97°40'	183	1962 to 1977	16

Note: 1. Source: Golder Associates, 2009 (Secondary source: Meteorological Service of Environment Canada (EC, 2007)).

7.1.2 Description of Local Site Data

Comparison of local and regional observations from August 2007 to July 2008 was made for: 1) temperature (Table 7.1-3); 2) relative humidity (Table 7.1-4); 3) precipitation (Table 7.1-5); and wind speed and direction (Table 7.1-6). The comparison was based on months with less than six days of missing data. The available data cannot support a comparison of local and regional radiation and evaporation. No evaporation data have been collected at Minago, and net radiation is collected at the Minago climate station while only global radiation is available at the regional stations.

The operation of the Minago climate station began in August 2007, although no observations were made from September 12 to November 12, 2007. The station provided measurements consistently from December 2007 to July 2008. Less than a year of data are available at Minago for comparison. However, the data indicate the possibility of deriving long-term climate characteristics for the study area based on the location of the Minago Project relative to the regional climate stations.

Table 7.1-3 Recorded Local and Regional Air Temperature for 2007 and 2008

Month	Mean Monthly Air Temperature[1, 2]						
	Minago	Cross Lake	Flin Flon	Grand Rapids	Norway House	The Pas	Thompson
Aug-07	13.9	14.3	15.1	16.3	15.1	15.3	12.5
Dec-07	-18.4	-19.1	-17.1	-	-8.8	-17.7	-22.8
Jan-08	-19.7	-19.8	-18.7	-17.7	-19.4	-19.7	-22.4
Feb-08	-21.1	-	-19.7	-19.5	-22.5	-20.4	-24.9
Mar-08	-12.8	-13.7	-10.6	-	-14.0	-12.0	-17.2
Apr-08	-0.6	-0.9	0.1	1.2	-0.5	-0.3	-3.0
May-08	6.7	6.1	8.7	-	7.0	7.2	4.9
Jun-08	14.2	14.5	16.4	14.9	14.7	15.5	12.9
Jul-08	16.4	16.8	18.2	-	17.3	17.6	15.7

1 Insufficient or no data available denoted by a – symbol.

2 Data source: Golder Associates, 2009 (Secondary source: Victory Nickel (2008) for Minago and EC (2008b) for all other stations).

Table 7.1-4 Recorded Local and Regional Relative Humidity for 2007 and 2008

Month	Mean Monthly Relative Humidity[1, 2]		
	Minago	The Pas	Thompson
Aug-07	74.9	75.2	74.6
Dec-07	71.1	74.8	81.3
Jan-08	71.1	70.7	78.1
Feb-08	71.6	64.1	70.2
Mar-08	72.2	66.1	69.1
Apr-08	58.6	58.1	56.8
May-08	62.7	54.1	56.4
Jun-08	62.5	60.3	63.5
Jul-08	73.5	72.3	73.5

1. Relative humidity observations are available at Norway House. However, the period of record extends from 1975 to 2005 only (Table 7.1-1).
2. Data sources: Golder Associates, 2009 (Secondary source: Victory Nickel (2008) for Minago and EC (2008b) for all other stations).

Table 7.1-5 Recorded Local and Regional Rainfall for 2007 and 2008

Month	Monthly Rainfall[1, 2]						
	Minago	Cross Lake	Flin Flon	Grand Rapids	Norway House	The Pas	Thompson
Aug-07	50.3	79.8	78.0	40.2	50.5	61.5	107
Dec-07	0.0	0.0	0.0	-	-	0.0	0.6
Jan-08	0.0	0.0	0.0	0.0	-	0.0	0.4
Feb-08	2.0	-	0.0	0.0	-	0.0	0.0
Mar-08	0.0	0.0	0.0	-	-	0.0	2.8
Apr-08	4.5	6.9	0.0	0.0	-	3.0	0.4
May-08	5.4	4.4	4.2	-	-	10.1	20.4
Jun-08	36.6	15.7	39.2	97.4	-	40.4	46.5
Jul-08	133	167	127	-	-	131	151

1. Regional rainfall data are not adjusted for the undercatch factor. Insufficient or no data available denoted by a - symbol.
2. Data sources: Golder Associates, 2009 (Secondary source: Victory Nickel (2008) for Minago and EC (2008c) for all other stations).

The same seasonal patterns of cold and warm temperatures for the winter and summer months, respectively, are noticeable at Minago and all the regional stations (Table 7.1-3). The coldest and warmest temperatures are observed at the northernmost (Thompson) and southernmost (Grand Rapids) climate stations, respectively. On a monthly basis, the temperatures at Minago are within the range of those measured at the regional stations.

Relative humidity varies spatially as a function of local temperature, altitude, wind conditions, vegetation, soil moisture content and the presence of waterbodies. The data suggest that the mean monthly relative humidity at Minago is within the range observed at The Pas and Thompson from August 2007 to July 2008 (Table 7.1-4).

The Minago station is equipped with a tipping bucket and therefore, only rainfall can be measured. A similar seasonal rainfall pattern is observed at Minago and all regional stations, with little or no rainfall during the winter months (December to April) and a high monthly rainfall amount in July. On a monthly basis, the rainfall amounts at Minago are within the range observed at the regional stations (Table 7.1-5).

Wind speed varies with the local topography. Measured wind speeds are on average higher at Minago than at The Pas and Thompson. The wind blows from two major directions (east and west) for 50% of the observations at Minago, while observations at the regional stations are more evenly distributed among the eight major directions (Table 7.1-6).

Table 7.1-6 Local and Regional Wind Speed Characteristics for 2007 and 2008

Direction [1, 2]	Minago			The Pas			Thompson		
	Mean Speed (km/hr)	Probability of Occurrence Excluding Calm (%)	Probability of Occurrence Including Calm (%)	Mean Speed (km/hr)	Probability of Occurrence Excluding Calm (%)	Probability of Occurrence Including Calm (%)	Mean Speed (km/hr)	Probability of Occurrence Excluding Calm (%)	Probability of Occurrenc e Including Calm (%)
N	12.0	3%	3%	13.1	21%	19%	13.8	15%	14%
NE	9.9	2%	2%	9.6	6%	6%	14.6	13%	12%
E	19.0	23.0%	22%	11.2	10%	10%	11.0	14%	13%
SE	33.9	17%	16%	14.6	17%	16%	10.5	8%	7%
S	18.1	2%	2%	13.9	13%	12%	11.5	8%	7%
SW	21.0	4%	4%	10.9	4%	4%	11.1	6%	5%
W	25.2	32%	31%	15.7	12%	12%	13.4	19%	18%
NW	24.1	17%	16%	18.3	17%	15%	15.2	18%	17%
Calm [3]	-	-	4%	-	-	7%	-	-	7%
All	20.4	100%	100%	13.4	100%	100%	12.6	100%	100%

1. Norway House is not included, since its wind observations record does not extend up to 2007 and 2008 (Table 7.1-1). Insufficient or no data available denoted by a – symbol.
2. Data sources: Golder Associates, 2009 (Secondary source: Victory Nickel (2008) for Minago and EC (2008c) for all other stations).
3. Calm refers to wind below the detection limit of the instruments (*i.e.,* the wind speed is assumed to be zero).

7.1.3 Baseline Climate Characteristics

This section presents long-term air temperature, humidity, precipitation, evaporation, and wind characteristics derived for the Minago project site area. The long-term characterizations for each of the climate parameters were based upon observations from the regional stations.

7.1.3.1 Air Temperature and Humidity

Air temperature data from the six regional climate stations listed in Table 7.1-7 were used to characterize long-term regional and temporal variations at the Minago Project. The concurrent period of air temperature for these stations extends from 1968 to 2008. Table 7.1-7 and Figure 7.1-4 show the mean annual temperature at the regional stations, while Figure 7.1-5 provides the mean monthly values at these stations. Monthly mean, maximum and minimum temperatures are also provided for each regional station in Appendix 7.1.

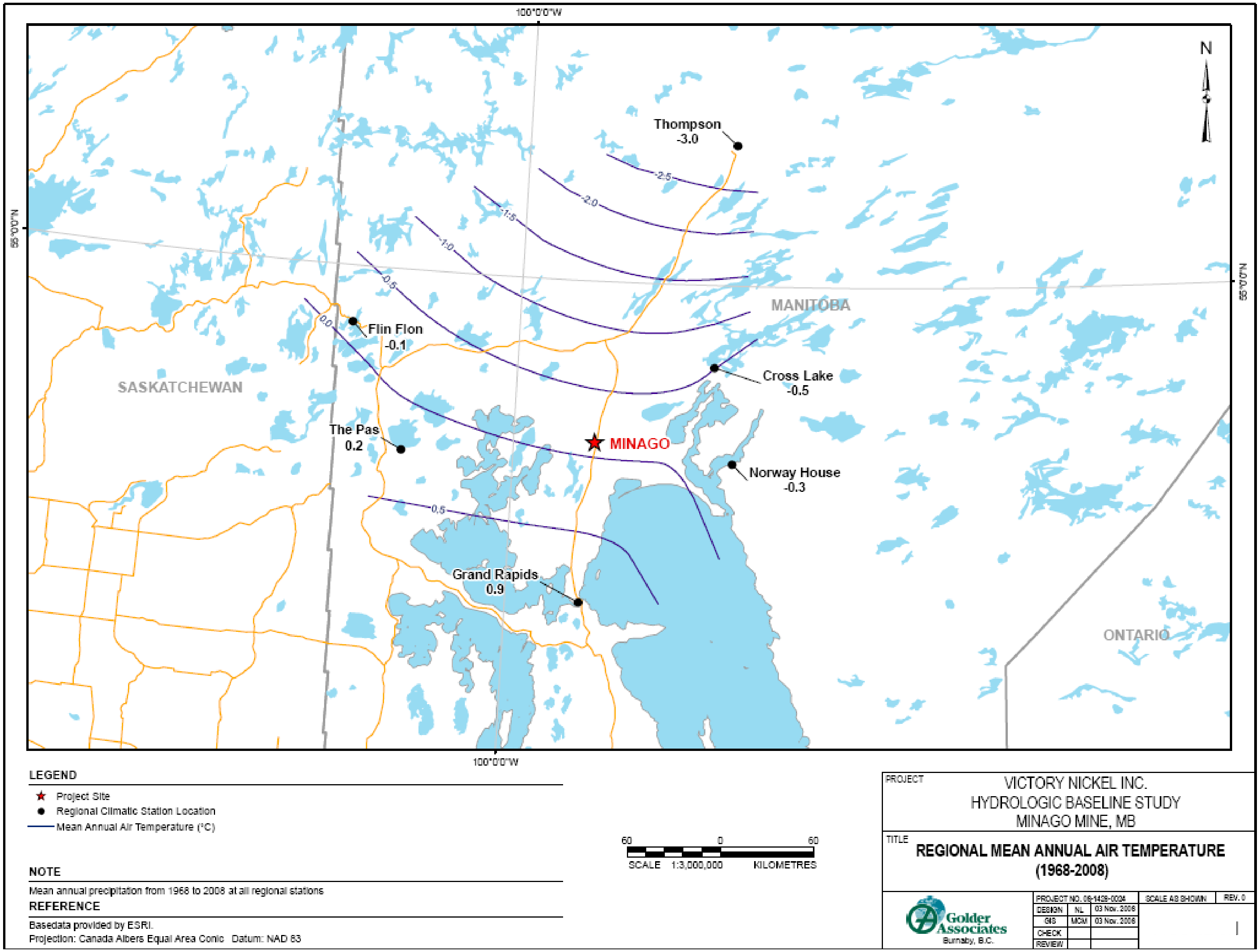
Temperatures tend to decrease with increasing latitude, with the warmest and coldest annual temperatures observed at the southernmost and northernmost stations of Grand Rapids (0.9 ºC) and Thompson (-3.0 ºC), respectively (Table 7.1-7 and Figure 7.1-4). Based on the regional spatial distribution of temperature in Figure 7.1-4 (i.e., isocontours), the mean annual temperature at the proposed Minago project site is estimated at -0.1 ºC from 1968 to 2008.

A similar seasonal variation of monthly temperature applies to all regional stations (Figure 7.1-5) and is expected to extend to the proposed Minago project site. The coldest and warmest mean monthly temperatures are observed in January and July, respectively, at all stations. Temperatures at Thompson are markedly lower than at other regional stations (Figure 7.1-5).

Table 7.1-7 Mean Annual Air Temperature at Regional Stations between

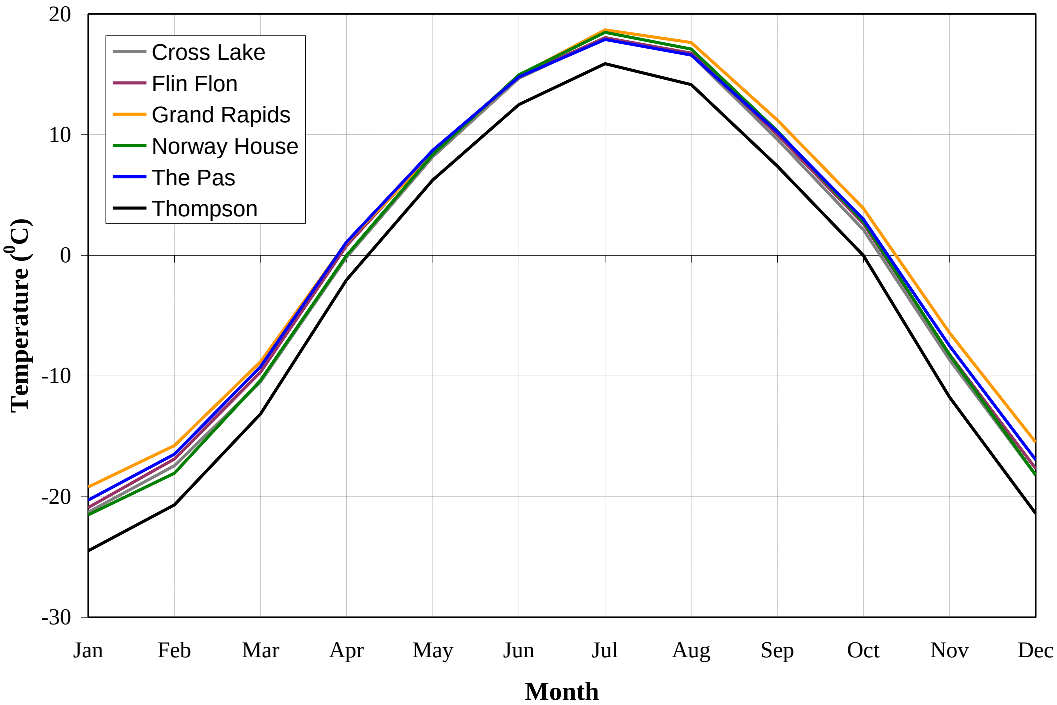
Station Name [1]	Months of Record [2]	Mean Annual Air Temperature (ºC)
Cross Lake	422	-0.5
Flin Flon	471	-0.1
Grand Rapids	476	0.9
Norway House	445	-0.3
The Pas	488	0.2
Thompson	488	-3.0

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008b)).
2. A complete record, from January 1968 to August 2008, equals to a total of 488 months. Only months with less than 6 days of missing data are considered.



Source: Golder Associates, 2009

Figure 7.1-4 Regional Mean Annual Air Temperature



Source: Golder Associates, 2009

Figure 7.1-5 Regional Mean Monthly Air Temperature

Long-term air temperature characteristics at Minago were derived using the data available from The Pas. This station is representative of regional variations, and has the advantages of having an extended period of temperature record and of being located relatively close to the proposed Minago project site.

Estimated long-term air temperature characteristics for the proposed Minago project site were obtained by subtracting a regional correction factor of 0.3 ºC from the observed values at The Pas for the period 1950 to 2008 (Table 7.1-8). This correction factor is based on the mean annual temperature of 0.2 ºC at The Pas and -0.1 ºC at Minago. Derived mean monthly air temperatures for the Minago project area are also provided from 1950 to 2008 in Appendix 7.1.

The derived mean annual temperature at Minago is -1.1 ºC for the 1950 to 1967 period, compared to -0.1 ºC from 1968 to 2008. This corresponds to an average mean annual temperature of -0.4 ºC for the 1950 to 2008 period. The coldest and warmest months are January (-21.5 ºC) and July (17.6 ºC), respectively. Sub-zero temperatures are observed from late October to late April.

Table 7.1-8 Derived Long-term Air Temperature and Relative Humidity Characteristics at Minago from 1950 to 2008

Month	Monthly Air Temperature (°C) [1, 2]			Monthly Relative Humidity (%) [1, 2]		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Jan	-26.3	-21.5 (-20.6)	-16.7	59.1	74.0 (74.0)	90.8
Feb	-22.9	-17.3 (-16.8)	-11.6	57.7	73.4 (73.2)	91.1
Mar	-16.4	-10.4 (-9.5)	-4.2	50.3	71.1 (71.1)	92.1
Apr	-5.6	0.2 (0.8)	6.0	43.7	66.3 (66.1)	92.5
May	1.9	8.2 (8.4)	14.4	42.0	65.5 (65.3)	93.9
Jun	8.5	14.3 (14.5)	20.1	48.1	69.8 (69.6)	95.8
Jul	12.0	17.6 (17.6)	23.2	55.2	72.4 (72.5)	92.0
Aug	10.6	16.2 (16.3)	21.7	57.1	74.5 (74.6)	94.5
Sep	5.0	9.8 (9.9)	14.6	59.1	78.2 (78.1)	96.7
Oct	-1.2	3.0 (2.7)	7.0	57.5	79.8 (79.8)	96.9
Nov	-11.6	-8.0 (-7.8)	-4.3	65.8	83.0 (83.0)	96.4
Dec	-21.7	-17.3 (-17.3)	-13.0	62.7	78.8 (78.8)	95.4
Annual	-26.3	-0.4 (-0.1)	23.2	42.0	73.9 (73.9)	96.9

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008b)).
2. The values in parentheses are the mean air temperatures for the period from 1968 to 2008.

Long-term relative humidity characteristics were also derived for Minago using the data available from The Pas from 1953 to 2008. As the marginal difference in elevation and air temperature between The Pas and Minago would result in negligible changes in relative humidity, no additional adjustments were made to the The Pas data. The resulting long-term characteristics of relative humidity are provided in Table 7.1-8, while mean monthly values from 1953 to 2008 are given in Appendix 7.1.

As shown in Table 7.1-8, the months of August to January tend to be relatively humid compared to the months of February to July. However, relative humidity is dependent upon the air temperature. Humidity indicates the amount of water in the atmospheric column, and relative humidity is the ratio of observed over saturated water vapor pressures. Saturated water vapor pressure decreases with decreasing air temperatures. Therefore, relative humidity would be expected to increase with decreased air temperature given the same amount of water in the \atmospheric column.

7.1.3.2 Precipitation

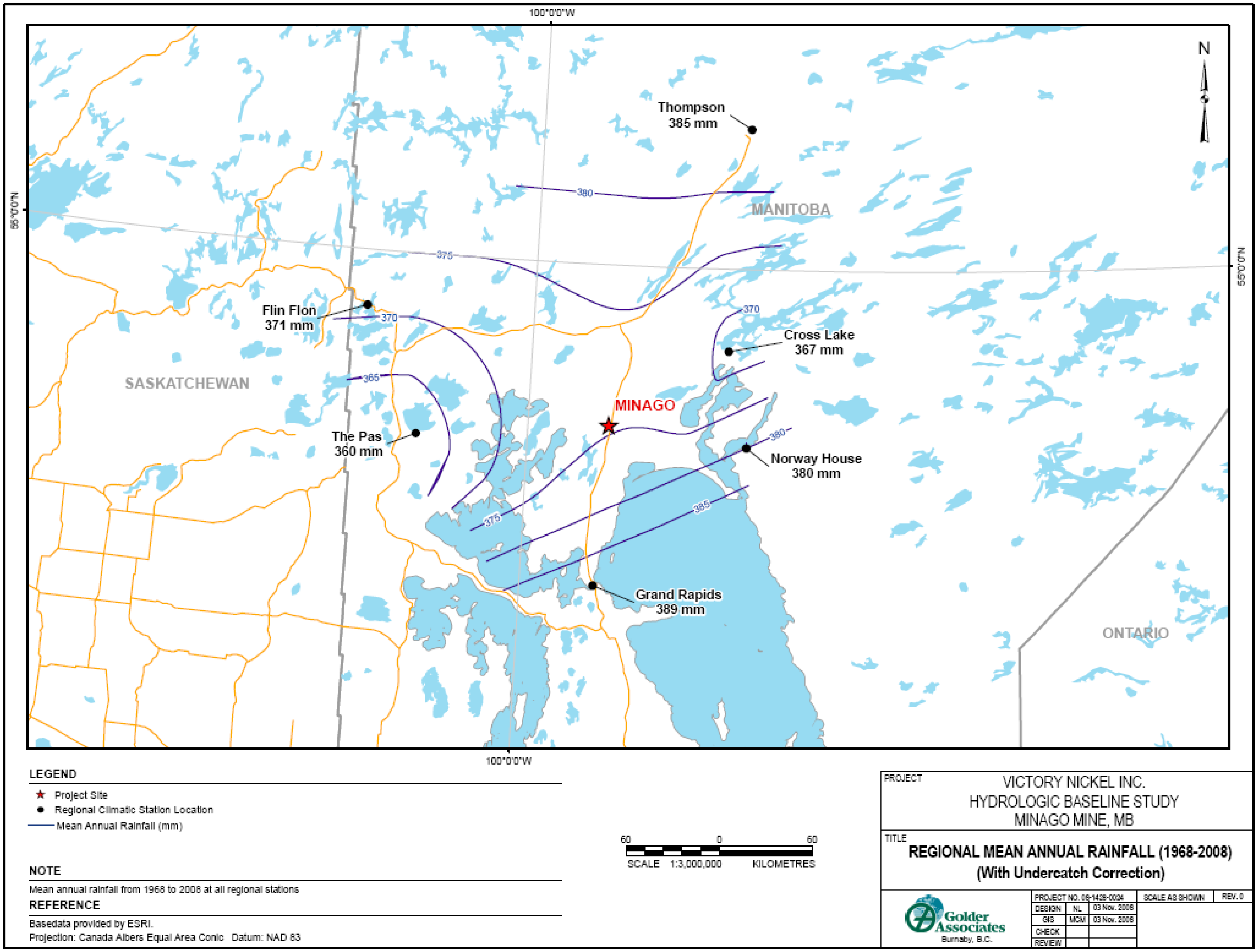
7.1.3.2.1 Long-term Precipitation

Data from the regional climate stations located at Cross Lake, Flin Flon, Grand Rapids, Norway House, The Pas and Thompson were also used to characterize long-term regional and temporal variations in precipitation at the Minago Project. The concurrent period of precipitation data for these stations extends from 1968 to 2008. Figures 7.1-6 to 7.1-8 and Table 7.1-9 present the mean annual rainfall, snow water equivalents and total precipitation for these stations over this period. Figures 7.1-9 to 7.1-11 provide the mean monthly values at the stations, respectively for rainfall, snowfall and total precipitation.

The snowfall water equivalent was estimated by multiplying the reported snowfall depth data by a consistent factor of 0.1 (rather than using varying snowfall densities). The total precipitation was estimated by adding the rainfall and snowfall amounts.

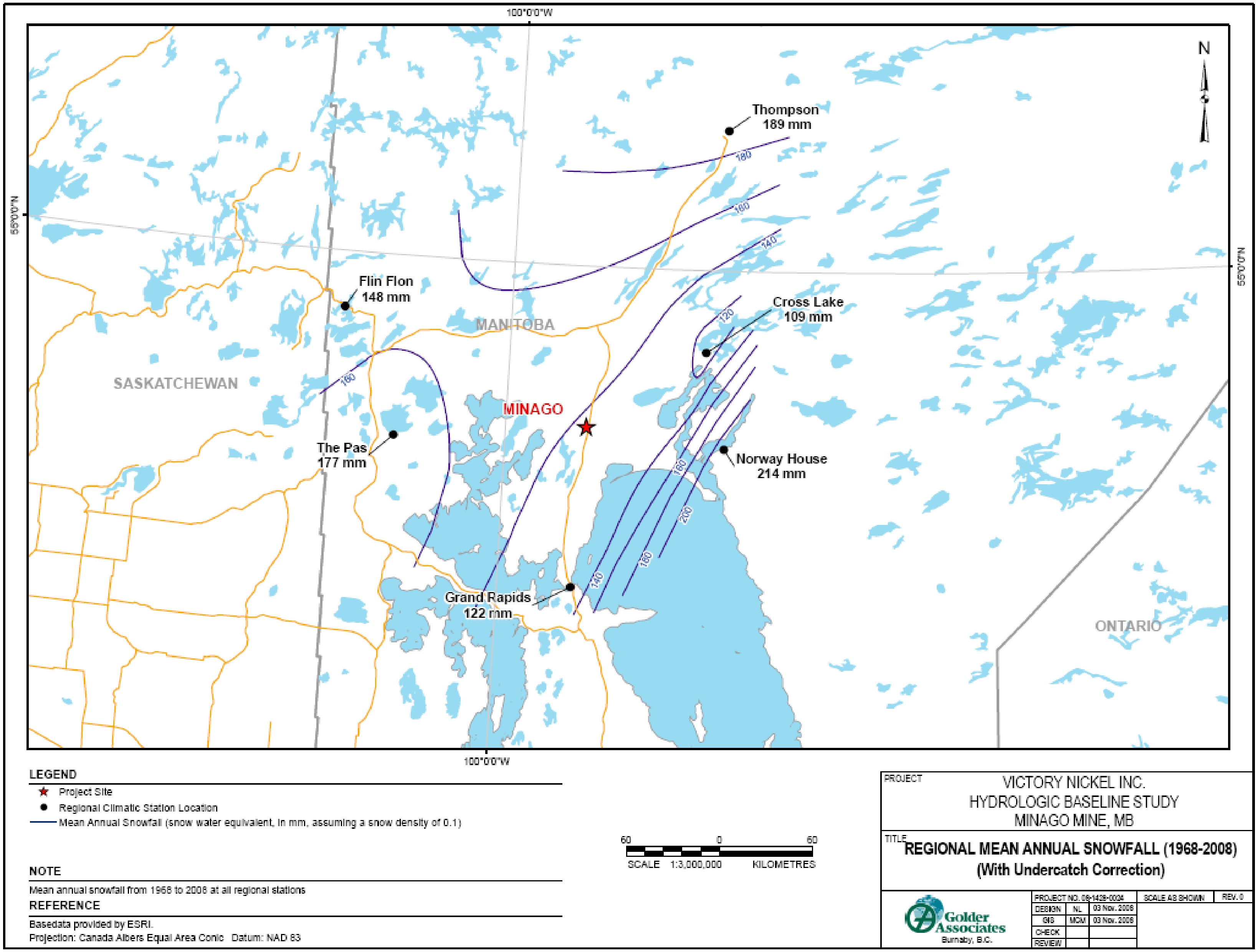
Rainfall and snowfall amounts were also adjusted using “under-catch” factors. Assessments of meteorological records in the Canadian north (Metcalfe et al., 1994) concluded that precipitation amounts are underestimated due to under-catch (i.e., the inability of a specific precipitation gauge type to accurately measure incoming precipitation depth owing to wind and sheltering effects, evaporative losses, etc.). Adjustments for the correction of precipitation under-catch were determined from adjusted precipitation data (Adjusted Historical Canadian Climate Data; EC, 2008d) for the stations listed in Table 7.1-9. The adjustments accounted for the following (Golder Associates, 2009):

- Wind under-catch and evaporation based on type of rain gauge;
- Gauge-specific wetting losses for individual rainfall events;
- Snowfall based on ruler measurements for period of record to minimize potential discontinuities associated with the introduction of the shielded Nipher snow gauge in the mid 1960s;
- Snow density corrections based on concurrent ruler and Nipher snow measurements; and
- Quantification of trace snowfall events.



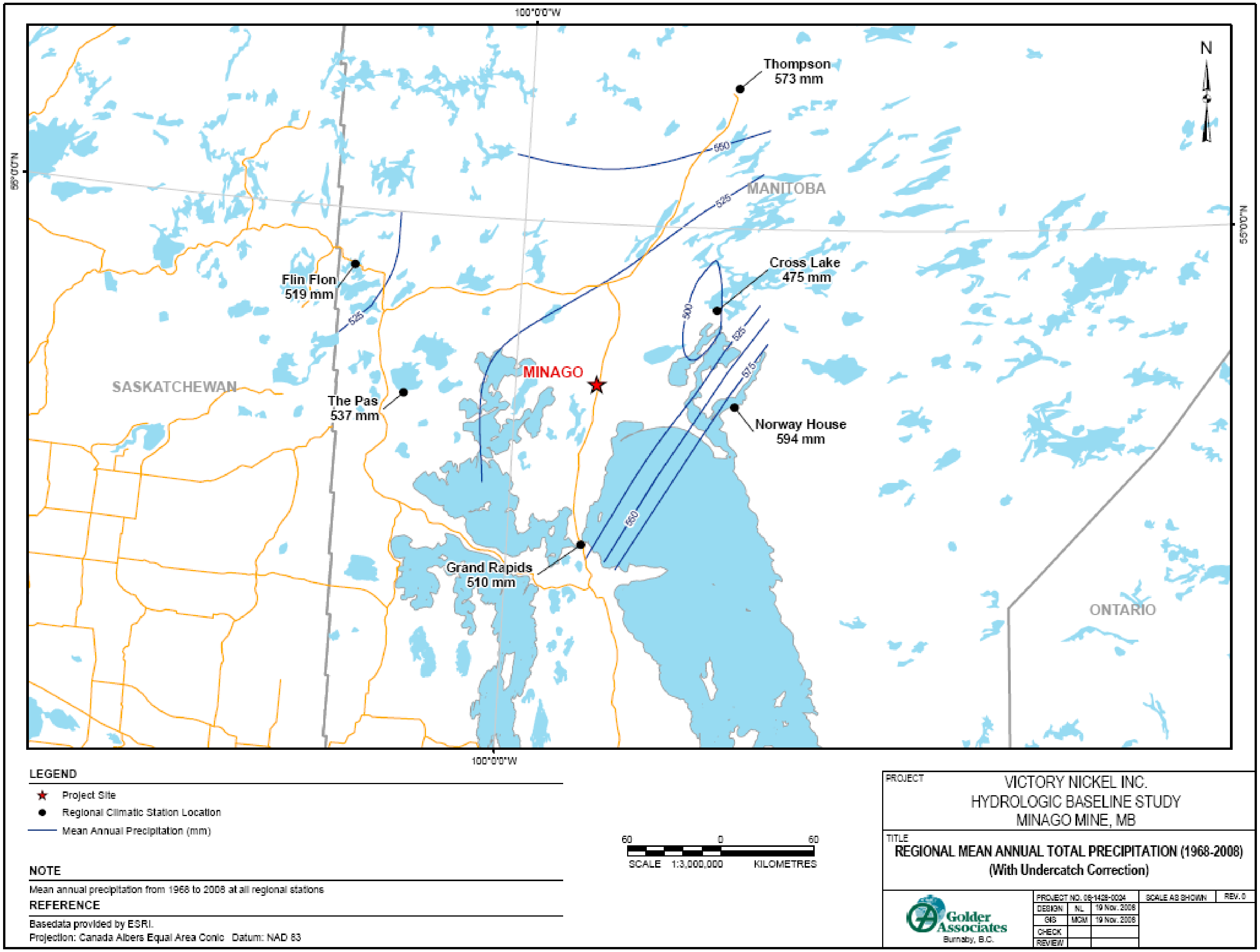
Source: Golder Associates, 2009

Figure 7.1-6 Regional Mean Annual Rainfall (1968-2008) (with Undercatch Correction)



Source: Golder Associates, 2009

Figure 7.1-7 Regional Mean Annual Snowfall (1968-2008) (with Undercatch Correction)



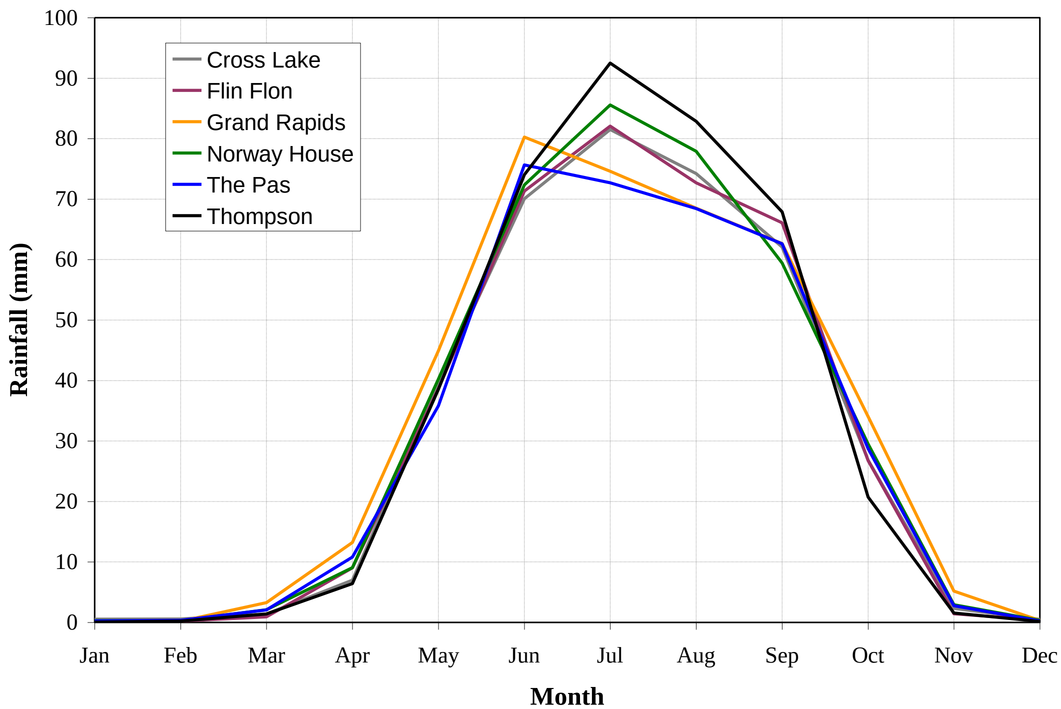
Source: Golder Associates, 2009

Figure 7.1-8 Regional Mean Annual Total Precipitation (1968-2008) (with Undercatch Correction)

Table 7.1-9 Mean Annual Precipitation at Regional Stations from 1968 to 2008

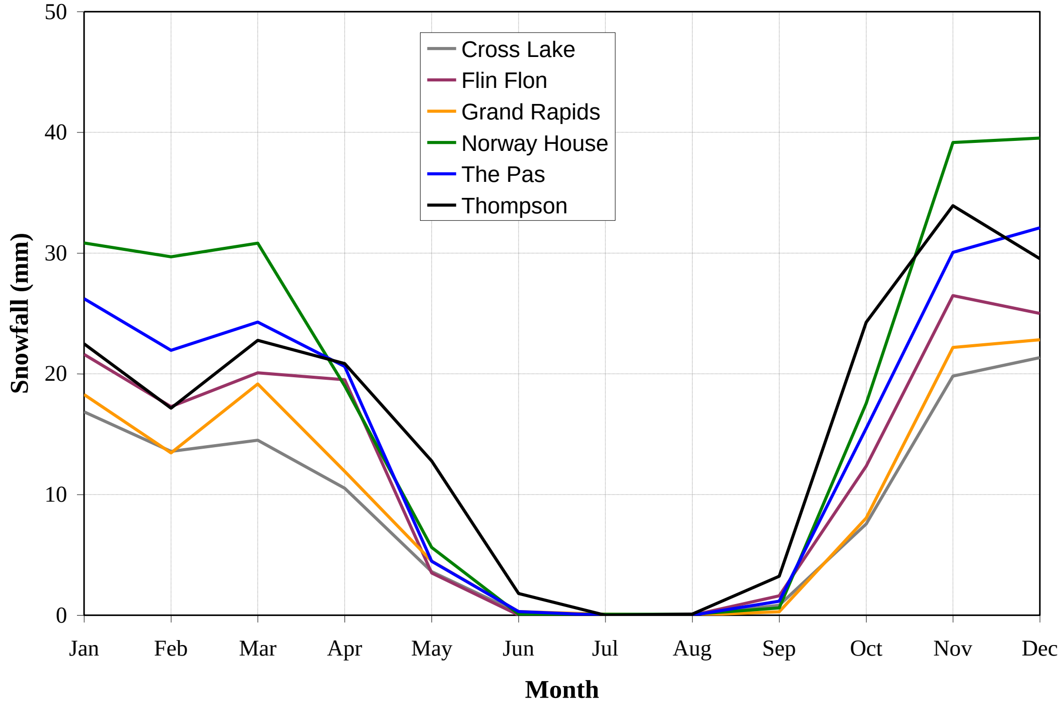
Station [1]	Months on Record [2]	Under-catch Factors [3]		Adjusted Precipitation (mm)		
		Rainfall	Snowfall	Rainfall	Snowfall [4]	Total Precipitation
Cross Lake	440	1.09	1.00	367	109	475
Flin Flon	488	1.07	1.00	371	148	519
Grand Rapids	488	1.05	1.09	389	122	510
Norway House	456	1.12	1.38	380	214	594
The Pas	488	1.10	1.14	360	177	537
Thompson	488	1.09	1.00	385	189	573

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008b)).
2. A complete record, from January 1968 to August 2008, equals to a total of 488 months. Only months with less than 6 days of missing data are considered.
3. No adjusted data were available for the Cross Lake station. The under-catch factors applied to Cross Lake are those of the nearest neighboring station (*i.e.,* Thompson).
4. The snowfall water equivalent was estimated by multiplying the reported snowfall depth data by a consistent factor of 0.1 (as opposed to applying varying snowfall densities).



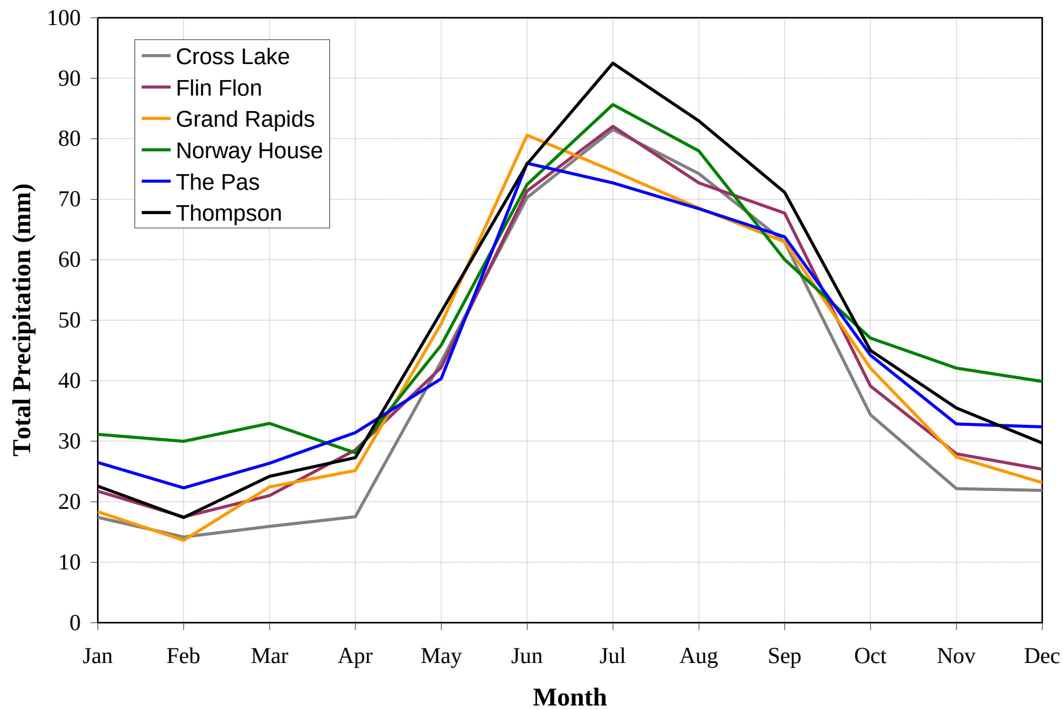
Source: Golder Associates, 2009

Figure 7.1-9 Regional Mean Monthly Rainfall



Source: Golder Associates, 2009

Figure 7.1-10 Regional Mean Monthly Snowfall (As Water Equivalent)



Source: Golder Associates, 2009

Figure 7.1-11 Regional Mean Monthly Total Precipitation

Figure 7.1-6 shows that annual rainfall is comparatively higher in close proximity to Lake Winnipeg than inland. Rainfall in regions away from Lake Winnipeg also tends to increase from south to north. Figure 7.1-7 indicates high snowfall (SWE) on the east side of Lake Winnipeg that gradually decreases westward. Snowfall eventually increases northward once inland to the west of Lake Winnipeg.

The data collected at the regional stations between 1968 and 2008 indicates that 73% of the precipitation in the region of the project site occurs as rainfall and consequently the spatial distribution of total regional precipitation shown in Figure 7.1-8 approaches that of rainfall as shown in Figure 7.1-6. Based on the regional spatial distribution of precipitation, illustrated in Figures 7.1-6 to 7.1-8 (i.e., isocontours), the estimated mean annual rainfall, snowfall (SWE) and total precipitation for the Minago project site from 1968 to 2008 are 375, 139 and 514 mm, respectively.

Figure 7.1-9 indicates a similar seasonal precipitation variation to all regional stations. Rainfall can occur at any time of the year, although it would be limited to isolated events during the months of November to March. Peak monthly rainfalls occur during the summer months of June and July (Figure 7.1-9).

Snowfall occurs at the regional stations from September to June, with the largest monthly amounts recorded from November to March (Figure 7.1-10). Based on the regional air temperature records, it is assumed that winter processes such as ground snow and ice covers are likely to be sustained from November to April. Any snowfall before November would be expected to melt in a few days, while those after April would contribute to the spring freshet.

Long-term precipitation characteristics at Minago were derived using the data available from The Pas. Both The Pas and Minago are located inland at roughly the same latitude and have relative warm air temperatures compared to most other regional stations. It is anticipated that the seasonal variation of precipitation would be the same at both stations.

In order to develop a precipitation record for the Minago Project, the precipitation data from The Pas for the period of 1950 to 2008 were adjusted based on the ratio of the annual precipitation at The Pas to the estimated annual precipitation at Minago. Specifically, rainfall amounts from The Pas were multiplied by a factor of 1.04 and snowfall was multiplied by a factor of 0.78. The resulting long-term characteristics at the project site are given in Table 7.1-10. Average annual precipitation at the project site is estimated to be 510 mm, of which rainfall accounts for 72% of the total (369 mm) and the remaining 28% consists of snowfall (SWE; 141 mm). Monthly rainfall, snowfall and total precipitation values derived for Minago for the period of 1950 to 2008 are also provided in Appendix 7.1.

Table 7.1-10 Derived Long-Term Precipitation Characteristics at Minago (1950-2008)

Month	Precipitation (mm) [1, 2]		
	Rainfall	Snowfall	Total Precipitation
Jan	0.2 (0.3)	20.1 (20.5)	20.2 (20.8)
Feb	0.2 (0.4)	17.5 (17.2)	17.8 (17.5)
Mar	1.6 (2.1)	20.9 (19.0)	22.4 (21.1)
Apr	11.0 (11.2)	15.8 (16.1)	26.8 (27.3)
May	38.6 (37.2)	4.2 (3.5)	42.8 (40.7)
Jun	74.2 (78.5)	0.2 (0.2)	74.4 (78.8)
Jul	78.3 (75.4)	0.0 (0.0)	78.3 (75.4)
Aug	69.6 (71.0)	0.0 (0.0)	69.6 (71.0)
Sep	64.6 (65.0)	1.1 (0.9)	65.8 (65.9)
Oct	27.5 (29.8)	11.5 (12.1)	39.0 (41.9)
Nov	2.9 (2.9)	25.3 (23.5)	28.2 (26.4)
Dec	0.2 (0.3)	24.8 (25.1)	25.0 (25.4)
Annual	369 (375)	141 (139)	510.2 (514)

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008b)).
2. The values in parentheses are the mean values for the period from 1968 to 2008.

7.1.3.2.2 Extreme Precipitation Events

The complete adjusted precipitation record at The Pas for the period of 1950 to 2007 was used in a frequency analysis to derive estimated extreme return period events at the Minago project site. The results of the analysis are presented below.

Annual and Monthly Precipitation

Table 7.1-11 presents the estimated annual rainfall, snowfall and total precipitation amounts at the Minago Project for dry and wet precipitation events with return periods from 5 to 1000 years. Similarly, Table 7.1-12 provides the dry and wet monthly total precipitation amounts with return periods from 5 to 1000 years. Extreme rainfall, snowfall and total precipitation are derived independently of one another. Therefore the sum of rainfall and snowfall would not equal total precipitation for a same return period in Table 7.1-11.

Table 7.1-11 Estimated Wet and Dry Extreme Annual Precipitations for the Minago Project Site

Return Period (Years)		Rainfall (mm) [1]	Snowfall (mm) [1]	Total Precipitation (mm) [1]
Wet	1000	596	289	739
	500	582	278	724
	200	562	262	703
	100	544	248	686
	50	525	233	666
	20	496	212	637
	10	470	193	610
	5	437	173	577
Mean [2]		369	141	510
Dry	5	303	109	446
	10	266	94	410
	20	234	82	380
	50	198	69	346
	100	173	60	323
	200	151	53	301
	500	122	44	275
	1000	102	38	257

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008b)).
2. The mean is roughly equivalent to the 2-year return period event.

Long Duration Rainfall Events

Rainfall intensity-duration-frequency (IDF) curves were determined for long-duration events ranging from 1 to 60 days using daily rainfall values derived for Minago based on the data collected at The Pas from 1950 to 2007. The resulting curves are presented in Table 7.1-13. The 30-day events are higher than any of the monthly events in Table 7.1-12 for the same return period. The estimation of 30-day events considers rainfall amounts that may overlap two consecutive months.

Short Duration Rainfall Events

Adjusted hourly rainfall data collected at The Pas from 1972 to 2007 were used to derive estimated project site rainfall IDF curves for events ranging from 1 to 24 hours. The resulting curves are presented in Table 7.1-14.

Table 7.1-12 Estimated Wet and Dry Extreme Monthly Precipitations for the Minago Project Site

	Return Period (Years)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wet [1]	1000	60	70	112	119	183	276	277	266	221	199	92	70
	500	57	64	101	108	168	252	256	245	205	176	87	67
	200	53	56	86	94	147	220	229	218	184	148	79	62
	100	49	50	75	84	132	197	208	196	167	128	73	58
	50	45	44	64	73	116	174	186	175	151	110	66	53
	20	37	36	51	60	95	145	156	146	128	87	57	47
	10	35	30	42	50	79	123	133	124	110	71	49	41
	5	29	25	32	39	62	100	108	100	90	55	40	35
Mean [2]		20	18	22	27	43	74	78	70	66	39	28	25
Dry [1]	5	11	10	11	13	21	44	44	36	38	19	16	16
	10	7.8	9.3	7.3	8.0	15	35	34	25	31	13	12	11
	20	5.4	8.9	5.1	4.9	12	29	28	17	26	8.4	8.6	7.2
	50	3.0	8.7	3.1	1.9	7.9	24	21	10	22	4.3	5.6	4.6
	100	1.5	8.7	1.9	0.1	6.0	21	17	5.9	20	1.9	3.9	3.5
	200	0.3	8.7	1.0	0.0	4.4	18	14	2.4	18	0.0	2.5	2.8
	500	0.0	8.7	0.0	0.0	2.8	16	11	0.0	17	0.0	0.9	2.2
	1000	0.0	8.6	0.0	0.0	1.8	14	9.3	0.0	16	0.0	0.0	2.0

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008b)).
2. The mean is equivalent to the 2-year return period event.

Table 7.1-13 Long-Duration Extreme Rainfall Estimates for Minago

Return period	Rainfall Depth (mm) for Various Durations [1]					
(Year)	1-day	3-day	5-day	10-day	30-day	60-day
2	40	57	65	80	132	193
5	53	76	86	106	168	245
10	62	87	99	122	189	276
20	71	97	110	135	208	304
50	82	108	123	151	231	336
100	90	116	133	161	248	358
200	98	123	142	171	263	378
500	110	131	154	182	284	402
1000	128	136	162	190	298	419

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008b)).

Table 7.1-14 Short-Duration Extreme Rainfall Estimates for Minago

Return period	Rainfall Depth (mm) for Various Durations [1]				
(Year)	1-hr	2-hr	6-hr	12-hr	24-hr
2	16	20	29	36	49
5	23	28	40	52	67
10	28	35	49	64	79
20	33	42	59	77	89
50	40	52	73	87	102
100	45	60	85	98	111
200	51	70	99	110	120
500	60	84	121	126	132
1000	67	96	139	140	141

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008c)).

As indicated in Table 7.1-14, the 24-hour events are roughly 20% higher than the 1-day events. Unlike the 1-day events, the 24-hour events consider recorded rainfall maxima that overlap 2 calendar days. An increase of 13% is typically assumed in the absence of supporting data (Watt et al., 1989), and therefore the estimates of 24-hour events in Table 7.1-14 may be conservative.

Probably Maximum Precipitation

Estimates of Probably Maximum Precipitation (PMP) for the Minago project site were derived using the Hershfield statistical approach (Hershfield, 1977). In this approach, extreme rainfall is expressed as:

$$X_T = U_x + K_{MT} * Std_x$$

where X_T is the extreme rainfall amount for a given return period T, U_x is the mean of the annual maximum series, K_{MT} is a frequency factor associated with a given duration, and Std_x is the standard deviation of the annual maximum series. For a 24-hr duration event,

$K_{M24} = 19 * (10)^{-0.000965*U24}$, resulting in a 24-hour PMP at Minago of 447 mm.

This estimate is considered applicable on a regional scale; however, significant spatial variability can be present in extreme precipitation events, particularly for small watersheds. Hopkinson (1999) developed PMP estimates for watersheds smaller than or equal to 1 km^2. Based on historical storms in the Canadian prairie region and the analysis of the maximum persisting dew point, Hopkinson (1999) estimated a 24-hour point PMP of 606 mm at the Flin Flon station. This estimate is considered applicable to smaller watersheds (<= 1 km^2) in the vicinity of the Minago Project since the mean annual rainfalls are similar between the study area and Flin Flon.

7.1.3.3 Evaporation

No evaporation record is available for the proposed Minago Project site. However, May to October pan and lake evaporation estimates are available at the Norway House, Grand Rapids and Pasquia Project stations. The evaporation records at these stations are summarized in Table 7.1-15.

Pan and lake evaporation follows a monthly distribution that is roughly similar for both variables. Lake evaporation is on average equal to 77% of pan evaporation.

The distribution of evaporation on a monthly basis is similar at all three regional stations. The total amount of evaporation is relatively equivalent at Grand Rapids (581 mm) and Norway House (549 mm), while it is lower at Norway House (354 mm).

It is assumed that the amount of evaporation at Minago would be similar to that Pasquia Project, since both locations are inland as opposed to located near large waterbodies, which is the case for the Grand Rapids and Norway House stations. However, based on the derived air temperature record presented in Table 7.1-8, it is anticipated that evaporation also occurs in April at the Minago Project. In this report, the additional evaporation in April was assumed to be similar to that for the month of October.

Table 7.1-15 Pan and Lake Evaporation Estimates at Regional Stations

Station	Data [1]	May	June	July	August	September	October	May to October Total
Norway House (1971 to 2000)	Mean Lake Evaporation	66	77	81	74	44	12	354
	% of Annual	19%	22%	23%	21%	12%	3%	
	Mean Pan Evaporation	84	101	107	96	59	17	464
	% of Annual	18%	22%	23%	21%	13%	4%	
	# Years	6	29	27	17	24	20	
Grand Rapids (1966 to 1978)	Mean Lake Evaporation	112	127	139	120	67	15	581
	% of Annual	19%	22%	24%	21%	12%	3%	
	Mean Pan Evaporation	134	165	181	155	87	20	742
	% of Annual	18%	22%	24%	21%	12%	3%	
	# Years	1	5	8	10	10	5	
Pasquia Project (1969 to 1985)	Mean Lake Evaporation	128	122	123	94	61	21	549
	% of Annual	23%	22%	22%	17%	11%	4%	
	Mean Pan Evaporation	170	159	157	124	81	28	720
	% of Annual	24%	22%	22%	17%	11%	4%	
	# Years	5	8	8	6	8	3	

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008c)).

Table 7.1-16 provides the derived long-term lake evaporation estimates at Minago. The estimates were derived assuming that:

- The monthly distribution of evaporation would be equal to the average distribution from the three regional stations; and
- The average total evaporation would be approximately 549 mm from May to October (Pasquia Project) plus an additional amount in April equal to that for the month of October, for an estimated total mean annual evaporation at the Minago Project of 566 mm.

Table 7.1-16 Long-term Lake Evaporation Estimates at Minago

Station	Data [1]	April	May	June	July	August	September	October	Total
Minago	Mean Monthly Evaporation (mm)	17.6	112	121	127	107	64.1	17.6	566
	% of Annual	3%	20%	21%	22%	19%	11%	3%	100.0%

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008c)).

7.1.3.4 Wind

Table 7.1-17 presents the distribution of the wind among the 8 major directions at the Norway House, The Pas and Thompson stations for the period from 1968 to 2008. The distribution at The Pas and Thompson is relatively similar to that shown for these two stations in Table 7.1-6 for the period of 2007 to 2008.

Based on the wind data presented in Tables 7.1-6 and 7.1-17, the wind distribution at Minago appears to differ from that at the regional stations. Moreover, the recorded mean wind speed at Minago appears to be higher than that at the regional stations. It should be noted however that the project site period of record is too short to draw definitive conclusions with respect to differences in wind characteristics between Minago and the regional stations. Assessment of wind characteristics at Minago is therefore limited to the estimation of extreme wind speeds based on hourly wind data recorded at the The Pas station from 1953 to 2008. The extreme hourly wind speeds for the Minago Project are provided in Table 7.1-18.

7.1.3.5 Sublimation and Snow Redistribution

The amount of water released from the snow pack during the spring thaw will depend on the amount of snow accumulated, redistributed, and/or sublimated over the winter period. Sublimation is the process by which ice and snow change directly to water vapor without passing through the liquid stage. Sublimation can occur directly from snowpack surfaces or during blowing snow events with overall rates dependent upon humidity and wind speed (Essery et al., 1999; Déry and Yau, 2002). Snow redistribution refers to snow erosion from, and deposition to, the snowpack due to wind.

Table 7.1-17 Regional Wind Characteristics from 1968 to 2008

Wind Direction	Norway House [1]			The Pas [1]			Thompson [1]		
	Mean Speed (km/hr)	Probability of Occurrence Excluding Calm (%)	Probability of Occurrence Including Calm (%)	Mean Speed (km/hr)	Probability of Occurrence Excluding Calm (%)	Probability of Occurrence Including Calm (%)	Mean Speed (km/hr)	Probability of Occurrence Excluding Calm (%)	Probability of Occurrence Including Calm (%)
N	13.6	13%	11%	14.4	14%	13%	13.9	13%	11%
NE	13.7	12%	10%	11.5	7%	6%	14.6	13%	12%
E	12.7	11%	9%	12.2	10%	9%	11.8	13%	11%
SE	11.5	8%	7%	15.3	20%	18%	10.5	8%	7%
S	15.1	14%	12%	13.2	12%	11%	12.2	10%	9%
SW	14.4	15%	13%	11.7	5%	4%	12.3	8%	7%
W	12.9	11%	10%	17.1	17%	16%	12.8	20%	17%
NW	14.1	16%	13%	19.3	15%	14%	14.2	15%	13%
Calm [2]	-	-	15%	-	-	9%	-	-	12%
All	13.5	100%	100%	14.3	100.0%	100.0%	12.8	100%	100%

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008c)).
2. Calm refers to wind below the detection limit of the instruments (*i.e.,* the wind speed is assumed to be zero).

Sublimation and snow redistribution can have a significant impact on snow pack depths and melt in northern environments, where humidity can be low and the land subject to high winds (Marsh et al., 1994; Pomeroy et al., 1997). The assessment of these two processes at Minago is based on the snowfall amounts and on snow survey observations, as discussed below.

Snow survey observations with more than 10 years of record for conditions in March of each year are available at nine (9) regional stations (Table 7.1-2). Table 7.1-19 presents the snow depth, snow water equivalent, and density characteristics at these stations.

The average snow depth and water equivalent at the regional stations listed in Table 7.1-2 are 480 mm and 81 mm, respectively, with observations ranging from 140 to 920 mm for snow depth and from 25 to 170 mm for snow water equivalent (Table 7.1-19). Snow density is the ratio of snow water equivalent to snow depth, and ranges from 0.07 to 0.47 mm/mm at the regional stations, with an average of 0.17 for all stations (Table 7.1-19).

Table 7.1-20 compares the snow water equivalent observed in March at the snow survey stations to the cumulated snowfall recorded at the corresponding nearest regional climate station between November and the March survey date. Snowfalls in September and October are not included, since recorded air temperatures suggest that any snow that fell during these months would have likely melted and therefore not contributed to the snow pack observed in March. All observations of snow water equivalent in Table 7.1-20 are lower than their corresponding accumulated snowfall, which indicates that snow erosion and sublimation of the snow pack exceeded snow

Table 7.1-18 Estimated Extreme Hourly Wind Speeds (km/h) at Minago

Wind Direction	Return Period							
	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	200 Year	500 Year
Annual Period (January to December) [1]								
N	46	51	53	56	58	60	62	63
NE	31	36	39	43	45	48	50	53
E	35	38	40	42	43	44	45	46
SE	46	50	52	54	55	57	58	60
S	40	44	47	50	52	54	56	59
SW	36	43	48	55	62	68	75	85
W	51	60	68	78	87	97	108	124
NW	56	62	66	71	75	78	82	87
Open Water Period (May to October) [1]								
N	44	50	52	55	57	58	60	61
NE	31	36	39	43	46	48	51	54
E	33	37	39	41	43	45	46	48
SE	43	47	50	53	55	58	60	64
S	38	42	45	48	50	52	54	56
SW	35	40	43	48	51	53	56	60
W	48	57	62	69	75	80	85	91
NW	52	58	60	64	66	67	69	71

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008c)).

Table 7.1-19 Summary of Snow Characteristics at Regional Stations

Station [1]	Observations in March	Snow Depth (mm)			Snow Water Equivalent (mm)			Density (mm/mm)		
		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Crossing Bay	20	250	480	770	33	79	107	0.08	0.17	0.24
Flin Flon	24	190	500	790	25	77	147	0.07	0.15	0.21
Norway House	14	410	550	700	46	101	152	0.11	0.18	0.24
Overflowing River	24	160	420	780	30	66	117	0.11	0.16	0.26
Pasquia Hills	22	140	450	820	27	73	160	0.09	0.16	0.22
Red Earth Lake	21	190	410	780	30	65	103	0.09	0.16	0.22
The Pas	35	150	470	920	38	92	170	0.12	0.20	0.47
Thicket Portage	14	390	560	730	56	113	170	0.13	0.20	0.25
Westray	24	230	440	880	30	67	145	0.10	0.15	0.22

1. Data source: Golder Associates, 2009 (Secondary source: EC (2007)).

deposition. The average annual loss from snow redistribution and sublimation is approximately 39%.

Loss due to snow redistribution and sublimation is dependent on local geography and conditions. A large portion of the Minago Project area would consist of open terrain with low lying vegetation. According to Essery et al. (1999), losses to sublimation for open tundra areas can reach up to 47% of the snow pack, and losses due to snow redistribution can account for an additional 18 to 22% for lakes and open tundra. However, the proposed project area is also partially covered with forest, and snow redistribution only constitutes a loss when snow leaves the watershed. Therefore, the total snow losses at Minago were presumed to be less than the values reported by Essery et al. (1999), and an estimate of 39% was assumed to be representative of losses for the Minago project area (Golder Associates, 2009).

Table 7.1-20 Snow Lost to Sublimation and Redistribution at Regional Station

Snow Survey Station	Snow Survey Station - Period of Record	Nearest Climate Station	Climate Station Snowfall - Period of Record	Average SWE (mm) [1]	Accumulated Snowfall (mm) [2]	Losses (%)
Crossing Bay	1966 to 1985	The Pas	1947 to 2008	79	136	42
Flin Flon	1962 to 1985	Flin Flon	1980 to 2008	73	92	20
Norway House	1962 to 1971 and 1974 to 1977	Norway House	1971 to 2008	91	143	36
Overflowing River	1962 to 1985	The Pas	1947 to 2008	66	138	52
Pasquia Hills	1962 to 1985	The Pas	1947 to 2008	73	138	47
Red Earth Lake	1965 to 1985	The Pas	1947 to 2008	65	137	53
The Pas	1962 to 1997	The Pas	1947 to 2008	92	130	30
Thicket Portage	1962 to 1977	Thompson	1968 to 2008	104	122	15
Westray	1962 to 1985	The Pas	1947 to 2008	67	138	51

1. Data source: Golder Associates, 2009 (Secondary source: EC (2007)).
2. Data source: Golder Associates, 2009 (Secondary source: EC (2008b)).

7.1.4 Climate Change relevant to Minago

In 2007, the Intergovernmental Panel on Climate Change (IPCC), a scientific body set up by the World Meteorological Organization (WMO) and by the United Nations Environment Programme (UNEP), released its Fourth Assessment Report on Climate Change. The report comprises three documents, each produced by a separate working group as follows: I - The Physical Science Basis; II - Impacts, Adaptation and Vulnerability; and III - Mitigation of Climate Change. The assessment was conducted by the world’s leading climate change experts and scientists, and represents the current state-of-knowledge on a global basis.

The following sections provide a summary of the information from Volume I – The Physical Science Basis as it pertains to Canadian northern latitudes and the Minago Project site. The information and descriptions presented are excerpted, paraphrased, or indirectly derived from the report. Where appropriate, chapter numbers are provided for reference.

7.1.4.1 Summary of Climate Projections for Minago

Mean annual temperatures in the northwestern part of North America are expected to rise by about 4.5^{O}C in the 100 years leading up to 2100 (i.e., increase from mean of 1980 to 1999 period to mean of simulated 2080 to 2099 period). This increase represents the median of the values projected by a series of 21 models for an average emissions scenario. The mean projected increase for a high emissions scenario is about 5.2^{O}C while the mean increase for a lower emissions scenario is about 3.1^{O}C (Golder Associates, 2009).

Mean annual precipitation for the same region and time period is projected to rise by about 21%. Of the 21 models for average emissions, the maximum and minimum projections for precipitation are increases of 32% and 6%, respectively (Golder Associates, 2009).

Following are detailed projections, including seasonal variations, and a discussion on observed climate changes.

7.1.4.2 Observed Changes

Observed changes in temperature, precipitation, snow cover, lake and river ice, and frozen ground are summarized as applicable to the Minago site. The descriptions focus on observations related to the Northern Hemisphere, North America, northern Canada, and the Artic.

Temperature (IPCC 2007 Report, Section 3.2; Trenberth et al., 2007):

- Global mean surface temperatures have risen by 0.74^{O}C over the last 100 years. The trend is not linear and is not always increasing. The rate of warming over the last 50 years is almost double that over the last 100 years (0.13^{O}C per decade vs. 0.07^{O}C per decade). The rate of warming over the last 25 years has been 0.18^{O}C per decade.
- Eleven of the last 12 years (1995 to 2006) rank among the 12 warmest years on record since 1850.
- Average arctic temperatures increased at almost twice the global average rate in the past 100 years. Arctic temperatures have a high decadal variability. A slightly longer warm period, almost as warm as the present, was also observed from the late 1920s to the early 1950s, but appears to have had a different spatial distribution than the recent warming.
- The length of the frost-free season has increased in most mid- and high-latitude regions. In the northern hemisphere, this is mostly manifested in an earlier start to spring.

- Changes in global and regional temperatures are influenced by changes in the large-scale atmospheric circulation. There are substantial multi-decadal variations in the Pacific sector with extended periods of weakened as well as strengthened circulation.

Precipitation and Surface Hydrology (IPCC 2007 Report, Sect. 3.3; Trenberth et al., 2007):

Temperature changes are one of the more obvious and easily measured changes in climate; however, these changes also drive changes in atmospheric moisture, precipitation, and circulation. Further, increases in temperature result in increased moisture-holding capacity of the atmosphere at a rate of about 7% per ^{O}C. All these factors combined lead to changes to the overall hydrologic cycle.

- *Global precipitation over land:* An analysis of global land precipitation anomalies from 1900 to 2005 indicates an increase in precipitation until the 1950s (relative to 1981-2000 base period) followed by a decline until the early 1990s and then a recovery since then. The linear trend is minimal and statistically insignificant.
- *Regional precipitation trends:* For most of North America, and especially over high-latitude regions in Canada, annual precipitation has increased over the 105-year period from 1900 to 2005.
- *Changes in snowfall:* Statistically significant increases in snowfall have been documented for most of Canada, particularly in the northern regions, up until at least 1995 when the analysis ended (Stone et al., 2002 in IPCC, 2007).
- *Evapotranspiration:* Global land evapotranspiration has been found to closely follow variations in land precipitation due its dependence on moisture supply. As precipitation has generally increased in northern latitudes over the past 100 years, presumably so has evapotranspiration. Not only does evapotranspiration depend on moisture supply, but also on energy available and surface wind. In other areas of the world, increased cloud cover, aerosols, and air pollution may contribute to reduced evapotranspiration rates.

Snow Cover (IPCC 2007 Report, Section 4.2; Lemke et al., 2007):

- Based on satellite data, in the Northern Hemisphere, snow cover in November, December and January has decreased over the 1966 to 2005 period. Decreases were observed in every other month, as well as a stepwise drop of 5% in the annual mean in the late 1980’s. The decrease in snow cover in February and March has resulted in a shift in the date of snowmelt start by about eight days since the mid-1960s.

River and Lake Ice (IPCC 2007 Report, Section 4.3; Lemke et al., 2007):

- Freeze-up and breakup dates for river and lake ice exhibit considerable spatial variability (with some regions showing trends of opposite signs). When data for the Northern Hemisphere is averaged over the past 150 years, freeze-up date has occurred later at a rate of 5.8 days per century, and the breakup date has occurred earlier at a rate of 6.5 days per century.

7.1.4.3 Projected Changes

7.1.4.3.1 Climate Models

Increasingly reliable regional climate change projections are now available for many regions of the world due to advances in modelling and understanding of the physical processes of the climate system. Atmosphere-Ocean General Circulation Models (AOGCMs) remain the foundation for projections while downscaling techniques now provide valuable additional detail. AOGCMs cannot provide information at scales finer than their computational grid (typically on the order of 200 km) and processes at the unresolved scales are important. Providing information at finer scales can be achieved through using high resolution dynamical models or empirical statistical downscaling. Downscaled climate change projections tailored to specific needs are only now starting to become available (IPCC 2007 Report, Section 11.1; Christensen et al., 2007).

The regional climate change projections are based on four potential sources: AOGCM simulations; downscaling of AOGCM-simulated data using technique to enhance regional detail; physical understanding of the processes governing regional responses; and recent historical climate change. The following general statements have been reported with respect to North America and/or the Arctic, and are relevant to the Minago region:

- The annual mean warming is very likely to exceed the global mean warming;
- Seasonally, warming is likely to be largest in winter and smallest in summer;
- Minimum winter temperatures are likely to increase more than the average;
- Annual mean precipitation is very likely to increase in Canada;
- The relative precipitation increase is very likely to be largest in winter and smallest in summer; and
- Maximum snow depth (snowfall) is likely to increase.

7.1.4.3.2 Projections for North America and Arctic Region

Climate projections are presented in the IPCC 2007 Report (Chapter 11; Christensen et al., 2007) for 30 sub-regions around the globe. The Minago project site (54^{O} 05'; 99^{O} 12') is within the "East Canada, Greenland and Iceland" (CGI) sub-region of North America.

Table 7.1-21 summarizes the regional average temperature projections from a set of 21 global models for the A1B emissions scenario. The A1B scenario represents a "middle-of-the-road" estimate of future emissions, with more extreme conditions characterized by scenarios B1 and A2. The ratio of global mean surface temperatures (projected changes for 2080 to 2099 based on 1980 to 1999 base case) are 0.69:1:1.17 for B1:A1B:A2 scenarios. Regional temperatures are shown to closely follow the global ratios.

The values shown in Table 7.1-21 represent the change between the mean values for the 2080 to 2099 simulated period as compared to the 1980 to 1999 base case (A1B Scenario). In effect, they represent the projected changes over a 100-year period ending in 2100. Table 7.1-22 presents similar information for changes in precipitation for the A1B Scenario.

For a more extreme case (A2), temperature changes can be estimated by factoring the A1B results by 1.17. Similarly, for reduced emissions, temperature changes for the B1 scenario can be estimated by factoring the A1B results by 0.69.

Table 7.1-21 Projected Regional Temperature Increase (^{O}C) for A1B Scenario

Period	Minimum	25th Percentile	Median (50th Percentile)	75th Percentile	Maximum
Winter (Dec-Feb)	3.3	5.2	5.9	7.2	8.5
Spring (Mar-May)	2.4	3.2	3.8	4.6	7.2
Summer (Jun-Aug)	1.5	2.1	2.8	3.7	5.6
Fall (Sep-Nov)	2.7	3.4	4.0	5.7	7.3
Annual	2.8	3.5	4.3	5.0	7.1

Source: Golder Associates, 2009 (Secondary source : IPCC 2007 Report, Section 11.1; Christensen et al., 2007).

Note: Projections for CGI sub-region of North America; projections represent difference in mean temperature of 2080 to 2099 period compared to 1980 to 1999 base case.

7.1.4.3.3 Projections for Minago

The changes in temperature and precipitation discussed above are applicable to the Minago site. The absolute projected temperatures and precipitation for Minago are summarized in Table 7.1-23.

Table 7.1-22 Projected Regional Precipitation Increase (%) for A1B Scenario

Period	Minimum	25th Percentile	Median (50th Percentile)	75th Percentile	Maximum
Winter (Dec-Feb)	6	15	26	32	42
Spring (Mar-May)	4	13	17	20	34
Summer (Jun-Aug)	0	8	11	12	19
Fall (Sep-Nov)	7	14	16	22	37
Annual	8	12	15	20	31

Source: Golder Associates, 2009 (Secondary source : IPCC 2007 Report, Section 11.1; Christensen et al., 2007).

Notes: Projections for CGI sub-region of North America; projections represent difference in annual precipitation of 2080 to 2099 period compared to 1980 to 1999 base case.

Table 7.1-23 Projected Mean Temperature and Precipitation at Minago for the 2088 to 2099 Period

Annual Temperature / Precipitation	Derived Mean for 1980 to 1999 Period[a]	Median Projected Change[b]	Projected Mean for 2080 to 2099 Period
Temperature	0.1 ^{O}C	4.3 ^{O}C	4.4 ^{O}C
Precipitation	504 mm	15%	580 mm

Notes: Source: Golder Associates, 2009

(a) refer to Section 7.1.3;

(b) IPCC 2007 regional projections for CGI sub-region of North America for A1B emissions scenario (Christensen et al., 2007).

7.1.5 Effects Assessment Methodology

For the climate effects assessment, the following five climate VECCs have been selected:

- air temperature;
- precipitation;
- snowpack depth and snow water equivalent;
- wind velocity and direction; and
- relative humidity.

The rationale for this selection and baseline data are summarized in Table 7.1-24.

Any project effects on climate will be at a micro-climatic scale. The effects that will occur have been characterized according to the effects attributes defined in Table 7.1-25.

Table 7.1-24 Selected Climate VECCs

Parameter	Rationale for Selection	Linkage to Regulatory Drivers	Baseline Data for Environmental Assessment
Air temperature	• Influences type of precipitation, evaporation and snowmelt rate. • Influences dispersion of air emissions.	• Identified in EBS Workplan	• Field data • Regional data
Precipitation (snowfall and rainfall: mean daily, monthly, and annual; peak and drought)	• Controlling input to site hydrology and water balance. • Required for water management facilities design. • Influences surface erosion. • Influences natural hazards (landslides, avalanches, floods).	• Identified in EBS Workplan	• Field data • Regional data
Snowpack depth and snow water equivalent	• Influences runoff. • Can influence operability of mine operations, growing season, wildlife migration, and avalanche risk.	• Identified in EBS Workplan	• Field data • Regional data
Wind velocity and wind direction	• Can influence evaporation and controls snow drifting. • Affects dispersion of dust and air emissions.	• Identified in EBS Workplan	• Field data • Regional data
Relative humidity	• Affects evaporation and site hydrology.	• Identified in EBS Workplan	• Field data

Table 7.1-25 Effect Attributes for Climate

Attribute	Definition
Direction	
Positive	Condition of VECC is improving.
Adverse	Condition of VECC is worsening or is not acceptable.
Neutral	Condition of VECC is not changing in comparison to baseline conditions and trends.
Magnitude	
Low	Effect occurs that might or might not be detectable but is within the range of natural variability and does not compromise ecological, economic or social/cultural values.
Moderate	Clearly an effect, but unlikely to pose a serious risk to the VECC or represent a management challenge from an ecological, economic or social/cultural standpoint.
High	Effect is likely to pose a serious risk to the VECC and represents a management challenge from an ecological, economic or social/cultural standpoint.
Geographic Extent	
Site-specific	Effect on VECC confined to a single small area within the Local Study Area.
Local	Effect on VECC within the Local Study Area.
Regional	Effect on VECC within the Regional Study Area.
Duration	
Short-term	Effect on VECC is limited to the <1 year.
Medium term	Effect on VECC occurs between 1 and 4 years.
Long term	Effect on VECC lasts longer than 4 years, but does not extend more than 10 years after decommissioning and final reclamation.
Far future	Effect on VECC extends >10 years after decommissioning and abandonment.
Frequency (Short-term duration effects that occur more than once)	
Low	Effect on VECC occurs infrequently (< 1 day per month).
Moderate	Effect on VECC occurs periodically (seasonal or several days per month).
High	Effect on VECC occurs frequently throughout the year (weekly).
Reversibility	
Reversible	Effect on VECC will cease to exist during or after the project is complete.
Irreversible	Effect on VECC will persist during and/or after the project is complete.
Likelihood of Occurrence	
Unknown	Effect on VECC is not well understood and based on potential risk to the VECC, effects will be monitored and adaptive management measures taken, as appropriate.
High	Effect on VECC is well understood and there is a high likelihood of effect on the VECC as predicted.

7.1.5.1 Project Effects

Effects of the project on climate will be limited to the effects of vegetation clearing and project-related structures on localized wind exposure, speed and direction; deposition of precipitation; solar radiation; snowmelt rate and snow water equivalent etc., and the effects of the project site and access road snow plowing and compaction of snowpack. These effects will commence early in the construction phase and continue with the same intensity to the end of decommissioning. At closure, effects associated with project site structures will cease; however, localized effects due to site clearing will persist until vegetation will have been re-established on reclaimed areas.

The project will have very little effect on air temperature, precipitation, wind direction and velocity, solar radiation and relative humidity, because the controlling forces on these parameters are regional to global in scale. Any effects would be neutral, low magnitude, site-specific, short-term and of moderate frequency (seasonal). Most effects are reversible, though some (e.g., associated with access road clearing and operation) are functionally irreversible. The likelihood of effects occurring as predicted is high.

The project will have localized effects on snowpack depth, snow water equivalent and snowmelt rate. Road plowing, compaction of snow by mine machinery, and the deposition of windblown dust will result in localized increases and decreases in snow accumulation and melt rate. These effects can be characterized as both positive and adverse in terms of linkages to other VECCs. Compacted snow will have a lower snowpack depth, but a higher snow water equivalent than uncompacted snow. Changes in snowmelt rate are discussed in Section 7.4: Surface Water Hydrology.

In summary, the effects of the project on snowpack depth, snow water equivalent and snowmelt rate will be positive to adverse, of low magnitude (while measurable on a site-specific scale, it will not affect average snowpack depth, snow water equivalent or melt rate in affected stream basins), site-specific, short-term, and of moderate frequency (seasonal). Most effects are reversible, though some (e.g., associated with access road operation) are functionally irreversible. The likelihood of effects occurring as predicted is high.

7.1.5.2 Residual Project Effects and Significance

As noted above, any effects of the project on climate parameters will be very localized and well within the range of natural variability for these occurrences. Based on the criteria defined in Table 7.1-25, predicted effects of the project on climate parameters are considered to be not significant.

7.1.5.3 Cumulative Effects

Residual project effects are very localized and there are no additional activities in the foreseeable future, which would contribute to cumulative effects on climate on a local or regional scale. Therefore, there will be no significant adverse cumulative or residual cumulative effects in the project area. The likelihood of occurrence of effects as predicted is high.

7.1.5.4 Mitigation Measures

There will be no significant effects of the project on climate parameters; therefore, no mitigation measures are proposed.

7.1.5.5 Monitoring and Follow-up

Data collection at the climate station will continue during the construction, operation, and decommissioning of the mine. The climate station will likely be moved to a suitable site, to obtain wind speeds and directions that are more generally representative of the project site. Possible new locations are at the mine portal and processing area, or at the TWRMF. The accuracy and quality of field climate data will improve as the period of record increases in duration.

A dedicated snow course monitoring program will be installed, with monthly or weekly measurement of snowpack depth and snow water equivalent, to improve site-specific data on winter precipitation and to refine site water balances. Follow-up and monitoring programs are summarized in Table 7.1-26.

Table 7.1-26 Monitoring Programs for Climate

Program	Program Objectives	General Methods	Reporting	Implementation
Follow-up and Monitoring Programs				
Climate station data collection	• Confirm the accuracy of the climate characterization. • Detect climatic trends and continue data baseline.	• Automated data collection with periodic downloads as required	• Internal • Data could be shared with Manitoba or other interested parties, if desired.	Proponent
Snow course installation	• Measure snowpack depth and snow water equivalent at project site. • Refine estimates of winter precipitation and snowpack contributions to site hydrology (Section 7.4).	• Manual data collection on monthly or periodic basis for snowpack depth and snow water equivalent	• Internal	Proponent

7.1.5.6 Summary of Effects

Effects of project and cumulative effects on climate are summarized in Table 7.1-27.

Table 7.1-27 Summary of Effects on Climate

Potential Effect	Level of Effect						Effect Rating	
	Direction	**Magnitude**	**Extent**	**Duration/ Frequency**	**Reversibility**	**Likelihood**	**Project Effect**	**Cumulative Effect**
Construction, Operations and Decommissioning								
Localized increases in snowpack depth, water content and melt rate	Positive to adverse	Low	Site-specific	Short term, seasonal	Reversible to irreversible (ongoing access road use)	High	Not significant	Not significant
Localized changes in wind speed and direction, precipitation deposition, and solar radiation due to site clearing and project structures	Neutral	Low	Site-specific	Short term, seasonal	Reversible to irreversible (ongoing access road use)	High	Not significant	Not significant
Closure								
Ongoing localized effects of clearing and snow plowing on wind, solar radiation and snowpack	Positive to adverse	Moderate	Site-specific	Short term, seasonal	Irreversible	High	Not significant	Not significant

7.2 Air Quality and Noise

7.2.1 Scope of Assessment

Air quality and noise were not formally assessed at the Minago Project as part of the conducted environmental baseline studies. The air quality at the site is excellent as over 98% of the site is vegetated and the site is located far away from any kind of settlement or development. The closest settlements are the very small settlement of Ponton, MB, approximately 68 km to the north of the Minago Project, and Grand Rapids with approximately 1,000 residents (town and Grand Rapids First Nations), approximately 100 km south of the project. The closest city is the City of Thompson, a regional trade and service centre of Northern Manitoba. Thompson is approximately 225 km northeast of the Minago Project and has 13,500 residents. Besides equipment that was working during the exploration phase at Minago, the noise at the Minago Project is limited to the sounds of wilderness and road traffic in the vicinity of Highway 6.

To obtain air quality results for undeveloped land in northern Manitoba, Manitoba Conservation records were obtained. Currently, Manitoba Conservation compiles air quality records, but only for larger cities and/or cities with or near mine developments. Thus, provincial air quality results are not available for undeveloped land in northern Manitoba.

Manitoba Conservation posts records for air quality stations in Winnipeg, Brandon, Thompson, and Flin Flon in Manitoba and Creighton in Saskatechwan. Creighton is located approximately 4 km from Flin Flon. Winnipeg and Brandon are the two largest cities in Manitoba and are over 485 km away from the Minago Project. Thompson is home to Vale Inco's Manitoba Operations, which include two underground operations, the Thompson Mine and the Birchtree Mine, and the Thompson Open Pit. In addition, Thompson hosts Vale Inco's 15,000-ton per day capacity mill; a smelter, which produces 1,400 anodes per day; and a refinery, which produces more than 130 million pounds of 99.9% pure electrolytic nickel annually (Vale Inco, 2009). Flin Flon has Hudson Bay Mining and Smelting Company as major employer. Hudson Bay Mining and Smelting Company operates two mines, one concentrator, a zinc plant and a copper smelter in Flin Flon and vicinity (Hudson Bay, 2009).

7.2.2 Baseline Conditions

Mean annual ambient air quality results, compiled by Manitoba Conservation, are presented in Table 7.2-1. Listed annual mean air quality did not exceed guideline limits given in Table 7.2-1 and Appendix 7.2, except for ozone.

Table 7.2-2 lists mean annual and maximum 1-hour and 24-hour measurements of Particular Matter (PM). The maximum acceptable limits for PM_{10} (< 10 μm) and $PM_{2.5}$ (< 2.5 μm) were exceeded for several years and at several of the air quality monitoring locations listed in Table 7.2-2.

Tables 7.2-3 lists maximum 1-hour and 24-hour measurements for suphur dioxide and Manitoba guideline limits. Maximum acceptable and tolerable levels sulphur dioxide levels were exceeded in several years and at several air quality monitoring locations in the 2000 to 2007 period.

Table 7.2-1 Manitoba Mean Annual Air Quality

Manitoba Ambient Air Quality Data
Continuous Monitoring

POLLUTANT Conc. Units	STATION NUMBER & LOCATION	2000 ANNUAL MEAN	2001 ANNUAL MEAN	2002 ANNUAL MEAN	2003 ANNUAL MEAN	2004 ANNUAL MEAN	2005 ANNUAL MEAN	2006 ANNUAL MEAN	2007 ANNUAL MEAN	MANITOBA AMBIENT AIR QUALITY (JULY 2005) Maximum Desirable Level Concentration µg/m³ (ppm/ppb)	Maximum Acceptable Level Concentration µg/m³ (ppm/ppb)
CARBON (CO) ppm	9118 WINNIPEG, SCOTIA & JEFFERSON	0.48	0.46	0.37	0.29	0.24	0.21	0.22	0.3		
	9119 WINNIPEG, 65 ELLEN STREET	0.57	0.67	0.54	0.52	0.36	0.31	0.37	0.46		
NITROGEN DIOXIDE (NO2) pphm	5131 BRANDON, ASSIN. COMMUN. COLLEGE	0.69	0.52	0.58	0.61	0.54	0.53	0.5	0.56	60(0.032 ppm)	100(0.053 ppm)
	9118 WINNIPEG, SCOTIA & JEFFERSON	1.24	1.22	0.99	0.97	0.86	0.8	0.74	0.81		
	9119 WINNIPEG, 65 ELLEN STREET	1.66	1.43	1.43	1.4	1.33	1.25	1.27	1.27		
NITRIC OXIDE (NO) pphm	5131 BRANDON, ASSIN. COMMUN. COLLEGE	0.38	0.49	0.32	0.35	0.41	0.36	0.25	0.71		
	9118 WINNIPEG, SCOTIA & JEFFERSON	0.62	0.77	0.49	0.44	0.45	0.46	0.32	0.34		
	9119 WINNIPEG, 65 ELLEN STREET	1.1	1.1	0.93	0.89	0.93	0.85	0.73	0.74		
NITROGEN OXIDES (NOX) pphm	5131 BRANDON, ASSIN. COMMUN. COLLEGE	0.96	0.98	0.91	0.96	0.94	0.88	0.74	1.26		
	9118 WINNIPEG, SCOTIA & JEFFERSON	1.69	1.83	1.47	1.39	1.28	1.24	1.07	1.14		
	9119 WINNIPEG, 65 ELLEN STREET	2.55	2.48	2.33	2.32	2.26	2.1	2	2.01		
SULPHUR DIOXIDE (SO2) ppm	7251 FLIN FLON, 143 MAIN STREET	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	30(0.01 ppm)	60(0.02 ppm)
	7271[?] FLIN FLON, AQUA CENTRE	0	0	0	0	0	0	0	0		
	7281[?] FLIN FLON, HBM&S STAFFHOUSE	0.01	0	0.01	0.01	0	0.01	0.01	0.01		
	7291[?] CREIGHTON, SASK. CITY HALL	0	0	0	0	0.01	0	0	0		
	7301[?] FLIN FLON, HAPNOT COLLEGIATE	0	0	0	0	0	0	0	0		
	7351[?] THOMPSON, WATER TREATMENT PLANT	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		
	7361[?] THOMPSON, EASTWOOD SCHOOL		**0**	**0**	**0**	**0**	**0**	**0**	**0**		
	7371[?] THOMPSON, RIVERSIDE SCHOOL		**0**	**0**	**0**	**0**	**0**	**0**	**0**		
	7381[?] THOMPSON, WESTWOOD							**0**	**0**		
	9119[?] WINNIPEG, 65 ELLEN STREET								0.00041		
OXIDANTS OZONE (O3) pphm	5131 BRANDON, ASSIN. COMMUN. COLLEGE	2.58	2.64	2.7	2.77	2.22	2.19	2.7	2.5		30(15 ppb)
	9118 WINNIPEG, SCOTIA & JEFFERSON	2.05	1.94	1.94	2.29	1.99	2.03	2.3	2.3		
	9119 WINNIPEG, 65 ELLEN STREET	1.35	1.61	2	2.05	1.74	1.82	2.2	2.1		
(NH3) ppm	5131 BRANDON, ASSIN. COMMUN. COLLEGE	0.01	0.02	0.01	0.01	0	0.02	0.02	0		

Notes:
[?] denotes company supplied data
ppm parts per million
pphm parts per hundred million
ppb parts per billion

Source: Manitoba Conservation, 2007f

Table 7.2-2 Manitoba Conservation Mean Annual Particulates

Annual Mean Particulate Matter Monitoring (PM_{10})

POLLUTANT	STATION NUMBER & LOCATION	2000 ANNUAL ARITH/GEO MEAN	2001 ANNUAL ARITH/GEO MEAN	2002 ANNUAL ARITH/GEO MEAN	2003 ANNUAL ARITH/GEO MEAN	2004 ANNUAL ARITH/GEO MEAN	2005 ANNUAL ARITH/GEO MEAN	2006 ANNUAL ARITH/GEO MEAN	2007 ANNUAL ARITH/GEO MEAN
INHALABLE PARTICULATE (PM_{10})	7251 FLIN FLON, 143 MAIN STREET	24.2 / -	22.5 / -	22.6 / -	20.2/ -	16.3/ -	17.57/10.76	16.3/10.2	17.52/11.51
	7283 FLIN FLON, CREIGHTON SCHOOL A				16.9/14.6				
	7283 FLIN FLON, CREIGHTON SCHOOL B				17.1/14.5				
	7283 FLIN FLON, CREIGHTON SCHOOL			21 / 14		20.0/17.0	17.09/13.00	20.81/16.20	20.80/18.04
	7284 FLIN FLON, RUTH BETTS	12.4 / 10.3	14.8 / 12.3	13/11	12.9/11.4	12.0/9.7	10.53/8.69	12.01/9.22	10.24/8.48
	7285 FLIN FLON, SEWAGE PLANT	12.2 / 10.0	10.3 / 9.0	10/09					
	7381 THOMPSON, WESTWOOD					**8.5/ -**	**9.79/6.42**	**10.6/6.9**	**10.39/6.88**
	9119 WINNIPEG, 65 ELLEN STREET	18.7 / -	19.0 / -	21.4 / -	22.3/ -	17.3/ -	18.16/12.65	18.2/12.8	13.05/9.26
	9119 WINNIPEG, 65 ELLEN STREET	20.2 / 16.6	18.9 / 16.2	18.3 / 15.5	19.8/15.9	15.9/13.4	14.15/11.42	17.24/14.76	14.89/11.73
	5131 BRANDON, ASSIN. COMMUN. COLLEGE	19.8 / -	22.3 / -	21.9 / -	23.3/ -	20.9/ -	19.67/11.31	22.26/12.01	23.41/12.92

Notes:

All Concentration units for the above Table are in ug/m^3.
- No data available

Annual Mean Particulate Matter Monitoring ($PM_{2.5}$)

POLLUTANT	STATION NUMBER & LOCATION	2000 ANNUAL ARITH/GEO MEAN	2001 ANNUAL ARITH/GEO MEAN	2002 ANNUAL ARITH/GEO MEAN	2003 ANNUAL ARITH/GEO MEAN	2004 ANNUAL ARITH/GEO MEAN	2005 ANNUAL ARITH/GEO MEAN	2006 ANNUAL ARITH/GEO MEAN	2007 ANNUAL ARITH/GEO MEAN
INHALABLE PARTICULATE ($PM_{2.5}$)	9118[4] WINNIPEG, SCOTIA & JEFFERSON	5.7 / -	5.8 / -	5.7/-	5.6/ -	4.5/ -	4.60/3.03	4.97/3.26	4.90/3.21
	9119[1] WINNIPEG, 65 ELLEN STREET	6.2 / 5.2	6.2 / 5.5	6.5/5.8	8.6/7.2	8.0/6.5	6.13/5.28	7.24/6.25	6.63/5.52
	9119[4] WINNIPEG, 65 ELLEN STREET	4.2 / -	5.5 / -	6.2/-	5.3/ -	4.2/ -	4.48/2.84	4.66/3.00	4.44/2.95
	5131[4] BRANDON, ASSIN. COMMUN.		5.8 / -	5.2/-	6.0/ -	5.0/ -	4.70/2.82	5.52/3.13	4.78/3.04
	7251[4] FLIN FLON, 143 MAIN STREET					4.2/ -	4.21/2.17	5.01/2.39	5.60/2.97
	7381[4] THOMPSON, WESTWOOD					**3.7/ -**	**3.25/1.76**	**3.50/1.76**	**3.43/1.74**
	7283[4?] CREIGHTON SK, HIGH SCHOOL								11.18/9.21

Notes:

All Concentration units for the above Table are in ug/m^3.
1 - 24 Hour sample collected every six days according to NAPS schedule
4 - real-time continuous monitoring
- no data available

Source: Manitoba Conservation, 2007f

Table 7.2-2 (Cont.'d) Manitoba Ambient Air Quality – Maximum Particulate Matter

Maximum 24-hour/1-hour Particulate Matter Monitoring (PM_{10})

POLLUTANT	STATION NUMBER & LOCATION	2000 MAXIMUM VALUES 24/1-HR	2001 MAXIMUM DATA VALUES 24/1-HR	2002 MAXIMUM VALUES 24/1-HR	2003 MAXIMUM VALUES 24/1-HR	2004 MAXIMUM DATA VALUES 24/1-HR	2005 MAXIMUM VALUES 24/1-HR	2006 MAXIMUM VALUES 24/1-HR	2007 MAXIMUM VALUES 24/1-HR	MANITOBA AMBIENT AIR QUALITY (JULY 2005) Measurement Period	MANITOBA AMBIENT AIR QUALITY (JULY 2005) Maximum Acceptable Level Concentration
INHALABLE PARTICULATE (PM_{10})	7251 FLIN FLON, 143 MAIN STREET	123.7 / 440.7	197.6 / 500.0	145.2/1359.0	100.1/578.0	66.7/245.1	0	72.8/301.8	87.13/318.00		
	7283 FLIN FLON, CREIGHTON SCHOOL A				42.6/ -						
	7283 FLIN FLON, CREIGHTON SCHOOL B				58.7/ -						
	7283 FLIN FLON, CREIGHTON SCHOOL			93 / -		103.8/ -	97.08/ -	152.08/-	64.71/-		
	7284 FLIN FLON, RUTH BETTS	36.0 / -	66.0 / -	43 / -	28.0/ -	35.2/ -	28.86/ -	56.62/-	24.84/-	24-hour average	50
	7285 FLIN FLON, SEWAGE PLANT	42.1 / -	28.4 / -	38 / -							
	7381 THOMPSON, WESTWOOD					**32.1/159.5**	**45.85/373.60**	**74.2/372.6**	**53.24/401.00**		
	9119 WINNIPEG, 65 ELLEN STREET	62 / 233	93.9 / 398.4	166.7/501.0	88.7/262.9	104.4/248.6	93.65/433.80	72.0/273.9	154.30/61.90		
	9119 WINNIPEG, 65 ELLEN STREET	44.7 / -	49.7 / -	62.6 / -	45.7/ -	45.7/ -	47.19/ -	47.81/-	39.41/-		
	5131 BRANDON, ASSIN. COMMUN. COLLEGE	143.0 / 498.0	131.4 / 451.5	215.5/499.3	154.3/819.5	156.6/496.9	0	317.1/3975.2	0		

Notes:

All Concentration units for the above Table are in ug/m^3.

-- No guideline or objective

- No data available

Maximum 24-hour/1-hour Particulate Matter Monitoring ($PM_{2.5}$)

POLLUTANT	STATION NUMBER & LOCATION	2000 MAXIMUM VALUES 24/1-HR	2001 MAXIMUM DATA VALUES 24/1-HR	2002 MAXIMUM VALUES 24/1-HR	2003 MAXIMUM VALUES 24/1-HR	2004 MAXIMUM DATA VALUES 24/1-HR	2005 MAXIMUM VALUES 24/1-HR	2006 MAXIMUM VALUES 24/1-HR	2007 MAXIMUM VALUES 24/1-HR	MANITOBA AMBIENT AIR QUALITY (JULY 2005) Measurement Period	MANITOBA AMBIENT AIR QUALITY (JULY 2005) Maximum Acceptable Level Concentration
INHALABLE PARTICULATE ($PM_{2.5}$)	9118[4] WINNIPEG, SCOTIA & JEFFERSON	18.2 / 46.3	22.0 / 70.1	33.6/101.2	21.5/44.3	18.1/67.8	22.0/52.90	17.7/58.5	16.03/69.03		
	9119[1] WINNIPEG, 65 ELLEN STREET	18.3 / -	16.8 / -	18.7/-	25.2/ -	26.5/ -	22.86/ -	22.73/-	33.91/-		
	9119[4] WINNIPEG, 65 ELLEN STREET	9.1 / 32.6	19.5 / 70.1	36.2/88.7	23.2/43.6	19.6/86.9	37.76/390.90	22.0/55.1	12.81/59.00	24-hour average	30
	5131[4] BRANDON, ASSIN. COMMUN.		17.9 / 165.2	25.6/166.1	22.8/144.3	22.9/109.3	21.60/120.20	34.7/307.4	18.55/74.90		
	7251[4] FLIN FLON, 143 MAIN STREET					15.5/82.2	26.14/132.70	44.2/113.3	33.00/136.50		
	7381[4] THOMPSON, WESTWOOD					**15.7/63.5**	**18.28/53.50**	**32.9/139.9**	**45.04/155.00**		
	7283[4?] CREIGHTON SK, HIGH SCHOOL								40.74/-		

Notes:

All Concentration units for the above Table are in ug/m^3.

1 - 24 Hour sample collected every six days according to NAPS schedule

4 - real-time continuous monitoring

- no data available

Source: Manitoba Conservation, 2007f

Table 7.2-3 Manitoba Conservation Maximum 1-Hour and 24-Hour Sulphide Dioxide Measurements

POLLUTANT Conc. Units	STATION NUMBER & LOCATION	2000 MAXIMUM DATA VALUES 1-HR	2000 24-HR	2001 MAXIMUM DATA VALUES 1-HR	2001 24-HR	2002 MAXIMUM DATA VALUES 1-HR	2002 24-HR	2003 MAXIMUM DATA VALUES 1-HR	2003 24-HR	2004 MAXIMUM DATA VALUES 1-HR	2004 24-HR	2005 MAXIMUM DATA VALUES 1-HR	2005 24-HR	2006 MAXIMUM DATA VALUES 1-HR	2006 24-HR	2007 MAXIMUM DATA VALUES 1-HR	2007 24-HR
SULPHUR	**7251 FLIN FLON, 143 MAIN STREET**	1.45	0.29	0.52	0.19	0.99	0.17	0.81	0.13	0.65	0.15°	1.16	0.11°	0.5	0.12°	0.98	0.15°
DIOXIDE (SO2)	**7271[?] FLIN FLON, AQUA CENTRE**	0.12	0.02	0.54	0.06	0.44	0.05	0.67	0.09	0.39	0.11°	0.8	0.07°	0.67	0.09°	1.02	0.22°
ppm	**7281[?] FLIN FLON, HBM&S STAFFHOUSE**	0.97	0.23	0.47	0.09	0.74	0.1	0.77	0.08	0.39	0.08°	0.84	0.17°	0.48	0.09°	1.02	0.11°
	7291[?] CREIGHTON, SASK. CITY HALL	0.63	0.11	0.55	0.11	0.63	0.11	0.64	0.14	0.68	0.11°	0.66	0.15°	0.58	0.07°	0.93	0.16°
	7301[?] FLIN FLON, HAPNOT COLLEGIATE	0.68	0.12	0.33	0.03	0.38	0.03	0.59	0.04	0.32	0.03°	0.45	0.04°	0.38	0.05°	0.76	0.09°
	7351[?] THOMPSON, WATER TREATMENT	**1.02**	**0.12**	**0.32**	**0.04**	**0.19**	**0.04**	**0.78**	**0.07**	**0.34**	**0.08°**	**0.45**	**0.08°**	**0.87**	**0.09°**	**0.68**	**0.09°**
	7361[?] THOMPSON, EASTWOOD SCHOOL			**0.62**	**0.06**	**0.35**	**0.07**	**0.41**	**0.15**	**0.61**	**0.09°**	**0.77**	**0.08°**	**0.54**	**0.06°**	**0.53**	**0.04°**
	7371[?] THOMPSON, RIVERSIDE SCHOOL			**0.45**	**0.06**	**0.54**	**0.09**	**0.89**	**0.21**	**0.59**	**0.15°**	**0.35**	**0.06°**	**0.54**	**0.08°**	**0.46**	**0.06°**
	7381[?] THOMPSON, WESTWOOD													**0.54**	**0.05°**	**0.37**	**0.03°**
	9119 WINNIPEG, 65 ELLEN STREET															0.0378	0.00395

Notes:

All Concentration units for the above Table are in ug/m^3.

? denotes company supplied data

° Using 24-hour moving average

MANITOBA AMBIENT AIR QUALITY (JULY 2005)			
Measurement Period	**Maximum Desirable Level Concentration** ug/m^3 (ppm)	**Maximum Acceptable Level Concentration** ug/m^3 (ppm)	**Maximum Tolerable Level Concentration** ug/m^3 (ppm)
1-hour average	450(0.17)	900(0.34)	
24-hour average	150(0.06)	300(0.11)	800(0.31)

Source: Manitoba Conservation, 2007f

Recent 2008 and 2009 24-hour measurements of particulate matter at the Riverside station in Thompson, MB are given and illustrated in Appendix 7.2. None of those measurements exceeded guideline limits.

The proposed mine development at Minago is smaller than the current residential and mining related development at Thompson, and therefore air quality measured there is expected to be lower than is expected for the Minago Project.

7.2.3 Effects Assessment Methodology

The assessment of project effects on ambient air quality focused on the following Criteria Air Contaminants and Greenhouse Gases, which reflect the project emissions of concern with respect to human and environmental health.

Criteria Air Contaminants (CAC):

- particulate matter, including total suspended particulate (TSP); inhalable particulate matter (PM_{10}) and respirable particulate matter ($PM_{2.5}$) and sulphur dioxide (SO_2);
- nitrogen dioxide (NO_2);
- volatile organic carbon (VOC);
- carbon monoxide (CO);
- Greenhouse Gases:
    - carbon dioxide (CO_2);
    - methane (CH_4);
    - nitrous oxide (N_2O).

A description of these project related air contaminants and the Ambient Air Quality Objectives used to assess potential effects are provided in the following sections. Selected parameters are given in Table 7.2-4.

Temporal Boundaries

The temporal boundaries for the assessment encompass the period for regional air quality data that were used to characterize the baseline air quality as well as all phases of the project when emissions may potentially affect ambient air quality. These phases include construction (Year 2011 – 2013), operation (Year 2014 – 2021), and decommissioning (12 months after end of production). At closure, there will be no further project effects on ambient air quality.

7.2.3.1 Air Quality Parameters

Total Suspended, Inhalable and Respirable Particulate Matter (TSP, PM_{10} and $PM_{2.5}$)

Particulate matter is classified by the size of the particle. Particle size determines the velocity with which gravitational settling occurs, and the ease with which they penetrate the human respiratory tract. Generally, large particles settle out very close to the source, and very fine particles penetrate deep into the respiratory tract. Total suspended particulate matter encompasses all size ranges from approximately 100 micrometers (μm) to the sub micrometer range.

Table 7.2-4 Air Quality Parameters Analyzed, Selection Rationale and Data Sources

Parameter	Rationale for Selection	Linkage to Regulatory Drivers	Baseline Data for EAP
Particulate Matter, Inhalable Particulate Matter, Respirable Particulate Matter, SO_2, CH_4, N_2O	• Indicators of potential project effects from diesel generators and fugitive dust emissions • Parameters of concern with respect to human and environmental health	• Environmental Baseline Study Work Plan • Criteria Air Contaminants under National Ambient Air Quality Objectives	• Project-specific data for emission rates • Regional data for ambient air quality • Qualitative assessments and/or quantitative data
Greenhouse Gases including CO_2, CH_4, and N_2O	• Project will emit greenhouse gases • Contribution to national emissions and potential effects on climate change	• Environmental Baseline Study Work Plan • Kyoto Protocol	• Project specific data for emission rates

Inhalable (PM_{10}) and respirable ($PM_{2.5}$) particulate matter are comprised of very small particles that are less than 10 μm and 2.5 μm, respectively. Particles smaller than 10 μm can make their way deep into the respiratory tract and become lodged there. Over the past few years, greater concern with regard to these fine particles has led to research resulting in new sampling methods and criteria. In June 2000, the Canadian Council of Ministers of the Environment (CCME) adopted in principle Canada-Wide Standard (CWS) for particulate matter. Achievement of the CWS for $PM_{2.5}$ has been proposed for 2010. For it to be enforceable, it must be adopted by the Provincial or Territorial regulatory agencies. The CWS provides for a proposed $PM_{2.5}$ standard of 30 $\mu g/m^3$ (micrograms per cubic metre) for the fine (<2.5 μm) particulate fraction as a 24-hour measurement. Achievement is to be based on the 98th percentile of the ambient measurement annually, averaged over three consecutive years. Victory Nickel will exercise reasonable efforts to meet the $PM_{2.5}$ CWS.

Project-related sources of particulate matter (PM) include internal combustion and fired equipment such as the back up diesel generators and heaters when they are fired. The burning of land clearing debris would also generate PM. Fugitive and process dust is also considered PM. Combustion-related PM is generally in the respirable range (<2.5 μm), while fugitive and process dust are generally above the inhalable range (>10 μm).

Sulphur Dioxide (SO_2)

Sulphur dioxide (SO_2) is a colourless gas with a distinctive pungent sulphur odour. It is produced in combustion processes by the oxidation of sulphur in fuel. At high concentrations, SO_2 can have negative effects on leaf tissue, especially in sensitive species. At very high concentrations, there may be effects on human and animal health, particularly with respect to the respiratory system. The SO_2 can also be further oxidized and may combine with water to form the sulphidic acid component of "acid rain." Anthropogenic emissions comprise approximately 95% of global atmospheric SO_2. The largest anthropogenic contributor to atmospheric SO_2 is the industrial and utility use of heavy oils and coal. Oxidation of reduced sulphur compounds emitted by ocean surfaces account for nearly all biogenic emissions. Volcanic activity accounts for much of the remainder. Motor vehicles are relatively small contributors to the SO_2 content of the atmosphere (Wayne, 1991).

The mass of sulphur dioxide emissions related to the project are expected to be very low. These emissions are largely confined to construction equipment and back up diesel generators, when they are fired. They will be released through combustion processes of fuels that contain sulphur (gasoline, diesel oil, and waste oil). Propane contains negligible amounts of sulphur. The diesel oil and gasoline utilized on site will be low-sulphur (<15 ppm). Waste oil will contain generally low amounts of sulphur.

Oxides of Nitrogen (NO, NO_2)

Nitrogen oxides are produced in most combustion processes, and are almost entirely made up of nitric oxide (NO) and nitrogen dioxide (NO_2). Together, they are often referred to as NO_x. The NO_2 is an orange to reddish gas that is corrosive and irritating. Most NO_2 in the atmosphere is formed by the oxidation of NO, which is emitted directly by combustion processes, particularly those at high temperature and pressure, such as internal combustion engines. Nitric oxide is a colourless gas with no apparent direct effects on animal health or vegetation at typical ambient levels. The concentration of NO_2 is the regulated form of NO_x.

The levels of NO and NO_2, and the ratio of the two gases, together with the presence of hydrocarbons and sunlight are the most important factors in the formation of ground-level ozone and other oxidants. Further oxidation and combination with water in the atmosphere forms nitric acid, another part of "acid rain". Anthropogenic emissions comprise approximately 93% of global atmospheric emissions of NO_x (NO + NO_2). The largest anthropogenic contributor to atmospheric NO_x is combustion of fuels such as natural gas, oil and coal. Forest fires, lightning and anaerobic processes in soil account for nearly all biogenic emissions (Wayne, 1991). NO_x will be released by all internal and external combustion equipment on site, but in relatively small quantities. External combustion processes, such as fired equipment and land clearing burning are also potential sources of NO_x.

Carbon Monoxide (CO)

Carbon monoxide is a colourless and odourless gas. It is a product of incomplete combustion of hydrocarbons such as fossil fuels and wood. Motor vehicles, industrial processes and natural sources (fires) are some common sources. Typical concentrations in the atmosphere are 120 $\mu g/m^3$, while minimum levels known to produce cardiovascular symptoms in smokers is approximately 35,000 $\mu g/m^3$. CO will be released by all internal and external combustion equipment on site, but in relatively small quantities.

Volatile Organic Carbon (VOC)

Volatile Organic Compounds (VOCs) are carbon-containing (organic) compounds that readily evaporate into the air under ambient conditions. Many VOCs are of natural origin including methane. For example, VOCs are largely responsible for the pleasant odour perceived in a forest. Others may be potentially harmful to the environment, either directly through inhalation or indirectly as a contributor to ground level ozone and smog formation. Examples of VOC sources include: hydrocarbon fuels, paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids, graphics and craft materials including glues and adhesives, permanent markers, and photographic solutions. While VOCs are naturally present in the atmosphere and emitted by automobiles and industrial processes, the concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors. Some VOCs may have short- and long-term adverse health effects.

VOC emissions during construction will be largely generated from heavy equipment operation at the site. During the operations phase, VOC emissions will be generated largely by internal combustion engines (mobile and stationary) and heaters. Emissions of VOC at the project site will be relatively small.

Greenhouse Gases (GHG)

Greenhouse gases are emitted as a consequence of all internal and external combustion equipment on site, plus land clearing burning. Greenhouse gasses generally include all emissions of carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). The sum of all greenhouse gasses is generally expressed as a carbon dioxide equivalent (CO_2e). For the project, emissions of CH_4 are virtually absent as natural gas is not available as a fuel (natural gas is mostly methane). Diesel fuel and propane make up nearly all of the fuel used in the Local Study Area (LSA). Nitrous oxide is emitted as a byproduct of high-temperature combustion. These emissions are insubstantial. As such, in this assessment, it was assumed that GHGs are fully represented by emissions of CO_2 (e.g., $CO_2e = CO_2$). However, NO_x emission data is also included for all phases of the project.

There are currently no binding federal or provincial requirements or restrictions on the emission of greenhouse gases. However, aggressive targets for the reduction have been agreed to at the federal level with the ratification of the Kyoto Protocol. The quantities of GHG emissions resulting from the project will be estimated and considered in a larger context, consistent with the guidance provided by the Canadian Environmental Assessment Agency (CEAA, 2003).

7.2.3.2 Federal Ambient Air Quality Criteria

The Canadian (Federal) Ambient Air Quality Objectives are shown in Table 7.2-5. The objectives are denoted as Desirable, Acceptable and Tolerable as follows:

- The Maximum Desirable Level is the long-term goal for air quality and provides a basis for anti-degradation policy for unpolluted parts of the country, and for the continuing development of control technology.
- The Maximum Acceptable Level is intended to provide adequate protection against effects on soil, water, vegetation, materials, animals, visibility, personal comfort and well-being.
- The Maximum Tolerable Level denotes time-based concentrations of air contaminants beyond which, due to a diminishing margin of safety, appropriate action is required to protect the health of the general population.

Qualitative Assessment of Effects

In instances where emission rates of Criterial Air Contaminants (CACs) are very low, professional judgement can be used to assess potential effects without application of quantitative tools such as atmospheric dispersion modeling. In this instance, emissions have been estimated and expressed in terms, which allow comparison to other common sources. Baseline conditions have also been defined. As such, potential effects of the Minago Project have been assessed based on predicted and measured effects for like-sized sources in a similar context. In keeping with the Environmental Assessment guidelines, project effects were characterized according to effects attributes, detailed in Table 7.2-6.

7.2.3.3 Determination of Effects Significance

Air Quality

The significance of any adverse residual project and cumulative effects on ambient air quality will be determined based on the defined effects attributes, as follows. A residual effect will be considered significant, if it is a high magnitude effect of any geographic extent or duration. Otherwise, effects will be rated as not significant. A high magnitude effect on air quality is one

Table 7.2-5 Federal Ambient Air Quality Objectives

Pollutant and Units (alternative units in brackets)	Averaging Time Period	Canada-Wide Standards (CWS)			
		Target to be attained by 2010	Ambient Air Quality Objectives		
			Maximum Desirable	Maximum Acceptable	Maximum Tolerable
Nitrogen dioxide (NO_2) µg/m^3 (ppb)	1 hour	-	-	400 (213)	1000 (532)
	24 hour	-	-	200 (106)	300 (160)
	Annual	-	60 (32)	100 (53)	-
Sulphur dioxide (SO_2) µg/m^3 (ppb)	1 hour	-	450 (172)	874 (334)	-
	24 hour	-	150 (57)	300 (115)	800 (306)
	Annual	-	30 (11)	60 (23)	-
Total suspended particulate matter (TSP) µg/m^3	24 hour	-	-	120	400
	Annual	-	60	70	-
PM_{10} µg/m^3	24 hour	-	-	50 [1]	-
$PM_{2.5}$ µg/m^3	24 hour	30	-	-	-
Carbon monoxide (CO) mg/m^3 (ppm)	1 hour	-	15 (13)	35 (31)	-
	8 hour	-	6 (5)	15 (13)	20 (17)
Ozone (O_3) µg/m^3 (ppb)	1 hour	-	100 (51)	160 (82)	300 (153)
	8 hour	128 (65)	-	-	-
	24 hour	-	30 (15)	50 (25)	-
	Annual	-	-	30 (15)	-

Sources:

Health Canada <http://www.hc-sc.gc.ca/ewh-semt/air/out-ext/reg-eng.php#a3> (March 10, 2010)

[1] Manitoba Conservation. Objectives and Guidelines for various Air Pollutants: Ambient Air Quality Criteria (updated: July 2005).

Table 7.2-6 Effect Attributes for Air Quality

Attribute	Definition
	Direction
Positive	Condition of VECC is improving.
Adverse	Condition of VECC is worsening or is not acceptable.
Neutral	Condition of VECC is not changing in comparison to baseline conditions and trends.
	Magnitude
Low	Within normal variability of baseline conditions.
Moderate	Increase/decrease with regard to baseline, but within limits and objectives.
High	Singly or as a substantial contribution in combination with other sources causing exceedances or impingement upon limits and objectives.
	Geographic Extent
Site-specific	Effect on VECC confined to a single small area within the Local Study Area (LSA).
Local	Effect on VECC within Local Study Area (LSA).
Regional	Effect on VECC extends beyond the LSA. Assessment of the project effects on climate change are characterized in the context of contributions to Manitoba emissions and national emissions only.
	Duration
Short-term	< 1 month
Medium-term	< 1-24 months
Long-term	> 24 months
Far future	Effect on VECC extends >10 years after decommissioning and abandonment.
	Frequency (Short-term duration effects that occur more than once)
Low	Frequency is within range of annual variability and does not pose a serious risk to the VECC or its economic or social/cultural values.
Moderate	Frequency exceeds range of annual variability, but is unlikely to pose a serious risk to the VECC or its economic or social/cultural values.
High	Frequency exceeds range of annual variability and is likely to pose a serious risk to the VECC or its economic or social/cultural values.
	Reversibility
Reversible	Effect on VECC will cease to exist during or after the project is complete.
Irreversible	Effect on VECC will persist during and/or after the project is complete.
	Likelihood of Occurrence
Unknown	Effect on VECC is not well understood and based on potential risk to the VECC, effects will be monitored and adaptive management measures taken, as appropriate.
High	Effect on VECC is well understood and there is a high likelihood of effect on the VECC as predicted.

that results in a change in ambient air quality such that the maximum ground-level concentration of any identified substances of concern (CAC) results in an exceedance of the respective ambient air quality objective as defined by the Maximum Desirable Level.

Climate Change

The science of climate change has not been advanced to the point where a clear cause-and-effect relationship can be established between specific or even provincial/territorial and national emissions and subtle changes in global climate. Climate change is a global issue. The incremental increases in global emissions of greenhouse gases from anthropogenic sources are thought to be a substantial contributor to climate change. It is not possible to conclude with certainty that any given source of GHGs has a measurable cause-and-effect relationship on climate. As such, the incremental contribution of the project to national or global GHG emissions cannot be linked to specific changes in global climate. The estimated GHG emissions from the project are described in context with the total emissions from Manitoba and Canada. Estimates of the total GHG emissions have been obtained from federal regulatory agencies. In the absence of a measurable cause-and-effect relationship between GHG emission levels and climate change, no determination of significance has been made.

7.2.4 Project Effects

Emissions to air from the proposed Minago Project will consist of vehicle and equipment exhaust emissions, fugitive dusts and blasting residues, fugitive dust from ore processing and road dust from vehicle traffic. Although other mines in Manitoba have had dust problems associated with their Tailings Management Facilities (TMFs), no dust will be generated from the Minago TWRMF, where the tailings will be kept wet at all times. A vegetation cover will also be established on the tailings dams where applicable.

Noise emissions from the mine and mill facility will primarily be related to equipment operation, ore and waste rock handling and processing. Noise sources will be detectable to humans while on the mine site but are not expected to be noticeable offsite. Noise emissions from all of these sources will be managed in accordance with the Workplace Health and Safety Act.

The assessment of effects of project-related emissions on ambient air quality was subdivided into construction and operations phases. Emissions during decommissioning will be similar to those of construction, and project-related emissions will cease at closure.

The sources of construction phase emissions are internal combustion engines employed in construction equipment, light and heavy-duty vehicles, mining equipment and diesel electrical generators. There will also be emissions from mine heaters and transportation to and from the mine industrial complex. Operational phase emissions will be mainly fugitive dust from crushers on site, vehicular emissions from concentrate hauling, and emissions from the operation of diesel generators. Minor operational emissions include other road transportation. Estimated emission rates for each phase are based on information about project equipment and transportation activity provided by VNI and literature documenting emission rates for various types of equipment and vehicles. Assumptions that were used for the estimates of project related emissions are described below.

Emission estimates for diesel engines in all phases are based on the US EPA Tier 2 Standard for Non-road Diesel Engines which was in effect from 2001-2006 (US EPA, 2004). Tier 2 Standard Emission Factors/Limits vary according to engine power category; however, the highest emission factors among all engine ratings were employed to account for engine deteriorations and to provide a conservative estimate.

Equipment operation shifts were provided by VNI and were calculated based on Net Operating Hours per year. The estimation of CAC emissions assumes the application of best construction and operational practices and other mitigative actions, which have been confirmed by VNI. For example, emissions of sulphur dioxide are reduced dramatically through the use of low sulphur diesel fuel (<15 ppm) for all internal and external combustion applications. Examples include light and heavy-duty motor vehicles, heavy construction equipment and back up electrical generators. Other mitigation measures for related equipment include maintenance as per the manufacturers recommended schedules and adherence to applicable criteria with respect to emission quality. Fugitive dust will be reduced through the minimization of activities that generate large quantities of dust when windy and the application of a dust suppressant to unconsolidated working surfaces during periods of heavy activity and/or dry periods.

7.2.4.1 Construction

Construction phase emissions will be comprised of construction and mining equipment emissions, and vehicular traffic emissions. A summary of the estimated emissions during the construction and commissioning phases are presented in Table 7.2-7.

The largest source of CACs in the construction phase will be the construction and mining equipment – largely mobile sources. It is expected that the number of vehicles and heavy equipment used during the construction phase will be operated intermittently over time and distributed spatially such that the atmosphere will effectively disperse the emissions and minimize the potential for effects on local air quality.

It is expected that the heavy equipment and vehicles, i.e. the mobile sources of CACs, used during the construction phase will be operated for extended periods, but distributed spatially such that the atmosphere will effectively disperse the emissions. This will minimize the potential for effects on local air quality. Estimated project emissions of GHGs (CO_2) in the construction phase are approximately 0.05% of the total GHG emissions for Manitoba (2015 estimate) and 0.0015% of the projected 2015 emissions for Canada as a whole.

The substances of concern with respect to the combustion sources are $PM_{2.5}$, NO_x and SO_2 from stationary and mobile sources. Based on experience from similar projects, these emissions indicate that the potential for any exceedances of the applicable objectives is insubstantial. Based

Table 7.2-7 Estimated Air Emissions Associated with Minago Project - Construction Phase

Construction Emissions (20% of the operational phase fleet)										
Category of Vehicle / Model	Quantity	Flywheel Horsepower		Energy	Quantity of Diesel	Net operating hours	Quantity of litres	Quantity of CO_2		Quantity of N_2O
	units	HP	kW	MJ/hr	litres/ hour	hours/ unit per year	litres/unit per year	Overall kg/ year/ Total	Overall kilotonne/ year Total	Overall kg/ Year Total
Hydraulic Backhoe – Caterpillar 385CL (4 Cu.m.)	1	513	282	1,015.2	26.3	1,237	32,534	88,817	0.09	3
Utility Backhoe – Caterpillar 336DL (2 Cu.m.)	1	268	200	720	18.7	1,237	23,074	62,991	0.06	2
218 Tonne Haul Truck – Komatsu 830E – AC	15	2,360	1,761	6,339.6	164.2	1,421	233,383	9,557,021	9.56	280
Wheel dozer – Caterpillar 854K	1	801	597	2,149.2	55.7	1,237	68,875	188,028	0.19	6
Grader – Caterpillar 16M	1	296	221	795.6	20.6	742	15,294	41,752	0.04	1
Track Dozer c/w Ripper – Caterpillar D10T	3	581	433	1,558.8	40.4	371	14,982	122,705	0.12	4
Blast hole Stemmer – Caterpillar 262C	1	82	61	219.6	5.7	371	2,111	5,762	0.006	0
Front end loader – Le Tourneau L-1350	1	1,600	1,193	4,294.8	111.3	1,237	137,634	375,740	0.38	11
Secondary drill – Sandvik Pantera DP 1500	1	350	261	939.6	24.3	1,237	30,111	82,203	0.08	2
Ambulance – Ford E-150 Commercial	1	320	239	860.4	22.3	80	1,783	4,868	0.005	0
Fire Truck – Pierce Velocity™ Custom Chassis	1	400	298	1,072.8	27.8	80	2,223	6,070	0.006	0
Vibratory compactor – Caterpillar CS56	1	156	116	417.6	10.8	247	2,672	7,295	0.007	0
Bus – ABC TD 925	2	450	336	1,209.6	31.3	495	15,512	84,694	0.08	2

Table 7.2-7 (Cont.'d) Estimated Air Emissions Associated with the Minago Project - Construction Phase

Construction Emissions (20% of the operational phase fleet)										
Category of Vehicle / Model	**Quantity**	**Flywheel Horsepower**		**Energy**	**Quantity of Diesel**	**Net operating hours**	**Quantity of litres**	**Quantity of CO_2**		**Quantity of N_2O**
	units	**HP**	**kW**	**MJ/hr**	**litres/ hour**	**hours/ unit per year**	**litres/unit per year**	**Overall kg/ Year Total**	**Overall kilotonne/ year Total**	**Overall kg/ Year Total**
Rough Terrane forklift – Sellick S160	1	114	85	306	7.9	495	3,924	10,713	0.01	0
Shop forklift – Hyster H100FT	1	78	58	208.8	5.4	495	2,678	7,310	0.007	0
Pick-up truck – Ford Ranger	9	143	107	385.2	10.0	1,237	12,344	303,301	0.30	9
Pick-up (crew cab) truck – Chevrolet Silverado 2500HD	9	360	269	968.4	25.1	1,237	31,034	762,504	0.76	22
Hiab truck (crane picker) – National 880D	1	330	246	885.6	22.9	742	17,024	46,475	0.05	1
Welding truck, Lube/fuel truck, Mechanics truck	6	143	107	385.2	10.0	1,237	12,344	202,201	0.20	6
Tire Handler – Caterpillar 980H	1	349	260	936	24.2	371	8,996	24,560	0.02	1
Integrated tool carrier – Caterpillar IT38G	1	160	119	428.4	11.1	371	4,118	11,241	0.01	0
Water truck – Caterpillar 785D	2	1,347	1,005	3,618	93.7	371	34,774	189,866	0.19	6
Sanding truck – Komatsu HD325-7	1	518	386	1,389.6	36.0	371	13,356	36,462	0.04	1
Total	**62**	**11,719**	**8,640**	**31,104**	**805.8**	**16,919**	**720,779**	**12,222,578**	**12.21**	**358**

on quantitative estimates of CAC emissions and a qualitative assessment of potential effects during construction, project effects are rated as adverse, low magnitude, site-specific, medium term and reversible. The likelihood that effects will occur as predicted is high based on observations of similar facilities in similar baseline conditions.

7.2.4.2 Operations

Sources of operations phase emissions include mining equipment, mine heaters, vehicular traffic and diesel generators. Crushing units will be driven by electric motors driven; therefore, emissions from those units are mainly fugitive dust. Fugitive dust estimates were provided by Hatch. Fugitive dust emissions from road traffic were not estimated in this assessment as they are insubstantial compared to those from mining operation.

Fugitive dust emissions during the operational phase were not calculated. However, Victory Nickel will exercise reasonable efforts to mitigate potential sources of fugitive dust. Mitigative measures will include but not be limited to dust suppression methods such as the use of water sprays (on roads, crushing and grinding areas, and in the bag house) and ventilation in confined areas.

Fugitive dust emissions from the mine mill complex crushers will be relatively small on a per annum basis.

The largest source during the operational phase will be the vehicular traffic (mobile sources). The substances of concern with respect to the combustion sources are $PM_{2.5}$, NO_x and SO_2. Inside the LSA, ground level concentrations of NO_2 are expected to be somewhat elevated at the most affected location under worst-case meteorological conditions. For the remainder of the time, the ground level concentrations of NO_2 will be indistinct from baseline conditions. The 1-hour and 24-hour concentrations of NO_2 are expected to be less than the most stringent applicable objective (Maximum Acceptable Level in Table 7.2-5).

For mobile sources of CACs (Table 7.2-8), it is expected that equipment will act as point sources during the operational phase and that emissions from these sources will be distributed spatially such that the atmosphere will effectively disperse the emissions. This will minimize the potential for effects on local air quality. Based on quantitative estimates of CAC emissions and a qualitative assessment of potential detrimental effects during operations, project effects have been rated as adverse, low magnitude, site-specific, medium term and reversible. The likelihood that effects will occur as predicted is high based on observations of similar facilities in similar baseline conditions.

Total GHG emission in the operations phase will be 61.1 kT/y. This emission was compared to GHG emissions estimates for Canada (2015) and Manitoba (2015) (Table 7.2-9). Estimated project emissions of GHGs (CO_2) in the operational phase are approximately 0.24% of the total GHG emissions for Manitoba (2015 estimate) and 0.008% of the projected 2015 emissions for Canada as a whole.

Table 7.2-8 Estimated Air Emissions Associated with the Minago Project - Operations Phase

Operational Emissions										
Category of Vehicle / Model	Quantity	Flywheel Horsepower		Energy	Quantity of Diesel	Net operating hours	Quantity of litres	Quantity of CO_2		Quantity of N_2O
	units	HP	kW	MJ/hr	litres/ hour	hours/ unit per year	litres/unit per year	Overall kg/ Year Total	Overal kilotonne/ year Total	Overall kg/ Year Total
Hydraulic Backhoe – Caterpillar 385CL (4 Cu.m.)	1	513	282	1,015.2	26.3	6,186	162,695	444,157	0.44	13
Utility Backhoe – Caterpillar 336DL (2 Cu.m.)	1	268	200	720	18.7	6,186	115,387	315,005	0.32	9
218 Tonne Haul Truck – Komatsu 830E - AC	15	2,360	1,761	6,339.6	164.2	7,104	1,166,749	47,778,379	47.78	1400
Wheel dozer – Caterpillar 854K	1	801	597	2,149.2	55.7	6,186	344,429	940,291	0.94	28
Grader – Caterpillar 16M	1	296	221	795.6	20.6	3,712	76,510	208,871	0.21	6
Track Dozer c/w Ripper – Caterpillar D10T	3	581	433	1,558.8	40.4	1,856	74,952	613,854	0.61	18
Blast hole Stemmer – Caterpillar 262C	1	82	61	219.6	5.7	1,856	10,559	28,826	0.03	1
Front end loader – Le Tourneau L-1350	1	1,600	1,193	4,294.8	111.3	6,186	688,281	1,879,006	1.88	55
Secondary drill – Sandvik Pantera DP 1500	1	350	261	939.6	24.3	6,186	150,579	411,082	0.41	12
Ambulance – Ford E-150 Commercial	1	320	239	860.4	22.3	400	8,916	24,341	0.02	1
Fire Truck – Pierce Velocity™ Custom Chassis	1	400	298	1,072.8	27.8	400	11,117	30,350	0.03	1
Vibratory compactor – Caterpillar CS56	1	156	116	417.6	10.8	1,237	13,383	36,535	0.04	1
Bus – ABC TD 925	2	450	336	1,209.6	31.3	2,474	77,527	423,299	0.42	12

Table 7.2-8 (Cont.'d) Estimated Air Emissions Associated with the Minago Project - Operations Phase

Operational Emissions										
Category of Vehicle / Model	Quantity	Flywheel Horsepower		Energy	Quantity of Diesel	Net operating hours	Quantity of litres	Quantity of CO_2		Quantity of N_2O
	units	HP	kW	MJ/hr	litres/ hour	hours/ unit per year	litres/unit per year	Overall kg/ Year Total	Overall kilotonne/ year Total	Overall kg/ Year Total
Rough Terrane forklift – Sellick S160	1	114	85	306	7.9	2,474	19,613	53,542	0.05	2
Shop forklift – Hyster H100FT	1	78	58	208.8	5.4	2,474	13,383	36,535	0.04	1
Pick-up truck – Ford Ranger	9	143	107	385.2	10.0	6,186	61,732	1,516,750	1.52	44
Pick-up (crew cab) truck – Chevrolet Silverado 2500HD	9	360	269	968.4	25.1	6,186	155,195	3,813,138	3.81	112
Hiab truck (crane picker) – National 880D	1	330	246	885.6	22.9	3,712	85,164	232,499	0.23	7
Welding truck, Lube/fuel truck, Mechanics truck	6	143	107	385.2	10.0	6,186	61,732	1,011,167	1.01	30
Tire Handler – Caterpillar 980H	1	349	260	936	24.2	1,856	45,006	122,865	0.12	4
Integrated tool carrier – Caterpillar IT38G	1	160	119	428.4	11.1	1,856	20,599	56,234	0.06	2
Water truck – Caterpillar 785D	2	1,347	1,005	3,618	93.7	1,856	173,964	949,843	0.95	28
Sanding truck – Komatsu HD325-7	1	518	386	1,389.6	36.0	1,856	66,816	182,408	0.18	5
Total	**62**	**11,719**	**8,640**	**31,104**	**805.8**	**84,611**	**3,604,285**	**61,108,976**	**61.1**	**1,791**

Table 7.2-9 Greenhouse Gas Emissions for Canada and Manitoba

Year	Estimated Total Greenhouse Gas Emissions	
	Canadian Total ($kT\ CO_2$ – equivalent/y)	Manitoba ($kT\ CO_2$ – equivalent/y)
2020	852,130[1]	27,000[4]
2015	813,000[2]	26,000[4]
2010	769,940[1]	26,000[4]
2005	734,000[3]	20,300[5]
2000	718,000[3]	20,200[5]
1995	642,000[3]	19,000[5]
1990	592,000[3]	18,000[5]

Sources:

1 National Resources Canada. "Trends in Greenhouse Gas Emissions" <http://atlas.nrcan.gc.ca/site/english/maps/climatechange/atmospherestress/trendsgreenhousegasemission> (March 11, 2010).

2 Environment Canada. 2005. National Climate Data and Informative Archive.

3 Environment Canada. "Canada's Greenhouse Gas Emissions: Understanding the Trends, 1990-2006" <http://www.ec.gc.ca/pdb/GHG/inventory_report/2008_trends/trends_eng.cfm#toc_4> (March 11, 2010).

4 "Comparative Greenhouse Gas Emissions (actual and projected) Alberta, Saskatchewan, Manitoba" <http://www.climatechangesask.ca/images/0827(01)GHGSKABMB-1990-2020.pdf> (March 11, 2010)

5 Environment Canada. "National Inventory Report, 1990-2005: Greenhouse Gas Sources and Sinks in Canada" <http://www.ec.gc.ca/pdb/ghg/inventory_report/2005_report/ta11_14_eng.cfm> (March 11, 2010).

Note: Data for 2000 and beyond are projections.

The project site is favorably close to existing infrastructure including PTH6 and a 230 KV high voltage transmission line running beside PTH6 on the eastside of the road. Therefore, there will be no genset (with the exception of back-up diesel generations) on site to provide power. Green power from Manitoba Hydro will be used during the construction, operational and decommissioning phases.

Other energy efficiency measures will be employed where economically viable. It is anticipated that the project operations will not result in discernible changes to regional, national, or global climate patterns. Emissions of GHGs from the project are not expected to result in any significant adverse environmental effects. It is therefore not considered further in the assessment. Under the authority of the Canadian Environmental Protection Act, 1999, the Government of Canada announced mandatory reporting requirements for those facilities in Canada that emit 100 kT or more of CO_2 equivalent annually (Canada Gazette, March 13, 2004). VNI will review GHG emissions once the operations have commenced and prior to the regulatory report date.

7.2.4.3 Decommissioning

In the decommissioning phase of the project, some effects on air quality are expected to occur. The magnitude of these effects is expected to be very low. The decommissioning of the industrial complex, the removal of facilities, and site closure may result in emissions of CACs and fugitive dust. The greenhouse gas emissions from the decommissioning phase are given in Table 7.2-10. The potential effects on air quality that may occur during decommissioning will be similar to those predicted for construction. However, the magnitude, frequency, and duration of those effects are expected to be of a much smaller scale. The limited number of vehicles and equipment usedduring decommissioning will allow for sufficient dispersion of these emissions and will minimize potential effects on local air quality. Estimated project emissions of GHGs (CO_2) in the decommissioning phase are approximately 0.008% of the total GHG emissions for Manitoba (2015 estimate) and 0.0002% of the projected 2015 emissions for Canada as a whole.

Mitigation will include the application of dust suppressants on unconsolidated working surfaces during periods of heavy activity and/or dry periods. The vehicles and heavy equipment will be properly maintained to minimize emissions. These measures will ensure that air quality will remain within the applicable ambient air quality objectives. As for the construction phase and based on quantitative estimates of CAC emissions and a qualitative assessment of potential effects during decommissioning, project effects during decommissioning are rated as adverse, low magnitude, site-specific, medium-term and reversible. The likelihood that effects will occur as predicted is high based on observations of similar facilities in similar baseline conditions.

7.2.4.4 Closure

No further project-related air emissions are expected at closure, with the exception of possible intermittent road or air access for site monitoring. These emissions are considered to be insubstantial and not significant.

7.2.5 Residual Project Effects and Significance

During project construction, operations and decommissioning, there will be emissions of CACs in particular $PM_{2.5}$, NO_x and SO_2. Effects on ambient air quality will be greatest during operations but projected emissions will not result in ground level concentrations in excess of the most stringent air quality objectives (Table 7.2-5). These 'Maximum Desirable' objectives represent the long-term goal for air quality. They provide a basis for anti-degradation policy for unpolluted parts of the country. As such, they provide a large margin of safety with respect to effects on soil, water, vegetation, materials, animals, visibility, and personal comfort and well-being.

Table 7.2-10 Estimated Air Emissions Associated with the Minago Project - Decommissioning Phase

Decommissioning Emissions (10% of the operational phase fleet)										
Category of Vehicle / Model	Quantity	Flywheel Horsepower		Energy	Quantity of Diesel	Net operating hours	Quantity of litres	Quantity of CO_2		Quantity of N_2O
	units	HP	kW	MJ/hr	litres/ hour	hours/ unit per year	litres/unit per year	Overall kg/ Year Total	Overall kilotonne/ year Total	Overall kg/ Year Total
Hydraulic Backhoe – Caterpillar 385CL (4 Cu.m.)	1	513	282	1,015.2	26.3	619	16,280	44,444	0.04	1
Utility Backhoe – Caterpillar 336DL (2 Cu.m.)	1	268	200	720	18.7	619	11,546	31,521	0.03	1
218 Tonne Haul Truck – Komatsu 830E - AC	2	2,360	1761	6,339.6	164.2	710	116,609	636,686	0.64	19
Wheel dozer – Caterpillar 854K	1	801	597	2,149.2	55.7	619	34,465	94,090	0.09	3
Grader – Caterpillar 16M	1	296	221	795.6	20.6	371	7,647	20,876	0.02	1
Track Dozer c/w Ripper – Caterpillar D10T	3	581	433	1,558.8	40.4	186	7,511	61,518	0.06	2
Blast hole Stemmer – Caterpillar 262C	1	82	61	219.6	5.7	186	1,058	2,889	0.003	0
Front end loader – Le Tourneau L-1350	1	1,600	1,193	4,294.8	111.3	619	68,873	188,022	0.19	6
Secondary drill – Sandvik Pantera DP 1500	1	350	261	939.6	24.3	619	15,068	41,135	0.04	1
Ambulance – Ford E-150 Commercial	1	320	239	860.4	22.3	40	892	2,434	0.002	0
Fire Truck – Pierce Velocity™ Custom Chassis	1	400	298	1,072.8	27.8	40	1,112	3,035	0.003	0
Vibratory compactor – Caterpillar CS56	1	156	116	417.6	10.8	124	1,342	3,662	0.004	0
Bus – ABC TD 925	2	450	336	1,209.6	31.3	247	7,740	42,261	0.04	1

Table 7.2-10 (Cont.'d) Estimated Air Emissions Associated with the Minago Project - Decommissioning Phase

Decommissioning Emissions (10% of the operational phase fleet)										
Category of Vehicle / Model	**Quantity**	**Flywheel Horsepower**		**Energy**	**Quantity of Diesel**	**Net operating hours**	**Quantity of litres**	**Quantity of CO_2**		**Quantity of N_2O**
	units	**HP**	**kW**	**MJ/hr**	**litres/ hour**	**hours/ unit per year**	**litres/unit per year**	**Overall kg/ Year Total**	**Overall kilotonne/ year Total**	**Overall kg/ Year Total**
Rough Terrane forklift – Sellick S160	1	114	85	306	7.9	247	1,958	5,346	0.005	0
Shop forklift – Hyster H100FT	1	78	58	208.8	5.4	247	1,336	3,648	0.004	0
Pick-up truck – Ford Ranger	9	143	107	385.2	10.0	619	6,177	151,773	0.15	4
Pick-up (crew cab) truck – Chevrolet Silverado 2500HD	9	360	269	968.4	25.1	619	15,530	381,560	0.38	11
Hiab truck (crane picker) – National 880D	1	330	246	885.6	22.9	371	8,512	23,237	0.02	1
Welding truck, Lube/fuel truck, Mechanics truck	6	143	107	385.2	10.0	619	6,177	101,182	0.10	3
Tire Handler – Caterpillar 980H	1	349	260	936	24.2	186	4,510	12,313	0.01	0
Integrated tool carrier – Caterpillar IT38G	1	160	119	428.4	11.1	186	2,064	5,636	0.006	0
Water truck – Caterpillar 785D	2	1,347	1,005	3,618	93.7	186	17,434	95,189	0.095	3
Sanding truck – Komatsu HD325-7	1	518	386	1,389.6	36.0	186	6,696	18,280	0.02	1
Total	**49**	**11,719**	**8,640**	**31,104**	**805.8**	**8,465**	**360,536**	**1,970,737**	**1.952**	**58**

Emissions will cease within approximately three years of decommissioning. Subtle effects on the most sensitive receptors, native vegetation in close proximity to the emissions, are expected to be virtually undetectable in as little as one growing season. Based on the criteria described in previous sections, residual project effects during all phases of the project are determined to be not significant.

These conclusions are based on a qualitative assessment of the emission quantities and preliminary quantitative analyses. Based on professional judgement a dispersion assessment of the largest emission source (mining equipments) was deemed unnecessary given the relatively small quantities of $PM_{2.5}$, NO_x and SO_2 discharged. The likelihood of effects occurring as predicted is high.

7.2.6 Cumulative Effects

The project local study area is relatively remote. It is 225 km from Thompson, Manitoba. Thompson will be the next nearest substantial source of CACs. As such, the Minago Project is not substantially influenced by anthropogenic emissions, save trace amounts of substances transported regionally and/or globally. Following the application of mitigating measures, the residual project effects on air quality are expected to be not significant. The potential for the residual project effects to have a significant effect in combination with effects of other activities in the area is negligible. This includes existing and ongoing activities, approved activities, and projects or activities expected to occur in the reasonably foreseeable future.

7.2.7 Mitigation Measures

Exhaust emissions will be minimized by keeping all vehicles and equipment in good operating condition. Fugitive dust emissions from crushing will be minimized through containment and a dust control system. Fuel emissions will be reduced through measurements such as:

- driver educational training on available fuel efficiency alternatives;
- tire maintenance program;
- vehicle speed control with the governor;
- reducing vehicle idling by turning off vehicles automatically, utilizing idle reduction systems like Auxiliary Power Units/Generator Sets;
- diesel Retrofit Technologies; and
- fuel additives.

Road dust will be managed as necessary through the application of non-toxic dust suppressants. Any effect of the project on ambient noise or air quality will be limited to the immediate project site and will not exceed workplace safety and health standards. A monitoring program that meets the Workplace Health and Safety Act and regulations will be developed to ensure that the human health will not be compromised. Table 7.2-11 summarized proposed mitigation measures for potential project effects and potential cumulative effects.

7.2.8 Monitoring and Follow-up

Follow-up Studies

There are no proposed follow-up baseline studies identified to improve predictive confidence or improve the database for effects monitoring purposes.

Monitoring Programs

There are no monitoring programs identified for project effects or cumulative effects.

Table 7.2-11 Mitigation Measures for Effects on Air Quality

Potential Project Effect	Mitigation Measures
Emissions of CACs, including respirable particulate matter, nitrogen dioxide and sulphur dioxide from vehicles, generators, and heaters potentially affecting human health and the environment, including vegetation and wildlife.	• Use low sulphur fuels including diesel fuel with a sulphur content,15 ppm and propane with negligible sulphur content. • Meet applicable criteria with respect to emission quality on all combustion-related equipment and provide maintenance according to manufactures specifications.
Emissions of fugitive dust from light and heavy duty motor vehicles, heavy construction equipment, construction activities and ore crushing activities potentially emit coarse particulate matter, which is both a nuisance and can potentially affect human health and the environment, including vegetation and wildlife.	• Apply dust suppressant (such as water spray to unconsolidated working surfaces and development rock and ore stockpiles) to minimize fugitive dust during periods of heavy activity and/or dry periods. • Minimize activities that generate large quantities of fugitive dust when windy. • Reseed disturbed areas and topsoil stockpiles to prevent fugitive dust from wind erosion.
Emissions of CACs and GHGs from the construction equipment and vehicular traffic with potential contributions to climate change	• Recover waste heat from the generators to heat the process building, assay lab and camp.
Emissions of CACs and GHGs from land clearing burning	• Apply best practices regarding clearing. • Do not use prohibited materials (waste oil, tires) as accelerants.
Potential Cumulative Effect	**Mitigation Measures**
N/A	• N/A

Notes: N/A = not applicable

7.2.9 Summary of Effects

Table 7.2-12 is a summary of the effects assessment conclusions including the level of effect and the overall effects rating.

Table 7.2-12 Mitigation Measures for Effects on Air Quality

Potential Effect	Level of Effect						Effect Rating	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effective
Construction								
Fugitive dust emissions from ground disturbance, heavy construction equipment, and vehicles with potential effects on human health, vegetation and wildlife.	Adverse	Moderate	Local	Medium Term	Reversible	High	Not significant	Not significant
Fugitive dust and emissions of CACs from mining equipment and auxiliary site vehicles.	Adverse	Low to Moderate	Local	Medium Term	Reversible	High	Not significant	Not significant
Particulates and VOC emissions from site clearing and burning of woody debris.	Adverse	Low to Moderate	Local	Medium term	Reversible	High	Not significant	Not significant
GHG emissions from combustion engines, diesel generators and land clearing burning	Adverse	Low to Moderate	Local	Medium term	Reversible	High	Not significant	Not significant
Operations								
Fugitive dust emissions from ore crushing and vehicle use with potential effects on human health, vegetation and wildlife.	Adverse	Moderate	Local	Long term	Reversible	High	Not significant	Not significant
Fugitive dust and emissions of CACs from mining equipment and auxiliary site vehicles.	Adverse	Moderate	Local	Long term	Reversible	High	Not significant	Not significant
Decommissioning								
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

7.3 Terrain, Surficial Geology and Soils

7.3.1 Scope of Assessment

7.3.1.1 Issues and Selection of Valued Ecosystem and Cultural Components (VECCs)

Table 7.3-1 provides a list of the terrain, surficial geology and soil 'Valued Ecosystem Cultural Components' (VECCs) that have been defined for the Environmental Assessment of the Minago Project.

As identified in Table 7.3-1, these VECCs were chosen for one or more of the following reasons:

- potential for project impacts was unclear;
- construction will alter current baseline conditions;
- impact of construction is unclear; and
- areas of specific concern to be defined.

7.3.1.2 Temporal Boundaries

The temporal scope of this environmental effects assessment includes all project-related environmental and cultural effects for service life of the open pit mine of 9 years, nickel process plant of 8 years and Frac sand process of 10 years. The environmental effects assessment includes baseline studies, construction, operation, decommissioning, and closure activities as described in Section 3.4 of this report.

7.3.1.3 Study Area

The Minago mine development project is located in northern Manitoba at latitude 54º15'N and longitude 99º12'W. It is accessible from Highway 6 between the communities of Grand Rapids and Thompson. The mine is at the boundary between the Minago and William River watersheds, which are both within the Nelson River hydrographic system.

The study area lies within the Localized Permafrost Zone, which was defined by Zoltai (1995). In that zone, permafrost occurs as small isolated lenses in peat. The hydrological and ecological impacts of their melting have been proven to have no significant effect on the surrounding area (Thibault and Payette, 2009). Moreover, Thibault and Payette (2009) have shown that over the last 50 years the southern limit of permafrost distribution has significantly migrated towards the north. Nowadays, it is therefore unlikely to observe permafrost in the Minago area.

The Minago River is a watercourse that flows in the northeast direction into Cross Lake, then the Nelson River. The William River flows from William Lake in the northeast direction. At roughly 20 km downstream of Highway 6, this watercourse turns 90º to the southeast direction and

Table 7.3-1 Terrain, Surficial Geology and Soil VECCs, Selection Rationale and Data Sources

VECC	Rationale for Selection	Linkage to EAP Report Guidelines or other Regulatory Drivers	Baseline Data for the Environment Act Proposal (EAP)
Key terrain features	• General description of project geography linked to terrain hazards and erosion potential. • Influences habitat capability.	• Information requested in the EAP Report Guidelines and Biophysical Assessment Work Plan.	• Field Data • Surficial Geology Mapping
Surficial materials	• Linkage to terrain hazards and erosion potential. • Construction will alter current baseline conditions and affect recreation potential and post closure ecosystems.	• Information requested in the EAP Report Guidelines and Biophysical Assessment Work Plan.	• Surficial Geology Mapping program • Field Data • VNI and Government of Manitoba baseline data
Key sediments with high erosion potential	• Areas of specific concern to be defined for planning and management. • Linkage to potential sedimentation of aquatic habitat.	• Information requested in the EAP Report Guidelines and Biophysical Assessment Work Plan.	• Terrain Mapping Program • Field Data
Natural terrain hazards	• Areas of specific concern to be defined for planning and management.	• Information requested in the EAP Report Guidelines and Biophysical Assessment Work Plan.	• Terrain Mapping Program • Field Data • VNI and Gov't of MB baseline data
Sensitive soil types	• Areas of specific concern to be defined for planning and management. • Construction will alter current baseline conditions and affect reclamation potential.	• Information requested in the EAP Report Guidelines and Biophysical Assessment Work Plan.	• Terrain Mapping Program • Field Data • VNI and Gov't of MB baseline data

discharges into Limestone Bay on Lake Winnipeg. A series of lakes, including Cross Lake, connects Lake Winnipeg to the Nelson River.

Coniferous vegetation and small to medium sized lakes are typical in the vicinity of the Minago Project. Generally, the site has low topographic relief. Limestone outcrops exist along an elevated ridge directly to the south and west of Minago. These outcrops also extend to the north and east of the property.

The Minago site is located in low, water-saturated, perennially flooded muskeg terrain. The soil conditions at the site are dominated by a surface cover of peat underlain by variable thicknesses of clay and then bedrock. There is an exposure of bedrock to the immediate west of the site. The site is generally waterlogged. A detailed description and characterization of the soil conditions encountered are provided herein. The overall mine development area covers about 1,300 ha.

Precambrian crystalline basement rocks underlie the entire Province of Manitoba. The Thompson Nickel Belt (TNB) forms part of these intensely metamorphosed rocks. Phanerozoic sedimentary rocks of the Western Canada Basin (WCB) unconformably overlie crystalline basement. Minago is located close to the north-eastern boundary of the WCB and the younger sedimentary rocks at Minago are typically about 60 metres thick.

The Local Study Area (LSA) for the assessment of project effects on terrain, surficial geology and soils is defined as the potential project disturbance footprint (conservatively defined as the total of VNI's claim areas directly affected by mine site facilities), buffered by 100 m to account for potential edge effects such as changes in drainage or induced localized instabilities. These buffers are large enough to accommodate potential changes in the development design and project footprint. They are also appropriate for the scale of interpretation conducted and can be predicted with a reasonable degree of accuracy and confidence to include the areas where impacts on terrain, surficial materials and soils are most concentrated.

The mine site is identified as the main area for the assessment of effects on wildlife. This area is defined by the potential extent of project disturbance of wildlife (including noise, traffic and human activity), which extends beyond the area of potential ground disturbance (Section 7.10: Wildlife).

A Regional Study Area (RSA) has not been defined for the terrain and soils assessment as the project effects on terrain and soils will be very localized and are not expected to overlap or act cumulatively with effects of other projects or activities in the region.

7.3.2 Assessment of Baseline Conditions

The objective of the baseline geotechnical and biophysical investigations and description was to describe terrain, surficial materials (geology) and soil conditions of the project area as a basis for the infrastructure design and impact and environmental assessment.

7.3.2.1 Data Collection Methods

A significant amount of background data exists for this project area. Previous studies conducted for VNI (including the 2006 Scoping Study) and previous mineral lease holders have presented baseline information including the bedrock geology, surficial materials, terrain hazards, and soil characteristics of the project area. Terrain, surficial materials and soil conditions were compiled and interpreted and supplemented with field geotechnical investigation programs (Wardrop, 2009b).

7.3.2.1.1 Geotechnical Investigation and Soil Sampling Program

Wardrop conducted geotechnical site investigations during the winters of 2007 and 2008, for the purpose of carrying out the feasibility level design of the various components of the project. The results of the investigations were used to define the characteristics of the overburden soils, the upper dolomite bedrock, and groundwater conditions across the site.

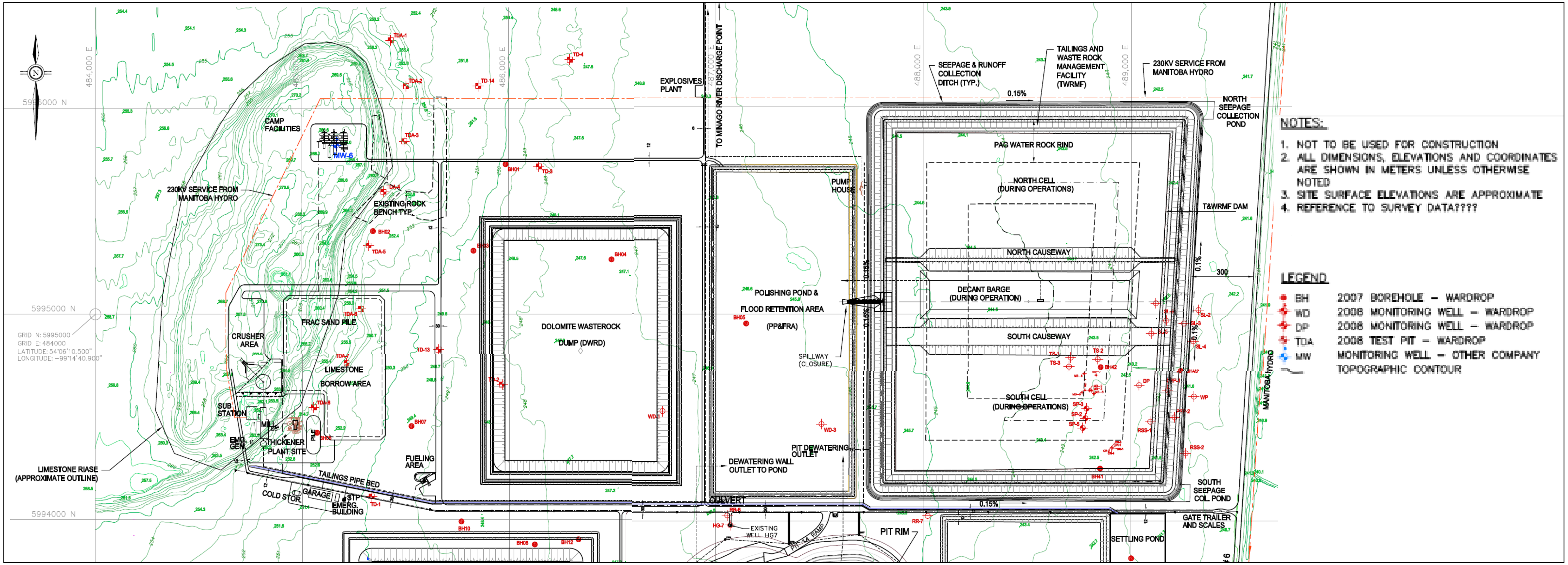
The scope of the geotechnical work, conducted to date, includes the following (Wardrop, 2009b):

- factual data and laboratory testing;
- site, materials, and tailings characterization;
- study of options for the TWRMF;
- engineering analyses – seepage, stability and settlement;
- geotechnical design of the TWRMF, rock dumps, and Overburden Disposal Facility (ODF);
- water handling and balance for the TWRMF and ODF as a part of the overall site water balance and management;
- conceptual tailings, waste rock and overburden deposition plans;
- construction considerations;
- borrow sources;
- performance monitoring;
- geotechnical closure issues;
- potential future optimizations; and
- Design Basis and Design Criteria.

The subsurface conditions at the site were investigated by drilling total of 90 boreholes and 8 test pits. The locations of the boreholes and test pits are shown on drawing in Figure 7.3-1.

A borehole survey was conducted by Pollock and Wright contracted directly by Victory Nickel in May 2008, approximately one month after completion of the field investigation program. A list of as-drilled boreholes, including their coordinates, elevations, and other pertinent information such as thickness and depth to the surface of the individual soil strata encountered, total drilled depths in overburden and bedrock is provided elsewhere (Wardrop, 2009b).

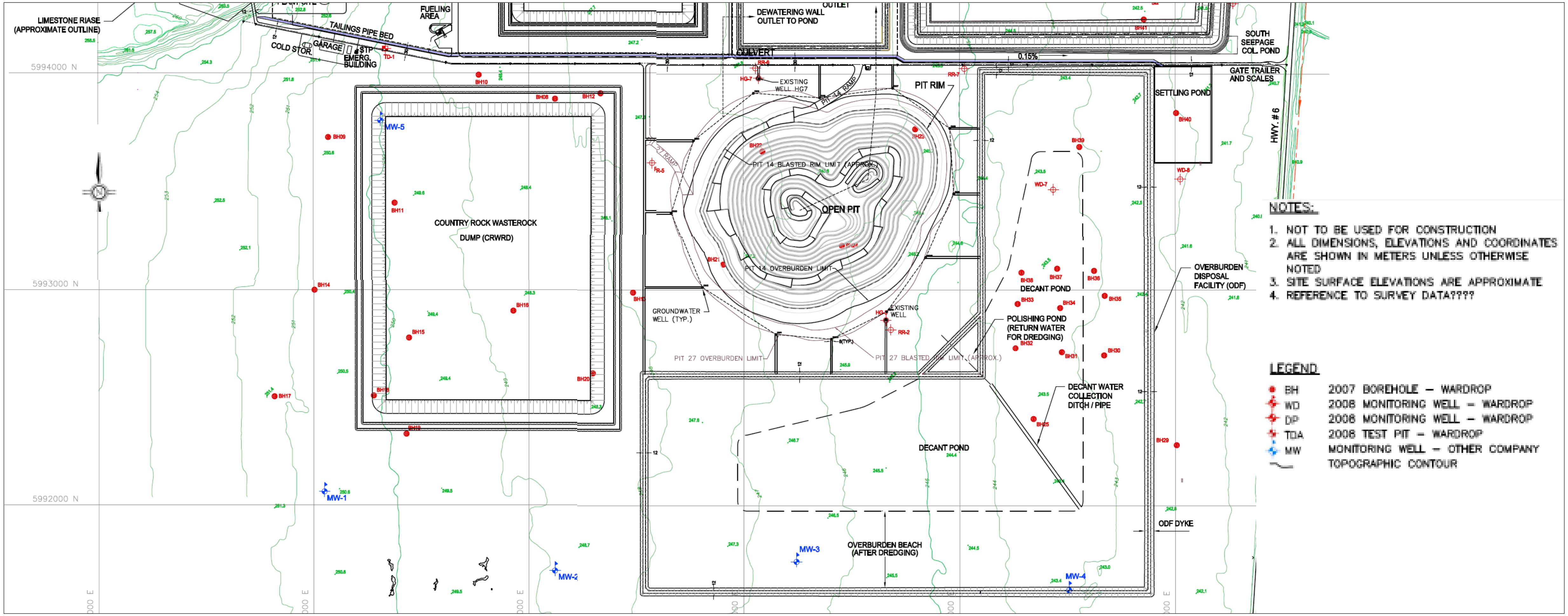
The bedrock was drilled with additional boreholes without sampling the overburden just beside Boreholes CR1, CR2, CR3, CR4, CR5, MB1, MB2, MB3, SP2, SP3, SP5, WD1, WD3, WD7, WD8, RR2, RR6, TD2, TD4, TD6, TD10, TD12, TD13 and TD14. Details about the subsurface conditions are provided in the Borehole and Test Pit Logs in Wardrop (2009b).



Source: adapted from Wardrop's Drawing 0951330400-T0002 (Wardrop, 2009b)

Figure 7.3-1 Geotechnical Site Plan for Minago

(**Note:** This Figure was reassembled out of six images taken from the original drawing to enhance the readability of the Borehole Numbers.)



Source: adapted from Wardrop's Drawing 0951330400-T0002 (Wardrop, 2009b)

Figure 7.3-1 (Cont.'d) Geotechnical Site Plan for Minago

(**Note:** This Figure was reassembled out of six images taken from the original drawing to enhance the readability of the Borehole Numbers.)

The drilling was carried out using an Acker Soil Sentry track-mounted hydraulic rig equipped with 125 mm diameter solid/hollow stem continuous flights auger operated by Paddock Drilling Ltd. of Brandon, MB. During drilling, samples from the upper 3.5 m of soils were recovered at 0.76 m intervals using a 50 mm O.D. split-spoon sampler by conducting Standard Penetration Tests (SPTs) in accordance with the procedures outlined in the ASTM Specification D1586. Below this depth, the soil samples were recovered at 1.52 m of intervals until auger refusal was encountered (Wardrop, 2009b).

Thin-walled Shelby tubes were used to extract undisturbed soil samples from the clay overburden. The Shelby tube samples were obtained from the upper firm clay unit in 2007 and from the lower soft to firm clay unit in 2008. Pocket Penetrometer (PP) tests were carried out on recovered cohesive soil samples to obtain index strength values (Wardrop, 2009b).

A total of six Nilcon Vane Tests and eight Standard Vane Tests were conducted in soft/firm formations to measure the in-situ Undrained Shear Strength of the soils. The Standard Vane tests were carried out by means of a Heavy Field Inspection Vane tester, model H-70. This instrument is capable of separately measuring the shear strength of the soils and the friction developed by the drilling rods. However, because the vane wings generally had only penetrated 0.3 m into the undisturbed soils, the evaluation of the test results did not take into account the rod friction (Wardrop, 2009b).

Soil samples obtained from the boreholes were logged and placed in labelled plastic bags. The undisturbed thin walled Shelby tube samples were sealed by paraffin and placed in insulated boxes. These samples were shipped to geotechnical laboratories upon completion of drilling. MDH Engineered Solutions' Saskatoon laboratory and Golder Associates' Mississauga laboratory conducted the soil laboratory testing in 2007 and 2008, respectively (Wardrop, 2009b).

Field identification of the soil strata was based on visual and tactile examination of the samples obtained from the split spoon sampler, a few auger samples and from the bottom of thin-walled Shelby tube samples. The recovered soil samples were then re-examined and inspected subsequently by Wardrop's representatives in Golder Associates' laboratory in July, 2008 (Wardrop, 2009b).

A total of twenty-four boreholes were drilled into the bedrock where the overburden thickness was minimal using HQ size wireline equipment which allowed recovery of 63.5 mm diameter rock cores. The recovered cores were placed in core boxes, logged and photographed and then shipped and stored at Victory's core shack in Grand Rapids, Manitoba. Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) values and Fracture Indices (FI) were recorded by Wardrop's representative at the site. These parameters were recorded in accordance with the conventions used by the International Society for Rock Mechanics (ISRM). Selected rock core samples were shipped to Queen's University for Uniaxial Compressive Strength (UCS) and dynamic shear modulus tests. In-situ single packer tests were conducted in the lower 3 m of explored bedrock in selected boreholes to determine the permeability ("k" value) of the Ordovician dolomite. A total of 13 packer tests were carried out in the winter of 2008 of which 11 were successful (Wardrop, 2009b).

The fieldwork was supervised on a full time basis by Wardrop's field representatives who witnessed drilling, sampling and in-situ testing procedures.

A total of seventy-two 50 mm diameter observation wells were installed in the clay overburden across the project site to monitor piezometric heads. An additional twenty-four 50 mm diameter observation wells were installed at the bottom of the boreholes drilled into the bedrock in order to monitor the piezometric heads originating in bedrock. The observation wells were designed with a screened portion at the bottom of a PVC pipe with an above-grade extension of approximately one meter. Well gravel was placed in the annular space between the borehole and the PVC pipe up to 50 mm above the screen segment. A mixture of granular bentonite and soil cuttings was used for sealing the wells above the screen (Wardrop, 2009b).

Additional geotechnical investigations to encompass additional site areas within the recently expanded property limits and to better define current designs are envisaged for future optimizations.

7.3.2.1.2 Geotechnical Characterization of Tailings

A geotechnical characterization of tailings was conducted at SGS Lakefield laboratory in Peterborough, Ontario. The tailings sample was generated from the lock cycle test, one of several metallurgical programs set up for the Minago Project (Wardrop, 2009b).

The tailings sample obtained from the lock cycle testing had solids content of 45% by weight. Additional testing included settling tests, sieve and hydrometer analysis, specific gravity test, Atterberg limits, standard proctor compaction test, hydraulic conductivity test, consolidated undrained triaxial test and an air drying test (Wardrop, 2009b).

Settling tests were conducted for both undrained and drained conditions. The settled sample in the drained settling test was further subjected to a constant head hydraulic conductivity test. Hydraulic conductivity tests were carried out on compacted samples using a flexible wall permeameter. Specific gravity, sieve and hydrometer tests were conducted as per ASTM requirements. The column drying test was conducted as per generic mining method rather than ASTM (Wardrop, 2009b).

7.3.3 Results

A summary of the surficial geology, subsurface conditions and a characterization of the stratigraphy encountered at the site are provided in the following sections.

7.3.3.1 Minago Geology

From a geotechnical standpoint, the relevant units of the stratigraphic column are the upper Ordivician dolomitic limestone and the Quaternary surface cover. Therefore, these units are depicted briefly in the following paragraphs.

7.3.3.1.1 Ordivician Dolomitic Limestone

The dolomitic limestone is fine grained, massive to stratified and varies in colour from creamy white to tan brown to bluish grey. Dolomite thickness ranges from 42 to 62 m with thickness increasing southward. The upper 24 m of the formation is stratified with horizontal clay/organic beds 1 to 5 mm in thickness at intervals ranging from millimetres to a metre. A stratified zone of dolomite breccia and microfracturing characterized by dolomite clasts in a carbonate clay matrix and varying in thickness from 0.3 to 3.0 m is located 15 m to 21 m below the surface of the formation. Scattered throughout the dolomite are occasional soft clay seams ranging from 1 to 2 centimetres (cm) in thickness. The seams may contain dolomite fragments and sand grains and vary in orientation from semi horizontal to semi vertical (Wardrop, 2009b).

7.3.3.1.2 Quaternary Surface Cover

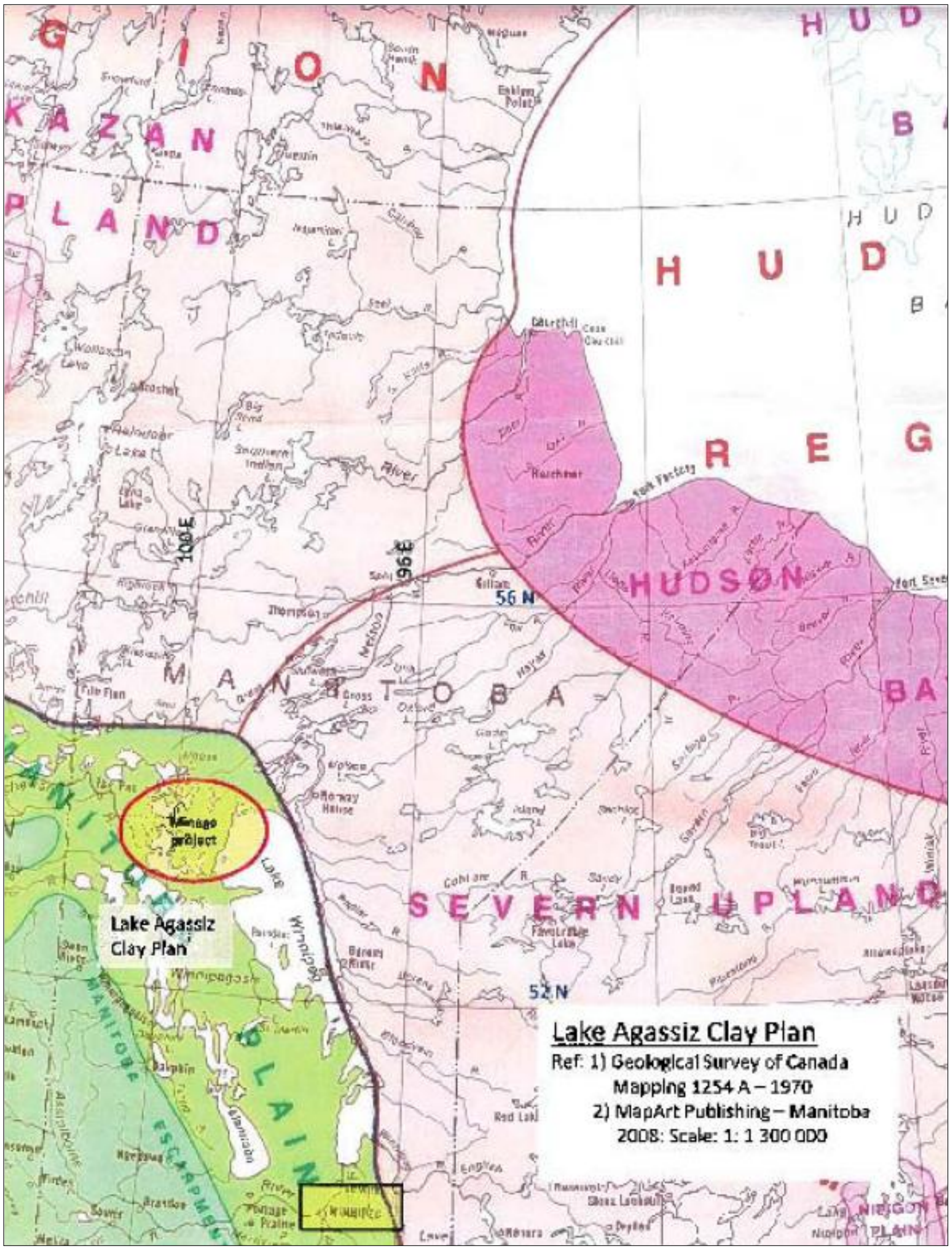
The Quaternary surface cover typically comprises up to 4 m of peat/muskeg that is generally underlain by up to 20 m of low permeability glacial lacustrine clays. The clays are dark brown to grey and carbonate rich. Peat/muskeg is formed by an accumulation of Sphagnum moss, leaves, and decayed matter (Wardrop, 2009b).

The underlying clay and sporadic till was deposited from former glacial Lake Agassiz, which once stretched across portions of Saskatchewan, Manitoba and western Ontario, impounded by retreating and transgressing Laurentian ice sheets. Lake Agassiz finally drained into the Arctic Ocean about 7400 BP (Before Present). Figure 7.3-2 shows the current extent of clays (coloured green) deposited by Lake Agassiz. The deposit contains silt and occasional sand and gravel (Wardrop, 2009b).

Glacial till was found locally below the clay across the project site. Geotechnical work on site identified three components of the glacial lacustrine clay: an upper low plasticity clay, a middle intermediate plasticity clay and a lower, high plasticity clay. Elsewhere in Manitoba, similar glacial lacustrine clay is found in areas prone to flooding and with challenging foundation conditions (Wardrop, 2009b).

7.3.3.2 Seismicity

As the Minago project is located in a region historically exhibiting low seismicity, an extensive evaluation extending beyond an examination of historic earthquakes was not considered necessary (Wardrop, 2009b). The 2005 National Building Code seismic hazard calculation indicating the acceleration levels for given probabilities is presented in Table 7.3-2.



Source: Wardrop, 2009a

Figure 7.3-2 Current Extent of Clays Deposited by Lake Agassiz

Table 7.3-2 Minago Project Area Regional Seismicity

Probability of Exceedance per Annum	Probability of Exceedance in 50 Years (%)	Return Period (years)	Peak Ground Acceleration (PGA) g
0.01	40	100	0.007
0.0021	10	475	0.021
0.001	5	1,000	0.035
0.000404	2	2,475	0.059

Source: Wardrop, 2009b

A return period of 475 years is identified for use in design of structures at the site with a corresponding Peak Ground Acceleration (PGA) of 0.021 g. This design value has been assumed to be applicable for the operational life of the mine. For the longer term post-closure phase, a return period of 2,475 years has been assumed with a corresponding PGA of 0.059 g (Wardrop, 2009b).

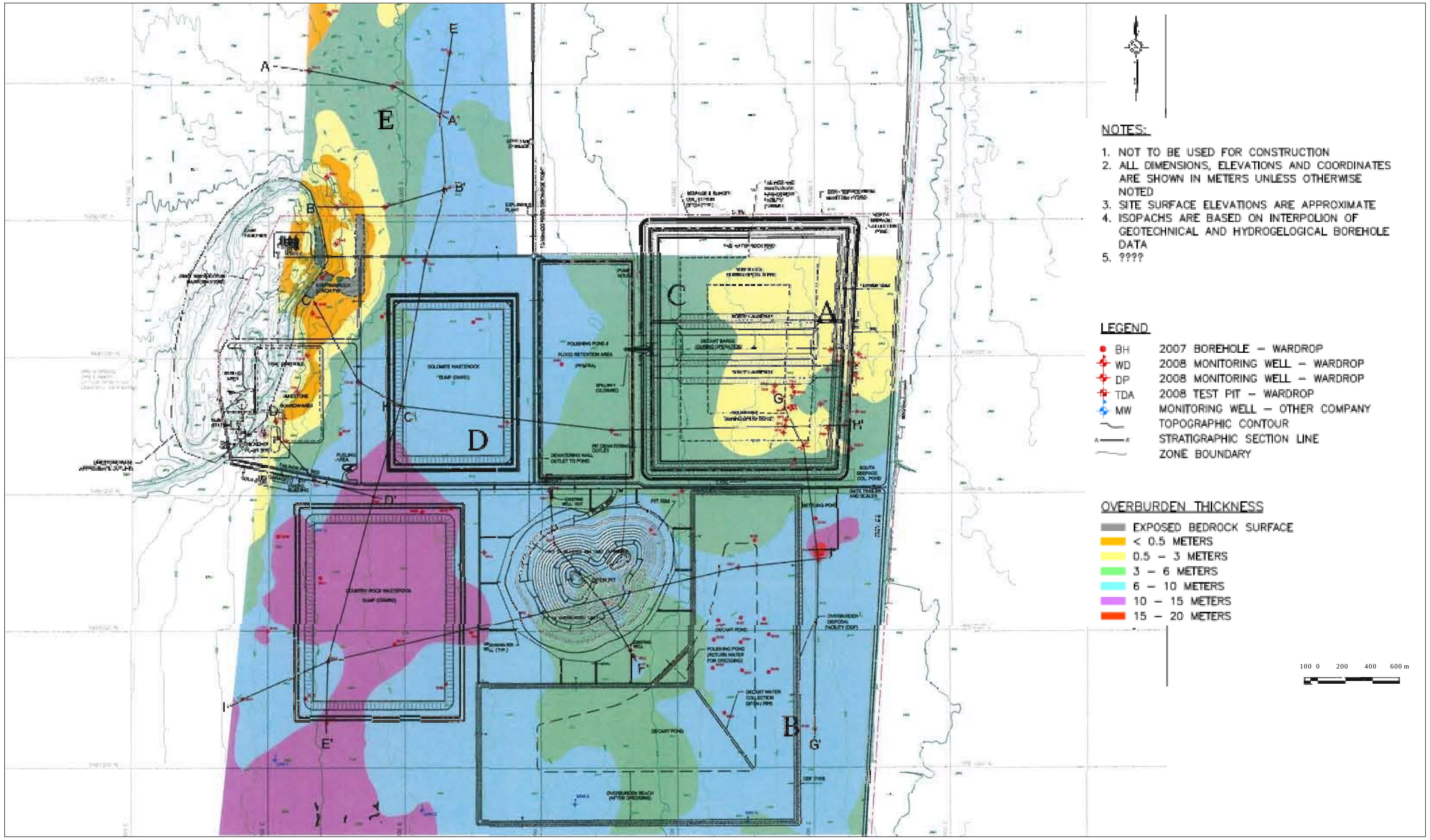
7.3.3.3 Geotechnical Properties

The project site was divided into five sectors in plan for the ease of reference as listed below:

- Zone A:.TWRMF;
- Zone B: ODF;
- Zone C: Polishing Pond and TWRMF;
- Zone D: Waste Rock Dumps; and
- Zone E: Northwestern Sector of the site.

The locations of the selected Zones, the general mine layout, and the overburden thicknesses are shown on Figure 7.3-3. Although Zone E was identified as a possible site for the TWRMF early in the design process, this area is not utilized in the current design.

The thickness and distribution of soil strata vary across the project site, and some of them were not encountered in all site zones. In general, Zone A exhibits relatively thin overburden, within 3 m below the ground surface, while Zone B and D exhibit relatively thick overburden ranging from 6 m to 15 m below the ground surface. One deep overburden pocket (21 m) was encountered within Zone B. The overburden in Zone C varies between 3 m and 10 m. Detailed geotechnical profiles are given elsewhere (Wardrop, 2009b).



Source: adapted from Wardrop’s Drawing 0951330400-T0003 (Wardrop, 2009b)

Figure 7.3-3 Minago Overburden Isopach Plan

Five main soil strata were identified within the overburden on the site comprising:

- Peat;
- low plasticity clay (CL);
- intermediate plasticity clay (CI);
- high plasticity clay (CH); and
- glacial till.

The overburden is underlain by a dolomite bedrock, except in a few area within Zone E where limestone outcrops were observed.

Figures 7.3-4 through 7.3-6 illustrate general site conditions of the subsoils. These figures show variations by Zones and by depth of the natural moisture content, recorded SPT N-values and Undrained Shear Strength, measured with a pocket penetrometer (Wardrop, 2009b). Figure 7.3-7 shows a compilation of geotechnical properties for the entire site and Figure 7.3-8 illustrates the variation of undrained shear strength with depth. On the upper part of Figure 7.3-8, the variation of the undrained shear strength obtained from the Nilcon and Standard field vane tests and unconsolidated undrained triaxial tests are shown versus depth. On the lower part of Figure 7.3-8, the normalized undrained shear strengths are plotted versus depth.

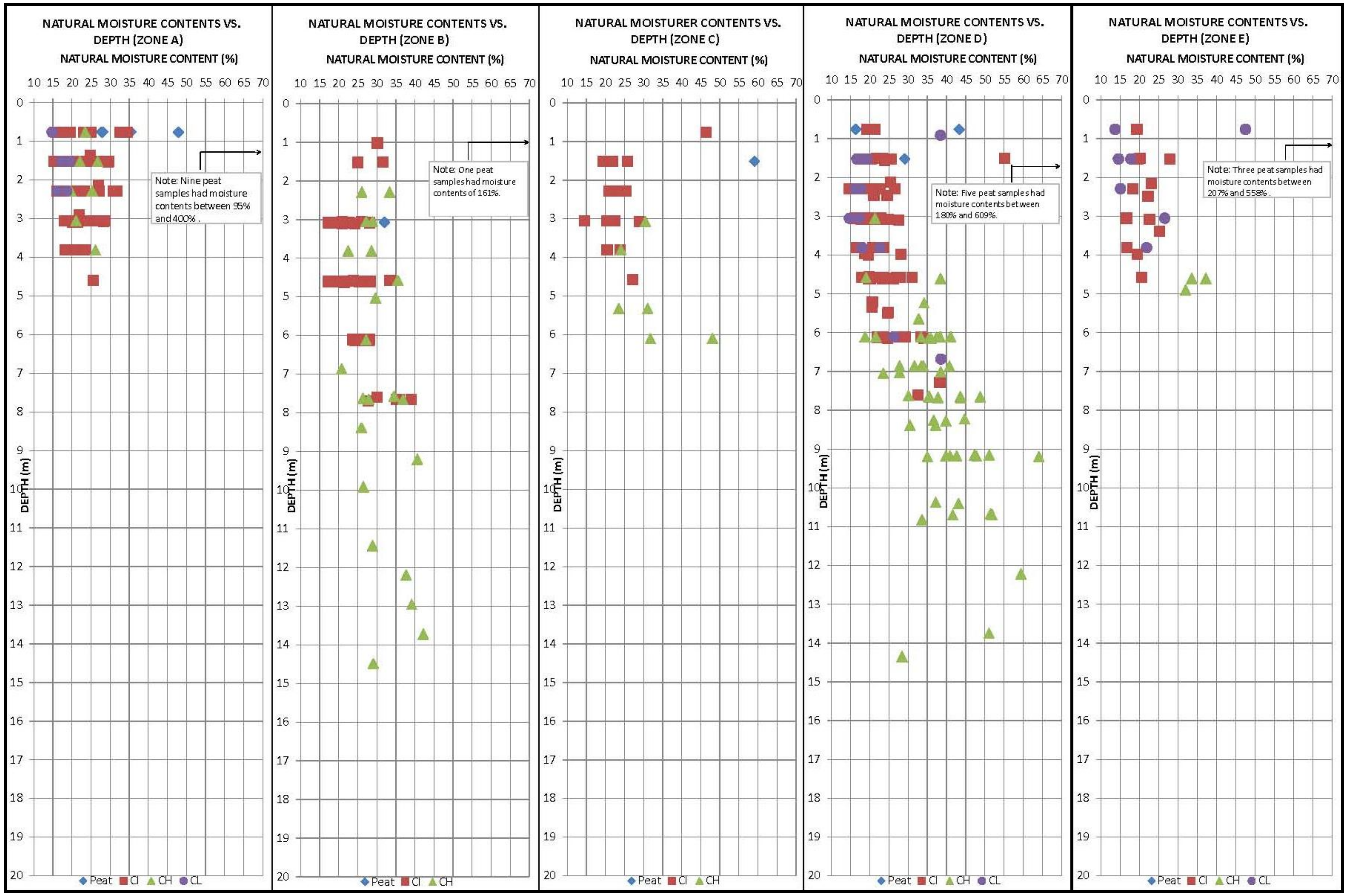
A summary geotechnical profile is presented in the following paragraphs. Detailed information is provided in Wardrop (2009b).

7.3.3.3.1 Peat/Muskeg

Peat with variable thicknesses of up to 4.0 m with an average thickness of approximately 1.6 m covers the entire project area. The peat is composed of fine to coarse but mainly fine fibrous peat of black and brown colour. It generally exhibits high moisture contents, ranging from 16% to 609%, with an average value of 178%. SPT ‘N’ values ranged from 0 blows per 0.3 m (i.e. drilling rod sunk by own weight) to 6 blows per 0.3 m, with an average value of approximately 3 blows per 0.3 m. The blow counts within this stratum suggest very soft to firm, but generally soft consistency. An Atterberg limits test had a liquid limit, plastic limit and plasticity index of 54%, 20% and 34%, respectively. During the fieldwork, the peat was generally frozen to a depth of approximately 0.5 m (Wardrop, 2009b).

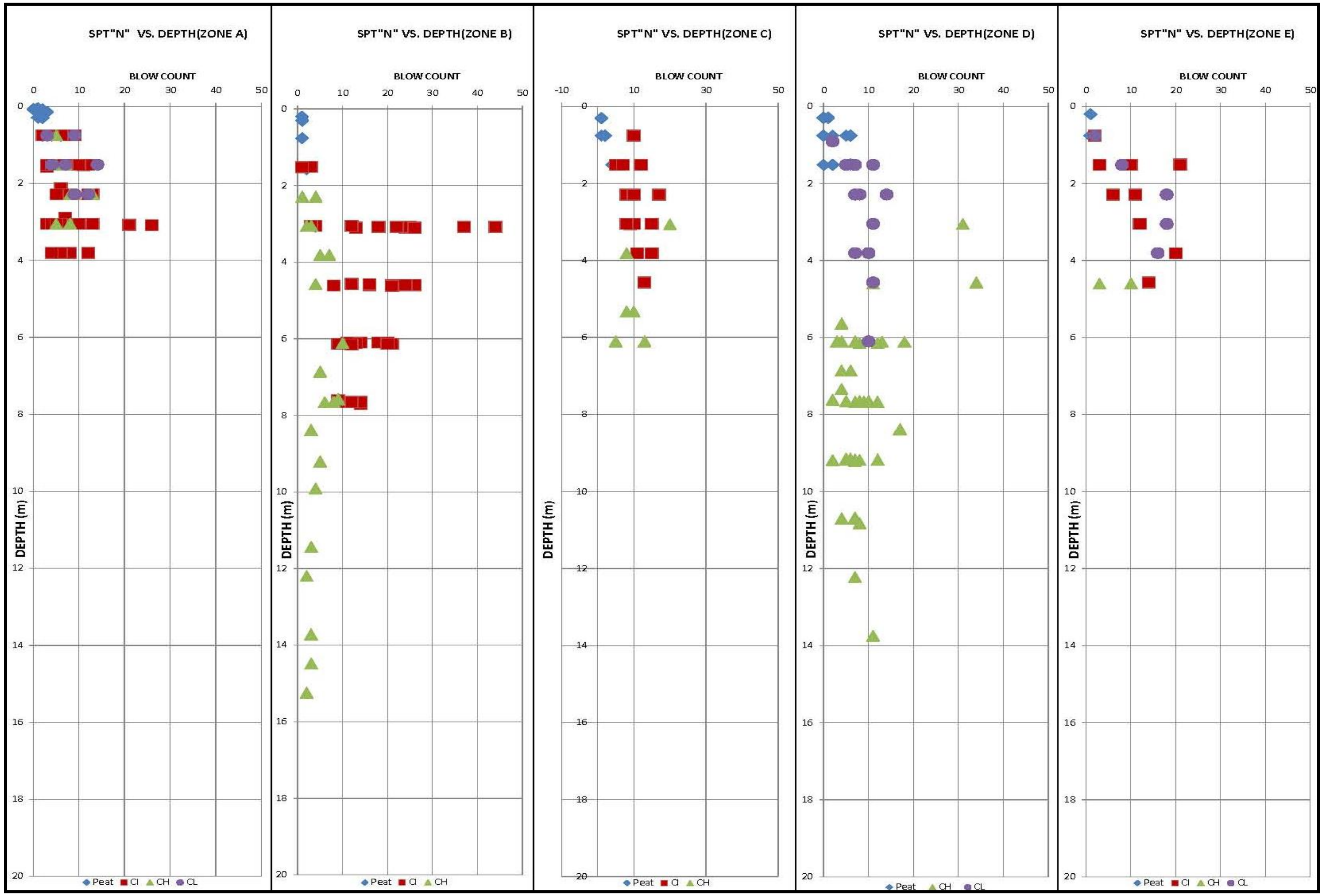
7.3.3.3.2 Low Plasticity Clay (CL)

Low plasticity clay was encountered in places underlying the peat. Based on the results of particle size analyses, this deposit is composed of 48 to 68% of clay, 28 to 44% silt and 4% to 8% sand. A trace of gravel was encountered in places within this clay deposit. The stratum was generally



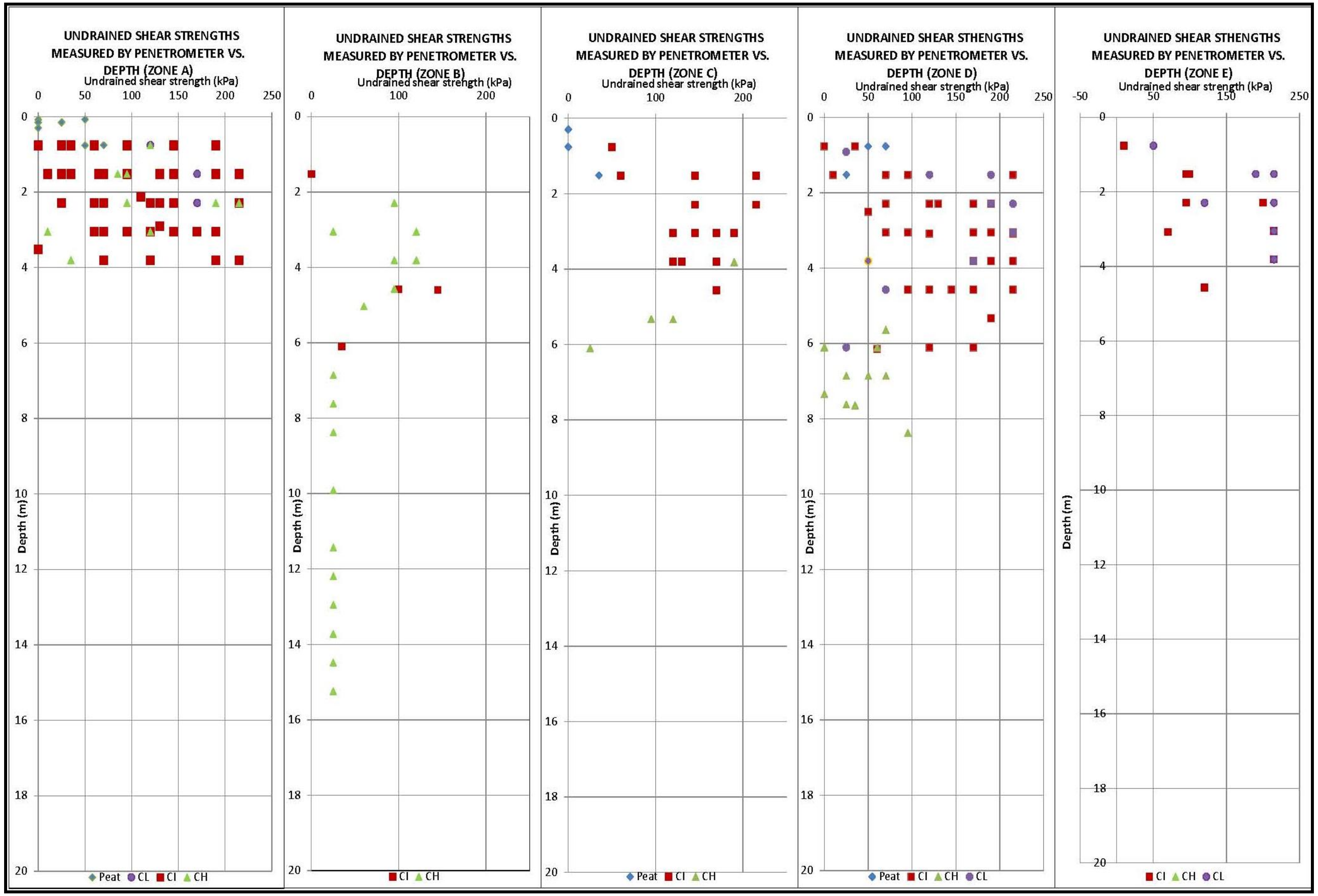
Source: Wardrop, 2009b

Figure 7.3-4 Variation of Natural Moisture Contents with Depth by Zones



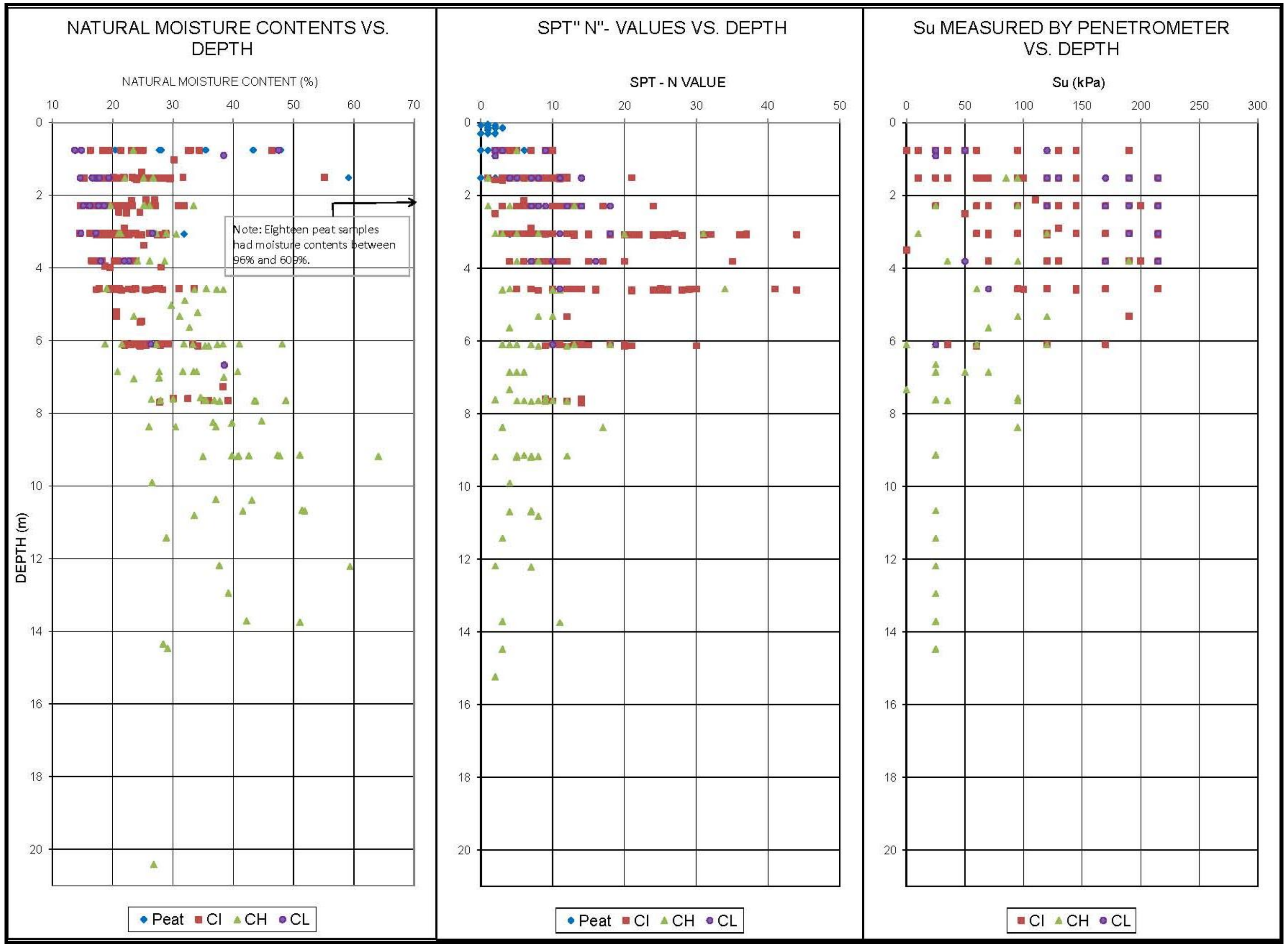
Source: Wardrop, 2009b

Figure 7.3-5 Variation of SPT "N" Values with Depth in the Clay by Zones



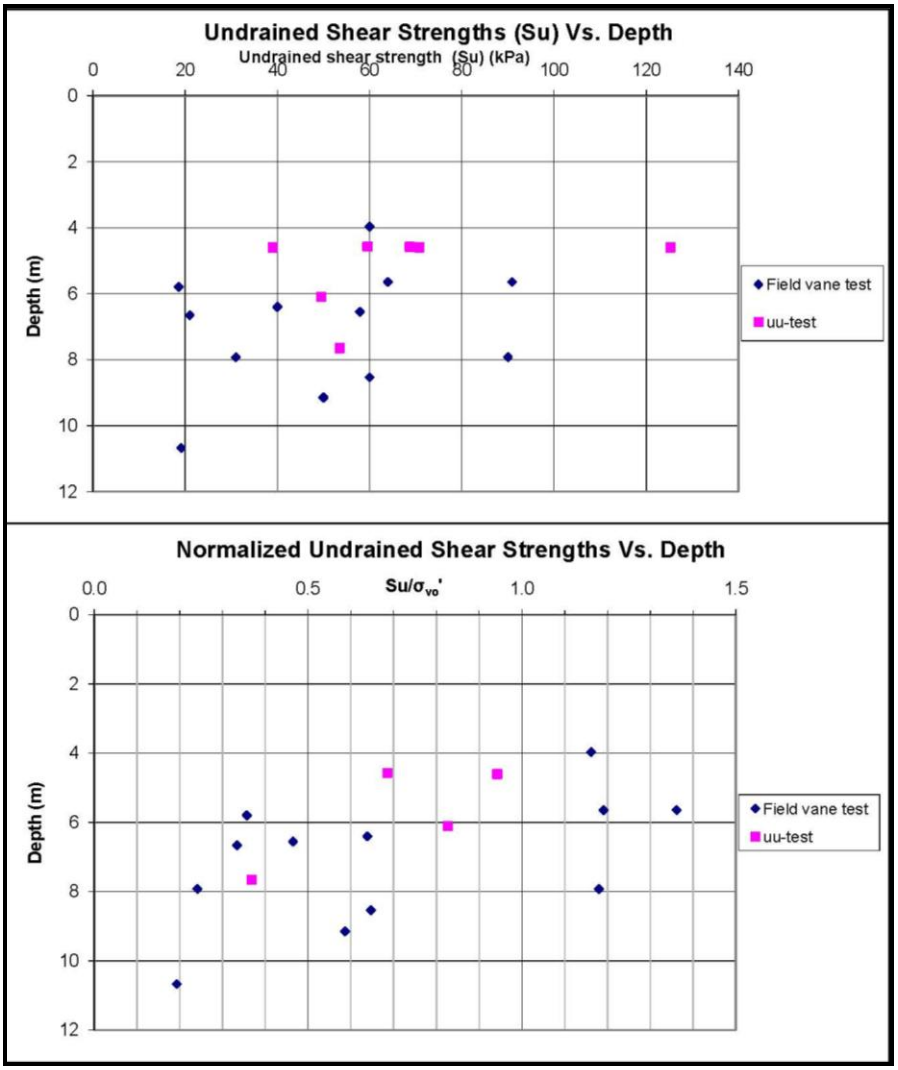
Source: Wardrop, 2009b

Figure 7.3-6 Variation of Undrained Shear Strengths of the Clay with Depth by Zones



Source: Wardrop, 2009b

Figure 7.3-7 Variation of Measured Moisture Contents, SPT "N"-Values and Undrained Shear Strengths with Depth in the Clay



Source: Wardrop, 2009b

Figure 7.3-8 Variation of Undrained Shear Strengths with Depth

brown to grey and moist to wet. The thickness of the stratum varied from 1.8 m to 4.0 m, averaging 3.0 m (Wardrop, 2009b).

The natural moisture contents of tested samples obtained from this deposit were between 14% and 48%, averaging 21%. Based on an Atterberg limits test, its liquid limit, plastic limit and plasticity index were 35%, 16% and 19%, respectively. SPT ‘N’ values of 2 blows per 0.3 m were generally recorded at the surface of this deposit suggesting a very soft consistency. This soft layer was normally within 1 m below the peat. Further down, the clay formation became firm to stiff with an average N-value of approximately 12 blows per 0.3 m. The unit weight of this clay was 18.1 kN/m³.

The undrained shear strength (Su) measured by Pocket Penetrometer (PP) testing ranged from less than 25 kPa to greater than 215 kPa and averaging about 158 kPa. A nilcon vane test conducted at a depth of 7.9 m in Borehole TD3 yielded an undrained shear strength of 31 kPa (Wardrop, 2009b).

7.3.3.3.3 Intermediate Plasticity Clay (CI)

Intermediate plasticity clay was encountered extensively across the site. This unit was found either immediately underlying the peat or below the low plasticity clay described in the preceding section. Based on the results of particle size analyses, this deposit is composed of 38 to 58% clay, 38 to 47% silt and 4% to 15% sand. A trace of gravel within this clay deposit was encountered in places. This clay was generally brown to grey and moist to wet. The thickness of the stratum varied from 0.5 m to 7.0 m, averaging approximately 3.4 m (Wardrop, 2009b).

The natural moisture contents ranged between 14% and 55%, averaging 23%. Liquid limits, plastic limits and plasticity indices in this deposit ranged from 33% to 54%, 15% to 22% and 18% to 32%, respectively. SPT ‘N’ values ranged between 1 and 54 blows per 0.3 m with an average N-value of 13 blows per 0.3 m, indicating very soft to hard, but generally stiff consistency. Low N-values (i.e. 1 to 2 blows per 0.3 m) indicating very soft consistency were recorded directly underneath the peat (Wardrop, 2009b).

The undrained shear strength (Su) inferred from Pocket Penetrometer (PP) testing ranged from 0 to greater than 215 kPa, averaging approximately 117 kPa. A nilcon vane test and a standard vane test conducted in Borehole TD4 yielded undrained shear strengths of 58 and 60 kPa, respectively. Based on the results of the standard vane test carried out in Borehole TD4, the sensitivity, which is the ratio of the undisturbed to remoulded shear strengths, of this type of clay was 2.1. The results of unit weight tests averaged to 19.6 kN/m^3 (Wardrop, 2009b).

Consolidated Undrained (CU) Triaxial tests with pore pressure measurements were carried out on undisturbed (Shelby tube) samples recovered from BH7, BH11 and BH29. Three samples were trimmed from each Shelby tube and tested under different confining pressures. Each specimen was saturated using the backpressure technique, consolidated and then subjected to compressive loading. The results of the tests, including gradation characteristics, initial and final state parameters (moisture contents, unit weights, void ratios, etc.) as well as the relevant compression shear test charts (e.g. stress-strain charts, stress paths, failure envelopes, etc.) are provided elsewhere (Wardrop, 2009b).

Based on obtained test results, the intermediate plasticity clay unit is considered to be in an over-consolidated state. The average over-consolidation ratio is 2.2. The average compression index (C_c) and recompression index (C_r) were 0.13 and 0.06, respectively (Wardrop, 2009b).

Hydraulic conductivity tests were carried out on undisturbed Shelby tube samples taken from BH9, BH10, and BH15. The tests were conducted under a pressure of 50 kPa applied to the samples. The results of these tests are summarized in Table 7.3-3.

Table 7.3-3 Measured Hydraulic Conductivities for Undisturbed CI Clay Samples

Borehole Sample	k (cm/s)
BH9-3	$6.0x10^{-9}$
BH10-2	$5.0x10^{-7}$
BH15-2	$2.0x10^{-6}$

Source: Wardrop, 2009b

Hydraulic conductivity perrmeability tests were also conducted on a disturbed sample taken from BH40, a combined sample from Boreholes TD4/TD6/TD10/TDA9, a combined sample from Boreholes TD1/TD2/TD13 and a combined sample from Boreholes SL4/SL5/SL6. Prior to the hydraulic conductivity test, these samples were compacted to 95% of their Standard Proctor Maximum Dry Density (SPMDD) (Wardrop, 2009b). The results of the permeability tests are summarized in Table 7.3-4.

The results of these hydraulic conductivity tests show that this type of clay, in compacted condition, is somewhat less permeable than in its natural state.

Table 7.3-4 Measured Hydraulic Conductivities for Compacted CI Clay Samples

Borehole – Sample	k (cm/s)
BH40-2	$7.0x10^{-9}$
Combined TD4/TD6/TD10/TDA9	$1.1x10^{-8}$
Combined TD1/TD2/TD13	$1.4x10^{-8}$
Combined SL4/SL5/SL6	$1.6x10^{-7}$

Source: Wardrop, 2009b

7.3.3.3.4 High Plasticity Clay (CH)

High plasticity clay (CH) is also present extensively across the site. This stratum was found either immediately underlying the peat or below the CL and CI clay. The presence of high plasticity clay appears to be dependent upon the overburden thickness. This unit is generally absent in areas where the overburden is less than 3 m thick. Its thickness increases proportionally with the increased overburden depth reaching a maximum of 9 m in Borehole BH10, where the total overburden was found to be 15 m thick. In a particular case, i.e. Borehole WD8 (sinkhole), the CH unit was 19 m in thickness. The average thickness of the CH stratum was approximately 3.5 m (Wardrop, 2009b).

Based on the results of the particle size analyses, the high plasticity clay is composed of 50 to 70% clay, 15% to 40 silt and 5% to 10% sand and gravel. Based on gradation characteristics, CH can be described as clay to clay and silt, with traces of sand and gravel (Wardrop, 2009b).

The natural moisture content of the tested samples obtained from this deposit varied from 19% to 64%, averaging 32%. Liquid limits, plastic limits and plasticity indices in this stratum ranged from 44% to 63%, 16% to 24% and 28% to 40%, respectively. SPT 'N' values between 1 and 34 blows per 0.3 m were recorded in this deposit indicating very soft to hard, but generally stiff consistency. The average N-value was found to be 8 blows per 0.3 m. Similar to CL and CI units, a soft layer, with up to 1 m in thickness, was found directly underneath the peat. The undrained shear strength (Su) inferred from Pocket Penetrometer (PP) testing ranged from 0 kPa to 215 kPa, averaging 67 kPa. The results of unit weight tests averages 18.6 kN/m^3 (Wardrop, 2009b).

Field nilcon vane tests and standard vane tests carried out at selected locations during site investigation indicate that the Undrained Shear Strength for this unit ranges from 19 kPa to 58 kPa and from 40 to 90 kPa, respectively, averaging 50 kPa. Based on the results of six standard vane tests carried out in Boreholes TD4, TD6, WD8 and RR2, the sensitivity, which is the ratio of the undisturbed to remoulded shear strengths, of this type of clay varied from 1.8 to 2.9 (Wardrop, 2009b). Unconfined Compression test conducted on a Shelby tube sample obtained from Borehole BH8 yielded an undrained shear strength of 53 kPa. The results of these tests are given elsewhere (Wardrop, 2009b).

Based on obtained test results, the CH clay unit is considered to be normally consolidated. The tests suggest that the clay has relatively high compressibility (average compression index (C_c) and recompression index (C_r) of about 0.26 and 0.11, respectively) (Wardrop, 2009b).

Hydraulic conductivity tests were conducted on three selected undisturbed Shelby tube samples taken from boreholes SL5, TD6, and TD13. The tests were conducted under pressures of 80 kPa, 140 kPa and 140 kPa applied to the samples, respectively. The results of hydraulic conductivity tests are summarized in Table 7.3-5.

Table 7.3-5 Measured Hydraulic Conductivities for CH Clay Samples

Borehole – Sample	k (cm/s)
SL5-ST	$7.0x10^{-9}$
TD6-ST	$3.8x10^{-9}$
TD13-ST1	$6.8x10^{-9}$

Source: Wardrop, 2009b

7.3.3.3.5 Glacial Till

Localized glacial till unit was found between the clay and the limestone bedrock. The thickness of the stratum was approximately 1.1 m. This unit is broadly graded and is generally composed of

12 to 30% clay, 23 to 35% silt, 33 to 35% sand and 27% to 30% of gravel. SPT-N values recorded in the till were generally greater than 8 blows per 0.3 m (Wardrop, 2009b).

7.3.3.3.6 Dolomite Bedrock

Dolomite bedrock was encountered at variable depths across the site. The greatest depth to the limestone bedrock surface was encountered at the southeastern portion of the site where it lies at approximately 23 m below the ground surface. This area is a suspected sinkhole or an area of deeper bedrock scouring during the glacial retreat. Presence of similar features in bedrock topography at other locations is probable (Wardrop, 2009b).

An elongated dolomite ridge (subcrop/outcrop) with generally south-north orientation is present at the northwestern site limit (Figure 7.3-1). The dolomite encountered in drill cores was generally fine grained with some shell fossils. In some boreholes, the bedrock was found highly weathered from its surface to depths of about 1.2 m. Elsewhere, the Rock Quality Designation (RQD) was generally between 50% and 100%, averaging 83%, indicating fair to excellent, but generally good quality bedrock (Wardrop, 2009b).

Packer test results were obtained for sections between 3 m and 6 m below the bedrock surface in 11 boreholes. The hydraulic conductivity (secondary permeability) calculated from the packer tests ranged from 1.3×10^{-4} cm/s to 1.3×10^{-3} cm/s, indicating relatively permeable characteristics of the bedrock (Wardrop, 2009b). The measured hydraulic conductivities (k values) are summarized in Table 7.3-6.

Table 7.3-6 Summary of Packer Tests for Dolomite Bedrock

Borehole	Depth (m)		k (cm/s)
	From	To	
SP2	11.4	14.4	9.7×10^{-4}
SP3	10.5	13.5	1.3×10^{-3}
SP5	11.7	14.7	1.3×10^{-3}
TD12	10.4	13.4	7.7×10^{-4}
TD13	7.5	10.5	1.0×10^{-3}
TD14	8.4	11.4	3.9×10^{-4}
TD2	6.6	9.6	1.4×10^{-4}
TD4	21.0	24.0	1.3×10^{-4}
WD1	6.6	9.6	8.2×10^{-4}
WD3	6.3	9.3	4.1×10^{-4}
WD8	6.0	9.0	3.6×10^{-4}

Source: Wardrop, 2009b

Uniaxial Compressive Strength (UCS) tests and Dynamic Shear Modulus tests were conducted on selected dolomite core samples. The samples tested were obtained from the footprint currently proposed for the TWRMF. The tests were completed at Queen's University Mining Engineering Rock Mechanics Laboratory in July and August 2008 (Wardrop, 2009b). The test results are summarized in Tables 7.3-7 and 7.3-8.

Table 7.3-7 Uniaxial Compressive Strength Tests in Dolomite

Borehole	Depth (m)	Density (T/m³)	UCS (MPa)	Young's Modulus (GPa)	Poisson's Ratio
CR1	7.1	2.67	108	36.49	0.20
CR2	6.3	2.62	87	38.48	0.21
CR3	6.9	2.66	118	39.88	0.21
CR4	6.8	2.66	88	31.88	0.15
CR5	7.7	2.66	105	41.72	0.17
MB1	5.5	2.54	78	34.11	0.24
MB2	5.3	2.57	129	38.05	0.23
MB3	6.3	2.62	83	34.21	0.22
SP2	3.4	2.57	72	34.16	0.19
SP3	6.2	2.64	116	39.44	0.18
SP5	4.6	2.59	103	41.07	0.18

Source: Wardrop, 2009b

Table 7.3-8 Dynamic Shear Modulus Tests in Dolomite

Borehole	Depth (m)	Solids Density (T/m³)	Shear Velocity (km/s)	Dynamic Shear Modulus (GPa)
SP2	4.9	2.56	3.32	28.29
SP3	5.0	2.60	3.24	27.20
SP5	7.9	2.66	3.59	34.21
MB1	3.9	2.66	2.99	23.81
MB2	4.1	2.57	3.09	24.49
MB3	6.9	2.41	3.00	21.68
CR1	6.8	2.41	3.47	28.99
CR2	7.3	2.66	3.39	30.62

Source: Wardrop, 2009b

7.3.3.3.7 Tailings Characteristics

The grain size distribution test showed that the tailings sample was relatively fine grained, containing 5% clay, 77% silt and 18% fine sand. Atterberg limits test gave a liquid limit of 42%, a plastic limit of 28% and a plasticity index of 14%. A standard Proctor test resulted in a maximum dry density of 1,697 kg/m³ at an optimum moisture content of 16.6%. The initial pulp density for both, drained and undrained conditions was 1.39 t/m³. When the test was completed nine days later, the density in drained and undrained conditions had increased to 1.66 T/m³ and 1.54 T/m³, respectively. The laboratory test results are given in Wardrop (2009b).

Hydraulic conductivity tests on two combined tailings samples (i.e. on initially dry specimen and on slurried sample) were carried out by SGS Minerals Services in Lakefield, ON (SGS) using the falling head testing method. Prior to conducting the tests, both samples were saturated. Based on the test results, the coefficients of permeability "k" were 8.2 x 10^{-6} cm/s and 2.0 x 10^{-5} cm/s for the initially dry and slurried samples, respectively (Wardrop, 2009b).

An air drying test was carried out by SGS on a combined tailings sample. The test results show that the bulk of the volume reduction at average room temperature with relative humidity varying between 20 and 50% occurs during the first 800 hours. Details of the test results are given in Wardrop (2009b).

Static and laboratory kinetic subaqueous column test results indicate that potential tailings material is NAG, due to very low sulphide sulphur content and moderate carbonate mineral content (URS, 2009i).

7.3.3.4 Surficial Groundwater Conditions

A total of 96 groundwater observation wells were installed as part of the geotechnical investigation. Seventy-two wells were installed in the overburden and 24 in the bedrock. The groundwater levels in the monitoring wells were measured between 1 day and more than 2 weeks after completion of the boreholes. The results of the ground water observations are listed in Tables 7.3-9 and 7.3-10.

A general representation of surficial groundwater conditions for different zones at the site is shown in Figure 7.3-9. A histogram of average piezometric levels originating from overburden and bedrock is presented in Figure 7.3-10.

As shown in Figure 7.3-9, piezometric levels in the wells with screen in the overburden were generally found within 1.0 m below the ground surface across the site. However, in some wells installed in boreholes in Zone D (BH8, BH13, BH19, and TD3), the groundwater levels were recorded at significantly greater depths, i.e. ranging from 5.7 m to 8.6 m (Wardrop, 2009b). This is also reflected on Figure 7.3-10 showing the average groundwater levels.

The piezometric heads recorded in the wells with screen in the dolomite bedrock indicate a confined aquifer with the exclusion of the bedrock outcrop in Sector E. These records are in general compliance with the interpretations presented by Golder Associates (2008b). In general, the heads reached within the uppermost 1.5 metres from the ground surface and in most cases

Table 7.3-9 Groundwater Level Measurements in Overburden

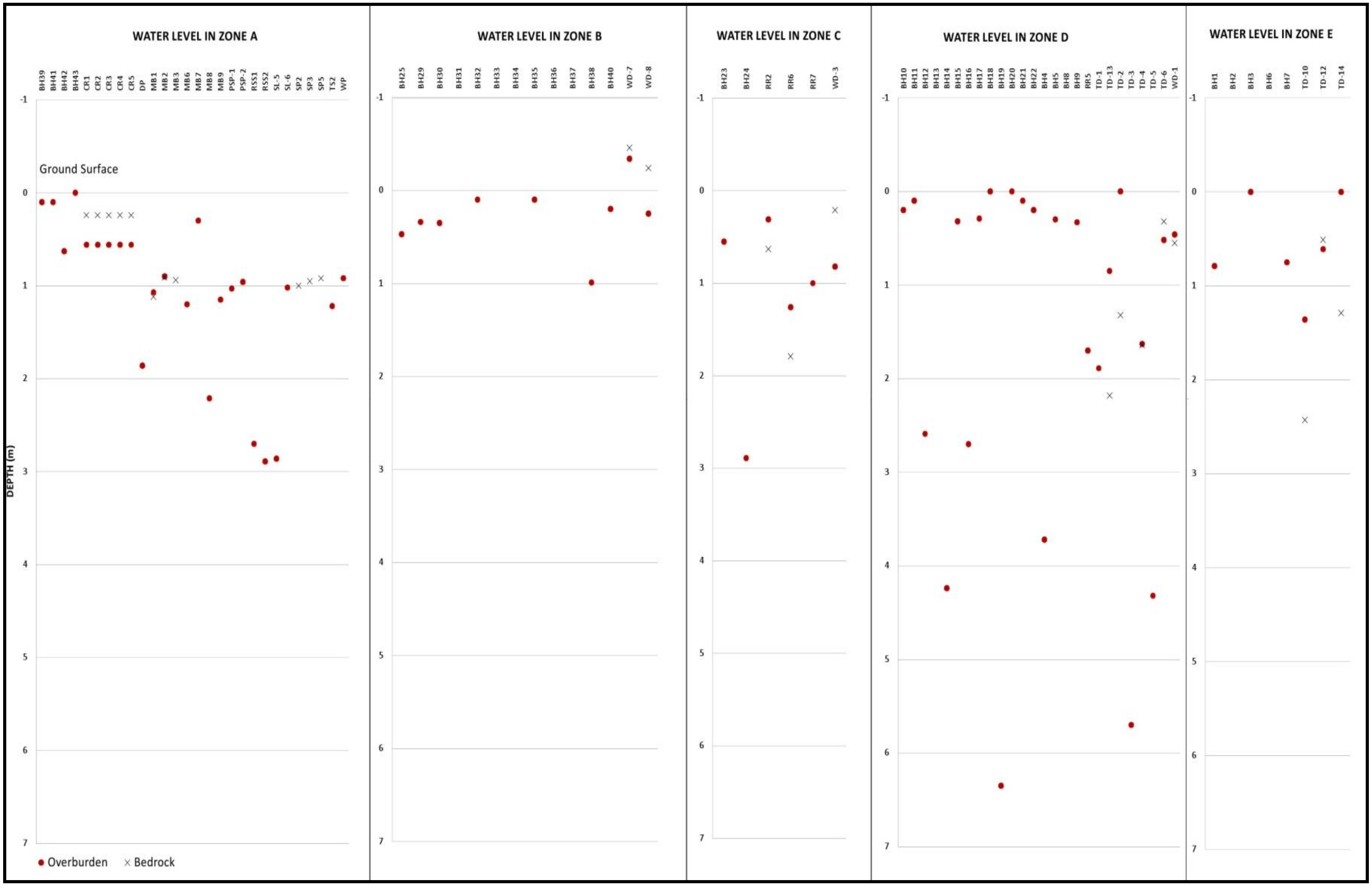
Zona A			Zone B			Zone C			Zone D			Zone E		
BH	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**
BH39	2/29/2007	0.1	BH25	2/29/2007	0.5	BH23	2/29/2007	0.6	BH10	2/29/2007	0.2	BH1	2/29/2007	0.8
BH41	2/29/2007	0.1	BH29	2/29/2007	0.3	BH24	2/29/2007	2.9	BH11	2/29/2007	0.1	BH3	2/29/2007	0.0
BH42	2/29/2007	0.6	BH30	2/29/2007	0.4	RR2	3/6/2008	0.3	BH12	2/29/2007	2.6	BH7	2/29/2007	0.8
BH43	2/29/2007	0.0	BH32	2/29/2007	0.1	RR6	3/6/2008	1.2	BH13	2/29/2007	8.6	TD-10	4/13/2008	1.4
CR1	3/6/2008	0.6	BH35	2/29/2007	0.1	RR7	4/13/2008	1.0	BH14	2/29/2007	4.2	TD-12	4/13/2008	0.6
CR2	3/6/2008	0.6	BH38	2/29/2007	1.0	WD-3	4/13/2008	0.8	BH15	2/29/2007	0.3			
CR3	3/6/2008	0.6	BH40	2/29/2007	0.2				BH16	2/29/2007	2.7			
CR4	3/6/2008	0.6	WD-7	3/6/2008	-0.3				BH17	2/29/2007	0.3			
CR5	3/6/2008	0.6	WD-8	3/6/2008	0.3				BH19	2/29/2007	6.4			
DP	3/6/2008	1.9							BH21	2/29/2007	0.1			
MB1	3/6/2008	1.1							BH22	2/29/2007	0.2			
MB2	3/6/2008	0.9							BH4	2/29/2007	3.7			
MB3	3/6/2008	FROZEN							BH5	2/29/2007	0.3			
MB6	3/6/2008	1.2							BH8	2/29/2007	7.8			
MB7	3/6/2008	0.3							BH9	2/29/2007	0.3			
MB8	3/6/2008	2.2							RR5	4/13/2008	1.7			
MB9	3/6/2008	1.2							TD-1	4/13/2008	1.9			
PSP-1	3/6/2008	1.0							TD-13	4/13/2008	0.9			
PSP-2	3/6/2008	1.0							TD-2	4/13/2008	FROZEN			
RSS1	3/6/2008	2.7							TD-3	4/13/2008	5.7			
RSS2	3/6/2008	2.9							TD-4	4/13/2008	1.6			
SL-5	4/13/2008	2.9							TD-5	3/27/2008	4.3			
SL-6	4/13/2008	1.0							TD-6	4/13/2008	0.5			
SP2	3/6/2008	FROZEN							WD-1	4/13/2008	0.5			
SP3	3/6/2008	FROZEN												
SP5	3/6/2008	FROZEN												
TS2	4/13/2008	1.2												
WP	3/6/2008	0.9												
Highest GW Level		0.0			-0.3			0.3			0.1			0.0
Lowest GW Level		2.9			1.0			2.9			8.6			1.4
Average depth		1.1			0.3			1.1			2.4			0.7

Source: Wardrop, 2009b

Table 7.3-10 Groundwater Level Measurements in Bedrock

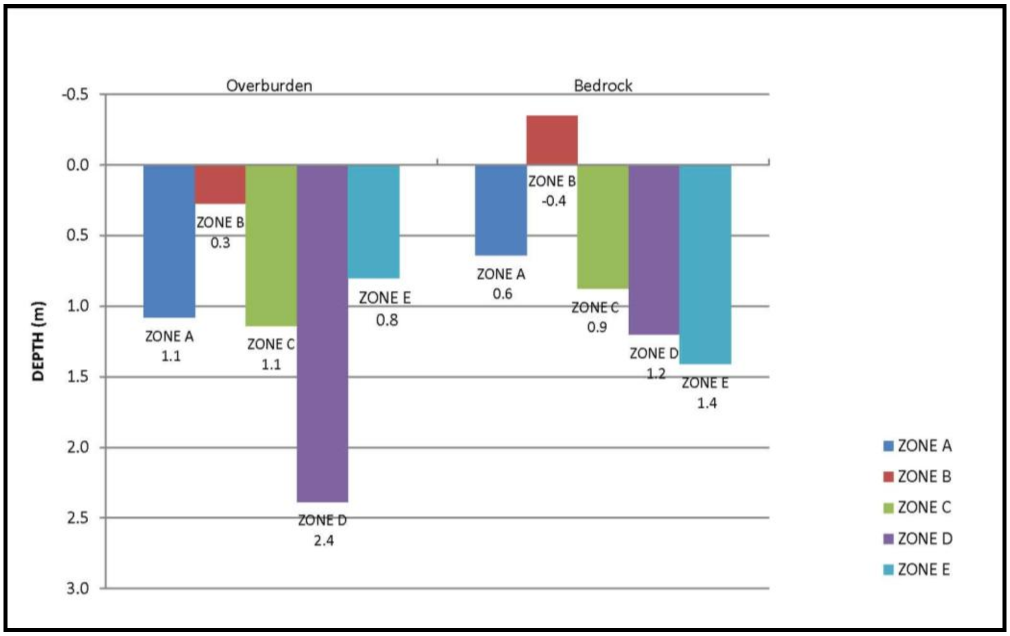
Zone A			Zone B			Zone C			Zone D			Zone E		
BH	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**
CR1	3/6/2008	0.2	WD-7	3/6/2008	-0.5	RR2	3/6/2008	0.6	TD-13	4/3/2008	2.2	TD-10	4/3/2008	2.4
CR2	3/6/2008	0.2	WD-8	3/06/2008	-0.2	RR6	3/6/2008	1.8	TD-2	4/3/2008	1.3	TD-12	4/3/2008	0.5
CR3	3/6/2008	0.2				WD-3	4/3/2008	0.2	TD-4	4/3/2008	1.6	TD-14	4/3/2008	1.3
CR4	3/6/2008	0.2							TD-6	4/3/2008	0.3			
CR5	3/6/2008	0.2							WD-1	4/3/2008	0.6			
MB1	3/6/2008	1.1												
MB2	3/6/2008	0.9												
MB3	3/6/2008	0.9												
SP2	3/6/2007	1.0												
SP3	3/6/2008	1.0												
SP5	3/6/2008	0.9												
Highest GW Level		0.2			-0.5			0.2			0.3			0.5
Lowest GW Level		1.1			-0.2			1.8			2.2			2.4
Average depth		0.6			-0.4			0.9			1.2			1.4

Source: Wardrop, 2009b



Source: Wardrop, 2009b

Figure 7.3-9 Groundwater Levels by Zones



Source: Wardrop, 2009b

Figure 7.3-10 Average Measured Groundwater Levels in Overburden and Bedrock

were somewhat higher (up to 0.5 m) than the ones measured in the overburden clays. This is clearly depicted on Figure 7.3-10. Artesian conditions were measured in Boreholes WD-7 and WD-8 where the piezometric heads reached 0.5 m above the ground surface (Wardrop, 2009b). Piezometric levels in Zone E were generally lower in the bedrock than in the overburden clay (Figure 7.3-10).

7.3.4 Terrain Stability

Terrain stability is a function of bedrock, surficial material, soil texture and thickness, surface expression, potential slip plains, slope, slope position, slope curvature, drainage, and vegetation. The terrain stability hazard classification was based on the criteria outlined in Table 7.3-11. This Table, adopted from work completed in British Columbia (Anonymous 1999), provides a brief interpretative description for each slope stability hazard class and outlines the major management implications expected of operations within the class.

7.3.4.1 Potential Surface Erosion

Erosion via water is the predominate form of erosion in the project area and was the focus of this assessment. Water erosion generally results in the formation of gullies and, on moraine, in the development of gravel covered surfaces where finer particles have been washed away. Surface erosion potential is a qualitative assessment of the potential for sediment generation during and after vegetation removal and construction. Areas of major concern are sensitive landforms, roads, recent landslides, and sites subjected to excessive anthropogenic disturbance.

Table 7.3-11 Terrain Stability Hazard Classification

Terrain Stability Class	Reconnaissance Stability Class	Interpretation
S	Stable	• Minor stability problems can develop. • Vegetation removal should not significantly reduce terrain stability. There is low likelihood of landslide initiation following vegetation removal. • Minor slumping is expected along road cuts, especially one or two years following construction. There is a low likelihood of landslide initiation following road building. • A field inspection by a terrain specialist is usually not required.
P	Potentially unstable	• Expected to contain areas with a moderate likelihood of landslide initiation following vegetation removal and/or road construction. Wet season construction or construction on sites underlain by permafrost will significantly increase the potential for road-related landslides. • A field inspection of these areas is to be made by a qualified terrain specialist prior to any development to address the stability of the affected area.
U	Unstable	• Expected to contain areas with a high likelihood of landslide initiation following vegetation removal or road construction. Wet season construction or construction on sites underlain by permafrost will significantly increase the potential for road-related landslides. • A field inspection of these areas is to be made by a qualified terrain specialist prior to any development to address the stability of the affected area.

Source: Anonymous, 1999.

Table 7.3-12, adopted from Anonymous (1999), provides a brief explanation for each surface erosion potential class mapped within the project area.

Factors influencing surface erosion include vegetative cover, soil texture, depth of surficial materials, vegetative cover, slope gradient and geometry, soil drainage and most importantly, surface water flow. The amount of surface water flow is a function of the amount of precipitation, soil permeability, and soil depth. In areas with high precipitation or snow melt, shallow soils and impermeable soils contribute to an increase in groundwater flow, which increases erosion.

Vegetative cover helps prevent erosion by decreasing the rate at which precipitation reaches the ground via leaves and stems, by forming a protective layer of moss and litter directly on the ground surface, and by anchoring soil in its place via roots. Slope gradient and geometry also play a major role in determining erosion. Increasing slope steepness increases the speed and

Table 7.3-12 Surface Erosion Potential Classification

Surface Erosion Potential Classes	Surface Erosion Potential	Interpretation
L	Low	• Flat to gently sloping, short slopes including flood plains and organics. • Disturbance of streams could initiate some bank and channel erosion. • Expect minor erosion of fines from ditch lines and disturbed soils. • Exercise care not to channelize water on more sensitive areas.
M	Moderate	• Moderately steep and long slopes and erodible soil textures including fine-textured materials. • Plan preventative remedial actions for disturbed slopes and sites underlain by permafrost. • Expect problems with water channelized down road ditches and across disturbed areas. • Water management is critical. • Plan for complete road deactivation. • Grass seed all disturbed sites.
H	High	• Moderately steep to steep slopes and highly erodible soil textures. • Sites with active surface erosion or gullying. • Major problems exist with water channelized on to or over these sites. • Problem avoidance may permit road development. • Immediate revegetation of all disturbed sites. • Severe surfaces and gully erosion problems exist. • Erosion concerns may take precedence over site disturbance.

Source: Anonymous, 1999

eroding potential of the surface water as it flows down the slope. An increase in speed also reduces the time that water has for infiltrating the ground thus contributing to increased surface flow. Erosion potential also increases with increasing slope length because longer slopes can receive and transmit a greater amount of rain or meltwater in total.

Soil texture not only influences soil permeability thus influencing surface water flow, but it also determines the ease by which the soil may be eroded. This is due to factors such as particle size and cohesiveness. Intermediate sized particles such as silt are the most easily eroded. Larger sand particles are not as easily eroded due to their higher cohesion values.

7.3.4.2 Terrain Hazards

Approximately 95% of the project area was classified as 'stable'. The site terrain is low and there are no signs of steep gully side walls and no side wall slumps.

7.3.4.2.1 Flooding Hazards

Floods related to ice-jams, snowmelt and summer rainstorms are possible hazards in lower reaches of most streams in the area. The potential for flooding is low considering the Minago Project site is located further upstream of the Oakley Creek watershed and occupies a small portion of the Oakley Creek watershed.

7.3.4.2.2 Erosion Potential

Ninety-five percent (95%) of the project area was rated as having a low erosion potential due to the occurrence of low terrain throughout the project area.

7.3.5 Effects Assessment Methodology

The objective of this assessment is to predict project and cumulative effects of the Minago Project on terrain, surficial materials and soils; to identify mitigation measures to both minimize adverse effects and associated impacts to terrestrial and aquatic habitat; and to support sound project design. In terms of selected VECCs (Valued Ecosystem and Cultural Components), this assessment concentrates on project effects on:

- surficial materials – alterations to existing surficial material affects local topography, drainage and soil character with associated effects on capacity to support vegetation and related ecological values;
- erosion potential – this is a key issue with any project involving ground disturbance with implications for the design of water management systems and protection of aquatic environments; and
- terrain hazards – this is of concern with respect to both project effects on terrain stability and effects of terrain stability on design and maintenance of facilities.

Information on the key terrain feature (river valleys only as there are no mountains) VECCs has been integrated in the terrain hazards and erosion potential. Further, there are no notable or unique terrain features that will be affected by the project. Information on the sensitive soils VECC has been integrated into the assessment of effects on the other three VECCs.

Potential interactions between project facilities locations and activities and identified VECCs are discussed along with mitigative best practices and requirements for site specific follow-up investigations. Residual project effects, assuming implementation of mitigation measures and follow-up investigations are characterized using the definition of effects attributes provided in Table 7.3-13. Implications of effects to reclamation and capacity for site revegetation are discussed in Section 3.4: Decommissioning and Closure Activities. The ecological context for identified effects on terrain, surficial materials and soils is discussed in Section 7.4: Surface Water Hydrology; Section 7.7: Benthos, Periphyton and Sediment Quality; Section 7.8: Fish Resources; Section 7.9: Vegetation; and Section 7.10: Wildlife.

Table 7.3-13 Effect Attributes for Terrain, Surficial Geology and Soils

Attribute	Definition
Direction	
Positive	Condition of VECC is improving.
Adverse	Condition of VECC is worsening or is not acceptable.
Neutral	Condition of VECC is not changing in comparison to baseline conditions and trends.
Magnitude	
Low	Effect occurs that might or might not be detectable, but is within the range of natural variability and does not comprise economic or social/cultural values.
Moderate	Clearly an effect but unlikely to pose a serious risk to the VECC but does not require specific management from a geotechnical, ecological, economic or social/cultural standpoint.
High	Effect is likely to pose a serious risk to the VECC and represents a significant challenge from a geotechnical, ecological, economic or social/cultural standpoint.
Geographic Extent	
Site-specific	Effect on VECC confined to a single small area within the Local Study Area (LSA).
Local	Effect on VECC within Local Study Area (LSA).
Regional	Effect on VECC within Regional Study Area (RSA).
Duration	
Short term	Effect on baseline conditions or VECC is limited to the <1 year.
Medium term	Effect on baseline conditions or VECC occurs between 1 and 5 years.
Long-term	Effect on baseline conditions or VECC lasts longer than 5 years but does not extend more than 10 years after decommissioning and final reclamation.
Far future	Effect on baseline conditions or VECC extends > 10 years after decommissioning and abandonment.
Frequency (Short Term duration effects that occur more than once)	
Low	Effect on VECC occurs infrequently (< 1 day per month).
Moderate	Effect on VECC occurs frequently (seasonal or several days per month).
High	Effect on VECC occurs continuously.
Reversibility	
Reversible	Effect on VECC will cease to exist during or after the project is complete.
Irreversible	Effect on VECC will persist during and/or after the project is complete.
Likelihood of Occurrence[1]	
Unknown	Effect on VECC is not well understood and based on potential risk to the VECC, effects will be monitored and adaptive management measures taken, as appropriate.
High	Effect on VECC is well understood and there is a high likelihood of effect on the VECC as predicted.

Note: 1. Characterizes the investigator's confidence that effect will occur as predicted based on the status of scientific or statistical information, experience and/or professional judgement of the author.

7.3.6 Determination of Effects Significance

A residual project or cumulative effect on terrain, surficial materials and soils will be considered significant if it is:

- a high magnitude adverse effect unless it is local in geographic extent; and
- a high magnitude adverse effect that is local in geographic extent and far future (> 10 years) in duration.

Otherwise, effects will be rated as not significant.

7.3.7 Project Effects

Potential effects on VECCs for terrain, surficial materials and soils are discussed by project phase in the following sections. Effects will be greatest during the construction phase and generally persist until decommissioning and site reclamation. The project has been designed to minimize the disturbance footprint as much as possible. Within the LSA, specific areas of ground disturbance will include:

- the open pit mine, waste rock dumps and industrial complex in the upper Oakley Creek drainage;
- the camp, borrow area, and Tailings and Ultramafic Waste Rock Management Facility (TWRMF); and
- the mine access road right-of-way off Provincial Trunk Highway 6 (PTH6) in the upper Oakley Creek drainage.

Table 7.3-13 gives a summary of effect attributes for terrain, surficial geology and soils.

To the extent possible all disturbed areas that become redundant to project activities (spent borrow areas, redundant access roads, laydown areas, etc.) will be progressively reclaimed during the active life of the mine. Accordingly, effects on surficial materials and soils should gradually decrease over the mine life. Major site facilities will be reclaimed in two stages during the decommissioning phase. At the end of operations, the open pit mine and ore processing plant and related site drainage facilities will be decommissioned and the site will be recontoured and reclaimed as much as possible. The Tailings and Ultramafic Waste Rock Management Facility (TWRMF) will remain as a permanent pond feature with passive drainage to the Oakley Creek watershed. In the event that the Communities of Interest (COI) request for some of the transportation corridors (TCs) and facilities to be left in service at closure and during care and maintenance, additional arrangements will be made accordingly.

7.3.7.1 Construction

7.3.7.1.1 Surficial Materials

The construction phase will have the greatest incremental impact on the terrain, surficial geology, and soil VECCs in the project area. Project effects in this phase include mine site and road building processes such as land consumption, movement and alteration of surficial materials and corresponding reductions in soil capability. This includes alteration of the road and project facilities sites, as well as impacts caused by the removal of aggregate from borrow pits for use in surfacing the roads. Aggregate from borrow pits will also be used for construction material and to stabilize sites underlain by soft soils where required. Reduction of soil capability can be caused by a number of factors including loss of topsoil, creation of impermeable layers during overburden replacement, and soil compaction (e.g., bottom of borrow pits).

Various mitigation measures will be employed to minimize these effects. The project has been designed to minimize the disturbance footprint. Much of the mine site, waste rock dumps and industrial complex will be located in an area that has been previously modified by pre-mining (exploration, logging and natural fires) activities. The borrow pit is on level ground, which will facilitate reclamation. Other measures, outlined in Table 7.3-14, include topsoil salvage and stockpiling for use during reclamation, limiting soil compaction where applicable, by limiting clearing and site disturbance to periods when the soil is dry or frozen, and progressive reclamation of disturbed areas during construction (spent borrow areas, laydown areas, road right-of-way). Follow-up studies will be conducted to test soils and develop detailed quantities and remediation requirements, if any, for reclamation purposes (Section 3.4: Decommissioning and Closure Activities). Progressive reclamation throughout the life of the project will provide the opportunity to test reclamation approaches and modify them as required to optimize productive capacity of reclaimed areas.

Based on these mitigation measures, effects on surficial materials and soil capability are characterized as adverse, moderate in magnitude (effects are not expected to give rise to a geotechnical, economic, ecological or socio/cultural management issue beyond identified best practices), local, far future (the road will remain in place at closure for an undetermined period of time), and ultimately reversible. The likelihood of effects as predicted is high based on observations of effects and mitigation effectiveness at other similar developments.

There is a moderate probability that soils may be contaminated (with petroleum products through spills). Victory Nickel will establish a monitoring program to determine potential hot spots and develop mitigative and remediation measures to deal with contaminated soils. Additional information is given in Section 9: Environment Management Plans.

7.3.7.1.2 Erosion Potential

Approximately 95% of the LSA was classified as having a low erosion potential. For those areas with erosion potential, mitigation measures include limiting the amount of disturbance and implementation of the Erosion and Sediment Control Plan (Section 9: Environmental Management Plan). The implementation of the Site Water Management Plan (Section 2.14) will minimize the

Table 7.3-14 Mitigation Measures for Effects on Terrain, Surficial Geology and Soils

Potential Project Effect	Mitigation Measures
Soil compaction and reduction in soil capability during all phases of the project	• Pre-site inspections will allow avoidance, where applicable of sensitive soil types. • Site clearing will be timed to minimize soil compaction. To the extent possible, top soil will by removed and stored. • Where possible, borrow pit locations will be selected based on sites that can be easily reclaimed. • Where possible, disturbed sites will be promptly revegetated (progressive reclamation) with appropriate plant materials and fertilization. • During the decommissioning and closure phases, overburden (surficial materials) will be re-sloped and laid down to avoid the creation of impermeable material. • Site clearing will be minimized during all project phases.
Terrain stability concerns during all phases of the project	• Most disturbances will be restricted to times when soils are dry. • Where possible, disturbed slopes will be re-sloped to a 2H:1V ratio. • Where possible, subsurface and surface drainage will be controlled to prevent slope instability. This includes re-establishing surface drainage as soon as possible. • Pre-site inspections will allow avoidance, where applicable, of unstable or potentially unstable sites.
Soil erosion following disturbance during all project phases	• Sites will be assessed for soil erosion potential and measures to minimize the effects of any such erosion will be employed. • Installation of the site water management system (Section 2.14) during construction and operation throughout the project will minimize drainage and erosion from disturbed areas. • Implementation of the Erosion and Sedimentation Control Plan (Section 9: Environmental Management Plan) throughout the life of the project will reduce soil erosion. • Immediate revegetation with appropriate plant materials and fertilization on all disturbed sites (except roads and mining sites) will minimize this effect. • Where possible, disturbed slopes will be re-sloped to a 2H:1V ratio. • Sites will be cleaned up and progressively revegetated with appropriate plant species when no longer in use.

Table 7.3-14 (Cont.'d) Mitigation Measures for Effects on Terrain, Surficial Geology and Soils

Potential Project Effect	Mitigation Measures
Soil erosion on roads	• Detailed design of the access road will identify requirements for structural elements required for road drainage management, including standard storm water catch basins and/or various forms of check-dams or fords designed to slow drainage. • Implementation of the Erosion and Sedimentation Control Plan (Section 9: Environmental Management Plan) throughout the life of the project will reduce soil erosion. • Where practicable, water barring of roads will also be employed. • Extraneous roads will be reclaimed as soon as practicable. These include roads used for deposit sires and borrow pits, material treatment areas, quarries and other facilities. For example, progressive reclamation techniques will be employed. That is sites and roads will be reclaimed as portions of the project area are decommissioned and closed. Main roads within the project site will remain open until all sites have been decommissioned and closed. This will provide access for reclamation equipment. Once these sites have been reclaimed, applicable roads will be decommissioned.
Contaminated Soils	• Develop appropriate contigency and response measures. • Develop appropriate transport, storage and handeling procedures to contol spills. • Track the volume of hydrocarbons on site (used versus supplied). • Ensure that the oil transfer systems are contained appropriately. • Develop monitoring programs that will identify, if any, contaminated soils.

drainage catchment for disturbed sites and provide a settling pond to minimize effects on receiving streams. If disturbance does occur, sites will be promptly revegetated with appropriate plant materials (e.g., grass mix for quick cover). Sites will be assessed for soil erosion potential and measures to minimize the effects of any such erosion will be employed. Finally, artificial slopes will also be kept to 2H:1V ratios, where possible (Table 7.3-14).

Road erosion will be addressed through detailed planning and design. These processes will outline structural modifications needed during the design of roadways including standard storm water catch basins and/or various forms of check-dams or fords needed to slow drainage. Where practicable, water barring of roads will also be employed and roads will be reclaimed when no longer in use (i.e., exhausted borrow pits, deposit sites, material treatment areas, other facilities, etc.). Impacts on construction on areas of high erosion potentials are expected to be adverse, moderate in magnitude, medium term and irreversible. The likelihood of effects as predicted is high based on observations of effects and mitigation effectiveness at other similar developments.

7.3.7.1.3 Natural Terrain Hazards

Terrain stability concerns may also occur during this phase of the project. This is insignificant because approximately 95% of the LSA was classified as stable. The mapping component of this project combined with pre-site inspections will allow avoidance, where applicable, of unstable or potentially unstable sites and appropriate design to minimize risks to project facilities as a result of terrain hazards. Site disturbance, where practicable, will also be timed (i.e., dry soils) to minimize stability issues. Artificial slopes for the most part will also be kept to 2H:1V ratios. Where possible, subsurface and surface drainage will also be controlled. This includes re-establishing surface drainage as soon as possible (Table 7.3-14).

Impacts associated with terrain stability will be potentially problematic throughout all project phases. For example, moderate slumping can be expected for the first two years following any disturbance. Accordingly, effects of construction on terrain hazards are expected to be adverse, moderate, site specific, long-term and ultimately reversible. The likelihood of effects is unknown until pre-site investigations are conducted. There is a moderate probability that soils may be contaminated with petroleum products through spills. Victory Nickel will establish a monitoring program to determine potential hot spots and develop mitigative and remediation measures to deal with contaminated soils (Manitoba Conservation, 1998). Additional information is given in Section 9: Environment Management Plans.

7.3.7.2 Operations

During operation, there will be little incremental disturbance of surficial materials or terrain hazards or increased erosion. Effects attributes are expected to be similar to the construction phase although some reductions in magnitude are expected as a result of progressive reclamation. Similar mitigation measure will continue to be applied.

There is a moderate probability that soils may be contaminated with petroleum products through spills. Victory Nickel will establish a monitoring program to determine potential hot spots and develop mitigative and remediation measures to deal with contaminated soils. Additional information is given in Section 9: Environment Management Plans.

7.3.7.3 Decommissioning

7.3.7.3.1 Surficial Sediments

During the decommissioning phase, the majority of impacts on surficial materials are positive with the possible exception of soil compaction. Mitigation measures for soil compaction includes operating on sites when soils are relatively dry. The improvements will be the result of the replacement, re-sloping and revegetating of overburden (including top soil). Overburden will be placed to ensure that an impermeable layer is not created. On sites that have been contaminated or otherwise adversely affected, soils will be removed, placed in a landfill and replaced with soil.

Most impacts on soil erosion will be positive during this phase of the project. Once again, these changes will be the result of topsoil replacement, re-sloping (2H:1V ratio) and revegetation. Some short term site-specific increases in erosion may occur in areas of ground disturbance to decommission facilities and before revegetation. Site water management will remain in place as long as possible during decommissioning to minimize the drainage catchment in these areas prior to restabilization. During this phase, mine roads will be utilized and maintained for the use of reclamation equipment. Once decommissioning of facilities is complete, extraneous mine site roads will be water barred, re-contoured, revegetated and fertilized. The mine access road will remain in place. Stabilization and establishment of vegetation on disturbed areas associated with these facilities during operations will provide ongoing erosion control at closure.

There is a moderate probability that soils may be contaminated with petroleum products through spills. Victory Nickel will establish a monitoring program to determine potential hot spots and develop mitigative and remediation measures to deal with contaminated soils. Additional information is given in Section 9: Environment Management Plans.

7.3.7.3.2 Natural Terrain Hazards

Decommissioning may result in terrain stability issues. If they occur, these issues will be negative and residual. Mitigation measures include re-sloping, revegetating and controlling subsurface and surface drainage.

7.3.7.4 Closure

No further effects on terrain, surficial materials and soils are expected at closure when all the facilities sites have been stabilized and reclamation is complete.

7.3.7.5 Residual Project Effects and Significance

As noted above, effects on terrain, surficial materials and soils are expected to be greatest during the construction phase. At worst, the residual effects on the selected VECCs (surficial materials and soil capability, erosion potential and terrain hazards) are expected to adverse, moderate in magnitude, long-term to far future and ultimately reversible. Most impacts are also avoidable or manageable through planning, pre-disturbance field inspections, ongoing monitoring throughout the operational phase and the implementation of mitigation measures. These effects are determined to be not significant. Based on previous studies, science, observations elsewhere and professional experience there is a high likelihood that these effects will manifest as predicted.

7.3.8 Cumulative Effects

Residual effects on terrain, surficial geology, and soil VECCs are stationary in nature and were all classified as being either site specific or local in extent. There are no other past, present or reasonably foreseeable projects, which will overlap with or increase the magnitude of the effect within the LSA. Accordingly, no cumulative effects expected.

7.3.9 Mitigation Measures

Table 7.3-14 provides a summary of mitigation measures.

7.3.10 Monitoring and Follow-up

7.3.10.1 Monitoring Programs

Table 7.3-15 provides a summary of proposed monitoring and follow-up programs for terrain, surficial geology and soils that have been identified for monitoring project effects (construction, operation, decommissioning, and closure phases). These programs include:

- A seasonal terrain stability assessment monitoring program is needed in identified areas of potential risk to determine if facilities have an impact on terrain stability.
- Contingency plans will need to be implemented if unexpected effects occur.
- A seasonal soil erosion monitoring program is needed to check the effectiveness of the site water management and the Erosion and Sedimentation Control Plan and determine if the construction and operational phases have resulted in the erosion of surficial materials. Contingency plans will need to be implemented, if unexpected effects will have occurred.

In addition, geotechnical monitoring will be required at the site. The proposed geotechnical monitoring program is outlined in the next subsection.

7.3.10.1.1 Geotechnical Monitoring

The site conditions are complex and the feasibility designs are based on interpretation of the geotechnical data. The extrapolations and assumptions used in the designs are best confirmed using an observational method which is a common practice in geotechnical engineering. Geotechnical performance monitoring should be tailored to confirm the feasibility design assumptions. The results of monitoring and their assessment will provide advance warning against potential problems and will allow sufficient time to implement preventative actions, if required (e.g., establishment of alert levels and necessary actions). Also, the monitoring results could be potentially used in optimizing the design if the design assumptions prove to be too conservative.

Initial monitoring involving instrumented test fills and large scale dewatering experiments is recommended during the detailed design geotechnical investigation. Test fills are of particular importance in gaining greater confidence in assumptions on engineering performance of site peat under the Dolomite WRD and Country Rock WRD. Also, large scale peat dewatering experiments could be started during the detailed engineering design stage in preparation for site dewatering required for foundation excavation for major site facilities (such as the TWRMF dam and dyke of the Polishing Pond).

The balance of instrumentation installation and monitoring is recommended during construction/operation/closure. Stage 1 construction of the TWRMF dam and both waste rock

Table 7.3-15 Monitoring and Follow-up Programs for Terrain, Surficial Geology and Soils

Potential Project Effect	Program Objectives	General Methods	Reporting	Implementation
Follow-Up and Monitoring Programs				
Soil chemical conditions limiting reclamation success	• Determine soil chemistry. • Initiate contingency plans to address unexpected effects, as required.	• Soil sampling and chemical analysis prior to construction and soil salvage.	• Internal • MB Gov't as required	Proponent
Soil physical conditions limiting reclamation success	• Determine soil physical conditions. • Initiate contingency plans to address unexpected effects, as required. • Refine materials balance for reclamation planning.	• Soil test pits and trenches to characterize physical conditions, parent materials, depths and approximate volume of suitable soil materials for reclamation.	• Internal • MB Gov't as required	Proponent
Terrain stability concerns	• Perform on site terrain stability assessments prior to development. • Initiate contingency plans to address unexpected effects, as required.	• Terrain stability assessments will determine site specific stability issues.	• Internal • MB Gov't as required	Proponent
Soil Erosion concerns	• Identify surficial materials with high erosion potentials. • Initiate contingency plans to address unexpected effects, as required.	• Erosion potential assessments will determine site specific erosion issues.	• Internal • MB Gov't as required	Proponent
Monitoring Programs				
Terrain stability	• Determine if the project has had an impact on terrain stability. • Initiate contingency plans to address unexpected effects, as required.	• Seasonal terrain stability assessments will determine site specific stability issues.	• Internal	Proponent
Soil Erosion	• Determine if the project has resulted in the erosion of surficial materials. • Initiate contingency plans to address unexpected effects, as required.	• Seasonal erosion assessments will determine site specific stability issues.	• Internal	Proponent
Contaminated Soils	• Determine if the project has resulted in soil contamination. • Initiate contingency plans to address unexpected effects, as required.	• Soil sampling will determine if soils have been contaminated or not.	• Internal • MB Gov't as required	Proponent

dumps are of particular importance. The same instrumentation program will be incorporated into subsequent stages.

Presented in Table 7.3-16 are the minimum instrumentation requirements.

Test fills are recommended to verify practical aspects of initial preloading of the peat at waste rock dump locations, and also the consolidation characteristics of the peat.

Table 7.3-16 Recommended Geotechnical Instrumentation

Instrument Type	Area Needed	Purpose
Piezometers (pneumatic, vibrating wire, etc)	Dam foundation	Monitor pore pressure build-up and dissipation during staged construction
Inclinometer Casings	TWRMF Dam	Monitor lateral deformation of dam crest and slopes
Optical Survey Targets	TWRMF Dam	Monitor deformations and movements
Settlement plates	TWRMF Dam foundation	Monitor ground settlement and heave
Stage / discharge measurement devices	Spillways (TWRMF dam, ODF dyke; runoff/seepage collection ditches; TWRMF decant pond, Polishing Pond , etc.	Monitor contribution of TWRMF to the overall site water balance.
Thermistors	TWRMF dam foundation and rockfill shell	Measurement of frost penetration to be analyzed together with settlement monitoring data; thermal performance of rockfill shell while the TWRMF dam is covered with snow and impacts of this on winter runoff/seepage.

Source: Wardrop, 2009b

It is also recommended that vibrations caused by blasting or by operation of heavy construction equipment near earth slopes be monitored to verify that they are of significance, or otherwise, to the stability of pit slope in overburden.

The geotechnical instrumentation program should be established and implemented in close co-ordination with other monitoring programs involved such as those required for open pit dewatering, water management and environmental purposes.

Further consideration should be given to checking on the potential existence of karstic features in the limestone and their possible implications on the design of foundations and earthworks.

7.3.10.2 Follow-up Studies

Table 7.3-15 provides a summary of proposed follow-up baseline studies needed to improve predictive capabilities or understanding of baseline conditions. These studies include:

- A baseline study to determine soil chemistry on sites that are scheduled to be disturbed. This study is needed to assess soil chemistry and determine if there are any constraints or limitations to achieving vegetation restoration and initiate contingency plans to address unexpected effects, as required (Section 3.4: Decommissioning and Closure Activities).
- A baseline study to determine soil physical conditions on sites scheduled to be disturbed. This study is needed to assess soil physical conditions and determine reclamation suitability and the approximate volume of suitable soil materials for reclamation (Section 3.4: Decommissioning and Closure Activities.
- Detailed terrain stability assessments are needed to determine site-specific stability issues and develop contingency plans to initiate construction techniques to mitigate these issues.
- Detailed soil erosion potential assessments are needed to identify surficial materials with high erosion potentials and develop contingency plans to initiate construction techniques to mitigate these issues.

7.3.11 Summary of Effects

Table 7.3-17 provides a tabular summary of the project effects on terrain, surficial geology and soils.

Table 7.3-17 Program Effects on Terrain, Surficial Geology and Soils

Potential Effect	Level of Effect						Effect Rating	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effective
Construction								
Damage to key terrain features	No effect	No effect	No effect	No effect	No effect	No effect	Not significant	N/A
Modification of surficial materials and reduction in soil capability	Adverse	Moderate	Local	Long-term to far future	Reversible	High	Not significant	N/A
Increased soil erosion	Adverse	Moderate	Local	Medium term	Reversible	High	Not significant	N/A
Terrain stability concerns	Adverse	Moderate	Local	Long-term	Reversible	Unknown	Not significant	N/A
Operations								
Damage to key terrain features	No effect	No effect	No effect	No effect	No effect	No effect	Not significant	N/A
Modification of surficial materials and reduction in soil capability	Adverse	Moderate	Local	Medium term to far future	Yes	High	Not significant	N/A
Increased soil erosion	Positive	Moderate	Local	Medium term	Yes	High	Not significant	N/A
Terrain stability concerns	Adverse	Moderate	Local	Long-term	Yes	Unknown	Not significant	N/A
Decommissioning								
Damage to key terrain features	No effect	No effect	No effect	No effect	No effect	No effect	Not significant	N/A
Modification of surficial materials and reduction in soil capability	Positive	Low	Local	Medium term to far future	Yes	High	Not significant	N/A
Increased soil erosion	Positive	Moderate	Local	Short term	Yes	High	Not significant	N/A
Terrain stability concerns	Adverse	Moderate	Local	Short term	Yes	Unknown	Not significant	N/A

Table 7.3-17 (Cont.'d) Program Effects on Terrain, Surficial Geology and Soils

Potential Effect	Level of Effect						Effect Rating	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effective
Closure								
Damage to key terrain features	No effect	No effect	No effect	No effect	No effect	No effect	Not significant	N/A
Modification of surficial materials and reduction in soil capability	No incremental effect	No incremental effect	No incremental effect	Far future	No incremental effect	No incremental effect	Not significant	N/A
Increased soil erosion	No incremental effect	No incremental effect	No incremental effect	No incremental effect	No incremental effect	No incremental effect	Not significant	N/A
Terrain stability concerns	No incremental effect	No incremental effect	No incremental effect	No incremental effect	No incremental effect	No incremental effect	Not significant	N/A

Notes: N/A = not applicable.

7.4 Surface Water Hydrology

This Section includes the characterization of stream flow in the creeks and rivers in the vicinity of the Minago Project, including prediction of the magnitude and frequency of occurrence of peak flows (floods) and low flows. Surface water hydrology integrates information on climate (rainfall and snowfall data) (Section 7.1: Climate) and groundwater hydrogeology (Section 7.6: Groundwater), as well as the effects of processes such as snowmelt and evaporation. Understanding the range of natural variability of surface water hydrology is important for project design and for understanding the sensitivity of stream and lake ecosystems to potential project effects.

Potential project effects on hydrologic conditions are evaluated and remediation and mitigation measures are described. The significance and likelihood of residual project and cumulative effects is characterized along with recommended monitoring programs and adaptive management measures. This section describes the effects of routine project activities on hydrology. Effects associated with accidents and malfunctions are discussed in Section 8: Accidents and Malfunctions.

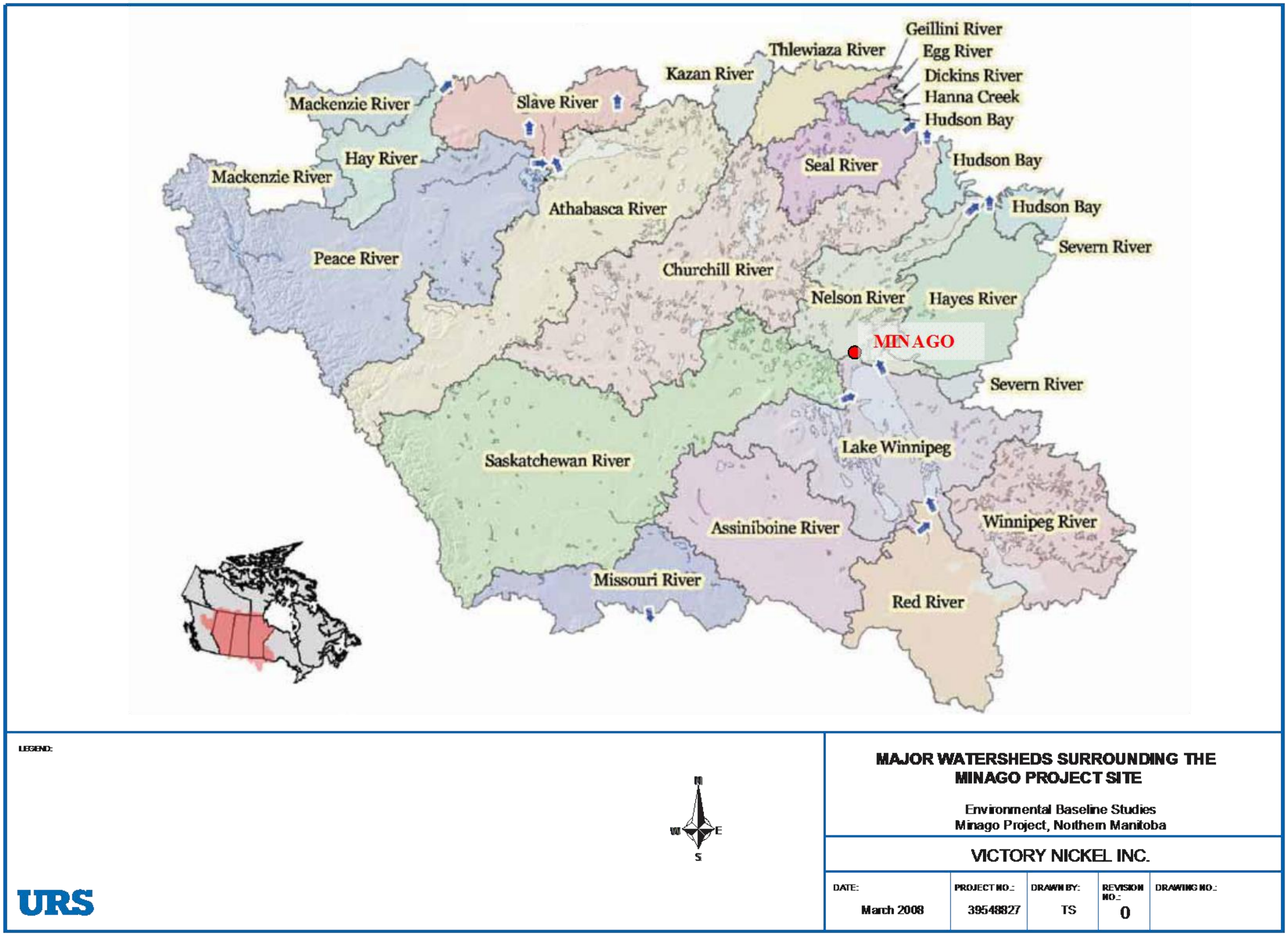
The scope of the surface water assessment, baseline conditions and the estimated impact of the project are detailed in the following sections. Hydrologic processes relevant to the Minago Project are summarized in Appendix 7.4 for readers unfamiliar with this topic.

Introduction to Hydrometric Assessments

The primary hydrologic issue associated with the Minago Project will be how it will affect the flow regimes in Oakley Creek, William River, and Minago River. The Minago Project Site is located within the Nelson River sub-basin, which drains northeast into the southern end of the Hudson Bay (Figures 7.4-1 and 7.4-2). The Minago River and Hargrave River catchments, surrounding the Minago Project Site, occur within the Nelson River sub-basin. The William River and Oakley Creek catchments at or surrounding the Minago Project Site, occur within the Lake Winnipeg sub-basin, which flows northward into the Nelson River sub-basin.

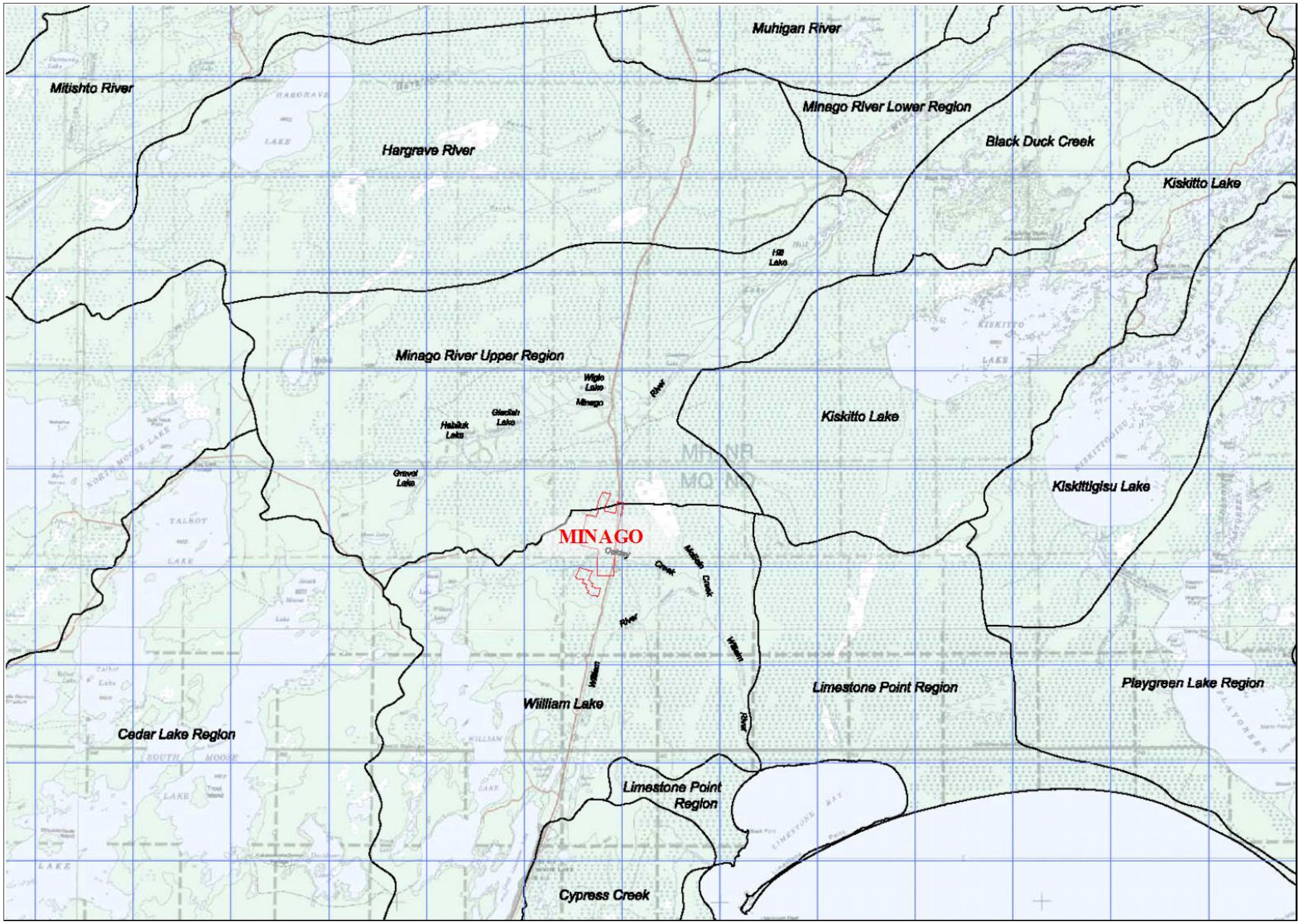
The footprint of the mine and surface facilities will be considerable and will consume some of the wetland and correspondingly reduce its reservoir capacity while increasing the intensity of flood events. Mine development and operation will also involve pumping of significant quantities of groundwater to surface and this will further increase flows in the streams draining the development area.

To assess and quantify the impact of the project on the hydrology of the adjacent streams, a baseline hydrologic study was undertaken to determine the long-term climatic and hydrometric characteristics of the area encompassing the proposed Minago Project development. Water quality sampling was initiated in the project area in 2006, while climate and hydrometric data collection started in 2007.



Source: adapted from URS, 2008a

Figure 7.4-1 Regional Hydrological Setting near the Minago Project



Source: adapted from URS, 2008f

Figure 7.4-2 Regional Hydrological Setting near the Minago Project

7.4.1 Scope of Hydrometric Assessment Program

In May 2006, Victory Nickel Inc. initiated a hydrometric monitoring program for the assessment of water quality within local watercourses. Pressure transducers have also been in operation at these stations since July 2007, for the assessment of water levels and streamflow.

Wardrop commenced the surface water hydrology program for the Victory Nickel Minago Project Site (the "Site") in August 2006, which was continued by URS Canada Inc. in 2007 with a widened scope (Wardrop, 2007; URS, 2008a). Starting in September 2007, KR Design Inc. collaborated with URS and VNI and continued hydrological assessements in 2008. In 2008, Golder Associates compiled a comprehensive database of available climatic and hydrologic characteristics for the Minago Project and derived representative hydrometric characteristics for the project area (Golder Associates, 2009).

The objectives of the hydrological assessment program were to:

- establish pre-mining hydrologic baseline conditions for the Minago Project Area;
- provide hydrologic baseline data required to complete an Environmental Impact Assessment of the Minago Project under the Manitoba *Environmental Assessment Act*;
- provide hydrologic baseline data required to complete bankable Feasibility Study on the Minago Project; and
- provide hydrologic baseline data for water quality modeling, engineering design, water management and determining impacts to aquatic resources.

7.4.1.1 Scope of Hydrometric Assessments conducted in 2006

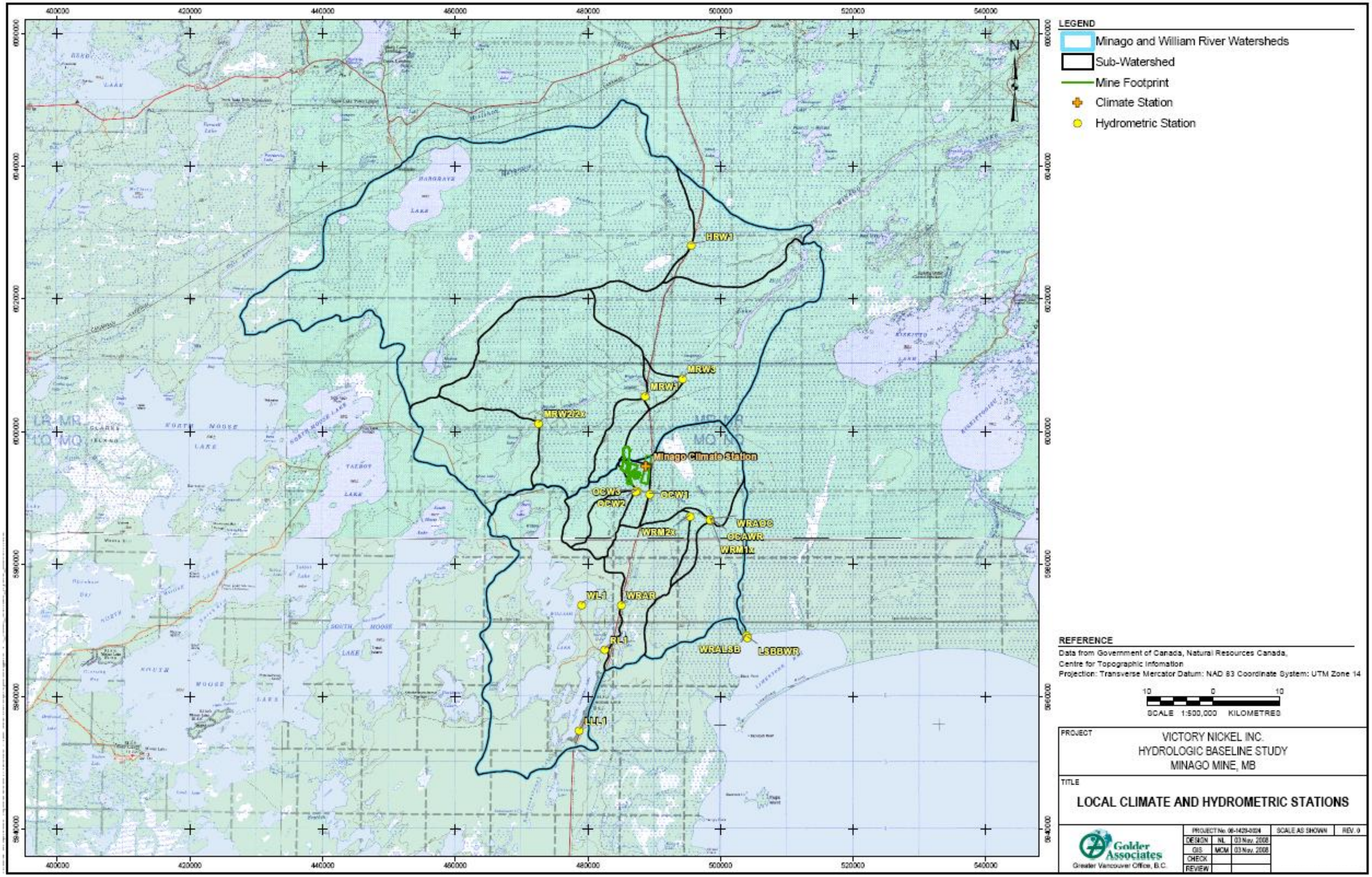
Wardrop collected streamflow data at OCW-1 on Oakley Creek and at MRW-1 on the Minago River once per month from August to October 2006 (Table 7.4-1, Figure 7.4-3). OCW-1 is located on the westside of Highway 6 and receives drainage from Oakley Creek and the ditches along Highway 6. Sampling station MRW-1 was established on the Minago River at the Highway 6 crossing, approximately 15 km north of Oakley Creek. Detailed field methods and streamflow records are given in Appendix 7.4. A detailed description of the watersheds and sampling locations is also provided in Appendix 7.4

Table 7.4-1 Coordinates of 2006 Streamflow Monitoring Locations

Monitoring Station	NAD 83 Northing (m)	NAD 83 Easting (m)
OCW-1	5990528	489238
MRW-1	6005275	488684

7.4.1.2 Scope of Hydrometric Assessments conducted in 2007 and 2008

URS conducted monthly hydrologic monitoring on Minago River, William River, Oakley Creek and Hargrave River between May and October 2007 (Table 7.4-2, Figure 7.4-3). Monitoring sites



Source: Golder Associates, 2009

Figure 7.4-3 Local Climate and Hydrometric Stations

Table 7.4-2 Local Hydrometric Stations

Drainage Network	Station [1]	Description	Watershed Surface Area (km^2)	Northing	Easting	Period of Record for the Transducer
Hargrave River	HRW1	Hargrave at Highway 6	1,512	6028072	495606	23-Jul-07 to 1-Nov-07, 9-May-08 to 6-Aug-08
Minago River	MRW1	Minago at Highway 6 (Alloway Lake outlet)	716	6005277	488671	15-Aug-07 to 4-Nov-07, 8-May-08 to 3-Aug-08
	MRW2/2x	Minago upstream of Habiluk Lake	214	6001166	472571	15-Aug-07 to 4-Nov-07, 9-May-08 to 6-Aug-08
	MRW3	Minago downstream of Highway 6, near power line cut	785	6007895	494274	No transducer installed
Oakley Creek [2]	OCW1	Oakley downstream of Highway 6	123	5990510	489322	27-Jul-07 to 4-Nov-07, 10-May-08 to 17-Aug-08
	OCW2	Oakley near mine site	92.6	5990961	487463	23-Jul-07 to 30-Nov-07, 11-May-08 to 16-Aug-08
	OCW3	Tributary to Oakley Creek	42.9	5990892	487230	No transducer installed
	OCAWR	Oakley upstream of confluence with William River	303	5986744	498457	17-Oct-07 to 5-Nov-07, 8-May-08 to 3-Aug-08
William River	WRW1x	William downstream of confluence with Oakley Creek	1,139	5986554	498523	23-Jul-07 to 4-Nov-07, 8-May-08 to 18-May-08, 3-Aug-08 to 14-Aug-08
	WRW2x	William upstream of station WRAOC	815	5987162	495416	23-Jul-07 to 15-Sep-07
	WRAOC	William upstream of confluence with Oakley Creek	836	5986647	498452	Broken transducer; new one installed in Aug 08
	WRAR	William at Highway 6	654	5973791	485078	Installed in Aug-08
	LLL1	Little Limestone Lake (at end of road)	Lake	5954922	478725	No transducer installed
	RL1	Russell Lake	Lake	5967117	482571	No transducer installed
	WL1	William Lake at end of access road	Lake	5973831	479083	No transducer installed
	WRALSB	William River Above Limestone Bay	Lake	5969206	503935	No transducer installed
	LSBBWR	Limestone Bay Below William River	Lake	5968889	504092	No transducer installed

Source: Golder Associates, 2009

1. The hydrometric data were obtained from Victory Nickel (2008)
2. The Oakley Creek drainage network is within that of William River.

were established on Minago River and Oakley Creek above and below proposed project area. The sites were selected to develop baseline hydrologic conditions upstream and downstream of the Project site (URS, 2008a). KR Design Inc. continued hydrologic monitoring on Minago River, William River, Oakley Creek and Hargrave River in May and August 2008. A detailed description of the watersheds and sampling locations is provided in Appendix 7.4. Field methods and streamflow results for the 2007 and 2008 assessments are also provided in Appendix 7.4.

On the Minago River, one site (MRW1) was located at the Highway 6 Bridge and another site (MRW2) was located several kilometres upstream near Habiluk Lake. MRW2 was relocated approximately 100 metres downstream in October 2007 because a beaver dam had been constructed just downstream of MRW2. This new monitoring location on Minago River was called MRW2x.

On Oakley Creek, one monitoring site (OCW1) was located approximately 100 metres downstream from the Highway 6 culverts, one site (OCW2) was located several kilometres upstream from the Highway 6 crossing, one site (OCW3) was located approximately 250 m upstream of OCW2, and another site (OCAWR) was located immediately upstream of the Oakley Creek and William River confluence. OCAWR was established in October, 2007. On William River, one site (WRW1X) was located approximately 100 metres downstream from the Oakley Creek/William River confluence and one site (WRW2X) was located several kilometres upstream from the confluence. A third monitoring site (WRAOC) was established in October 2007 immediately upstream from the Oakley Creek/William River confluence. In addition, streamflow was assessed just west of Highway 6 on William River (at William River at Road), starting in May 2008. On Hargrave River, one site (HRW1) was located at the Highway 6 Bridge.

7.4.2 Geographic Characteristics

The topography in the Minago and William River watersheds varies between elevation 210 and 300 m. The watersheds are located within the Mid-Boreal Lowland eco-region (Wiken, 1986). This eco-region is a relatively flat, low-lying area with extensive wetlands covering approximately half the area. Underlain by flat-lying, limestone bedrock, the project site area is covered almost entirely by a glacial and lacustrine overburden of fine material, and extensive peat deposits (Wiken, 1986; Betcher et al., 1995). The cold and poorly drained fens and bogs are covered with tamarack and black spruce. The mixed deciduous and coniferous forest in the other half of the area is characterized by medium to tall, closed stands of trembling aspen and balsam poplar with white and black spruce, and balsam fir occurring in late successional stages.

The Mid-Boreal Lowland eco-region is replaced to the north and east of the watersheds by the Hayes River Upland eco-region (Wiken, 1986). Standing vegetation in this region consists predominantly of dense medium to tall black spruce and jack pine with some paper birch. The shrub layer is dominated by ericaceous shrubs, willow, and alder. The ground cover consists of mosses and lichens, low ericaceous shrubs, and some herbs.

The Minago Project Area lies within the Localized Permafrost Zone (Zoltai, 1995). There, permafrost occurs as small, isolated lenses in peat. The hydrological impacts of their thawing have been proven to have no significant effect on bog hydrology (Thibault and Payette, 2009). Moreover, Thibault and Payette (2009) have shown that over the last 50 years, the southern limit of permafrost distribution has moved significantly towards the north.

Nowadays, it is therefore unlikely to observe permafrost in the Minago area. Hydrometric Data Inventory.

7.4.3 Hydrometric Data Inventory

7.4.3.1 Local Data

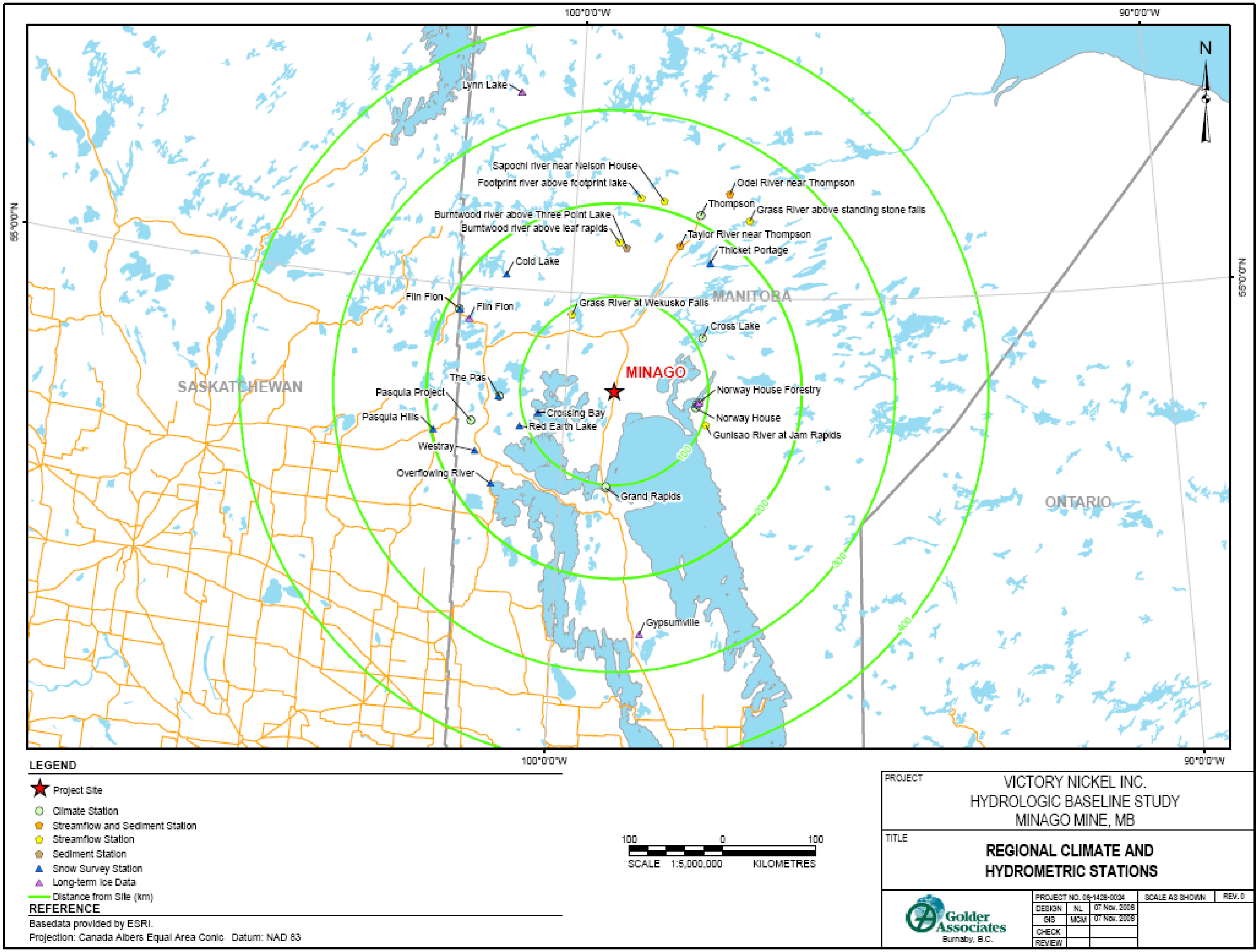
The collection of water quality samples has been undertaken on behalf of Victory Nickel by Wardrop Engineering in 2006, URS in 2007, and KR Design Inc. The monitoring network for the collection of climate and water level observations has provided data since July 2007. Figure 7.4-3 illustrates the station locations for the Victory Nickel's monitoring network. The sub-sections below detail the inventory of hydrometric data available from this monitoring network.

The local hydrometric monitoring program includes stations for the observation of in-stream water level and for the collection of water quality samples (Table 7.4-2 and Figure 7.4-3). Hydrometric stations equipped with a pressure transducer (i.e., HRW1, MRW1, MRW2/2x, OCW1, OCW2, OCAWR, WRW1x, WRW2x, WRAOC and WRAR) are those where water level can be determined within the period of record. The expanded version of the abbreviated hydrometric station names listed above are provided in Table 7.4-2. Measurements from the transducers were available from a period as early as late July 2007 up to as late as early November 2007, and from as early as May 2008 up to as late as mid August 2008. The transducers were not in operation during the 2007/08 winter period.

Water quality samples were collected at the hydrometric stations listed in Table 7.4-2. The analysis of the samples included the determination of total suspended solid (TSS) concentrations. Sampling typically occurred during spring summer and fall, and the last samples available for this study are those of the spring of 2008. One sample only was collected at Little Limestone Lake (LLL1) and Russell Lake (RL1) in September 2007, William River above Limestone Bay (WRALSB) and Limestone Bay below William River (LSBBWR) in October 2007, and William Lake (WL1) in May 2008. The surface water quality program is presented and discussed in Section 7.5.

7.4.3.2 Regional Data

Regional temperature and precipitation data are available from seven climate stations located in northern Manitoba. Regional evaporation estimates, relative humidity, wind and radiation are also respectively available at one or more of these stations (Figure 7.4-4). Regional precipitation data may be supplemented by a national database of snow survey and snow water equivalent information that is current up to 2004.



Source: Golder Associates, 2009

Figure 7.4-4 Regional Climate and Hydrometric Stations

Data from eight regional hydrometric stations are available from Water Survey of Canada (Table 7.4-3). River and lake ice information was available from the Canadian Ice Database (Table 7.4-4). Data from three regional sediment sampling stations (Table 7.4-5) was used to complete the database for the Minago Project.

7.4.3.2.1 Streamflow and Water Level

The Water Survey of Canada (WSC) branch of Environment Canada maintains a network of streamflow monitoring stations that record daily flows and flood peak discharges. Table 7.4-3 shows long-term WSC stations near the Minago Project with periods of record greater than ten years (EC 2008d), operating year-round, and with watersheds near the regional climate stations. The locations of these stations are shown in Figure 7.4-4.

7.4.3.2.2 Ice Regime

The Canadian Ice Database (CID; Lenormand et al., 2002) compiles observations of ice-cover duration and thickness for various sizes of water bodies and watercourses. Main data contributors include the Meteorological Service of Canada, the Canadian Ice Service, and provincial and territorial governments. The CID was used to identify available ice data in the Minago region. A total of 8 stations with long-term ice records within this region are listed in Table 7.4-4.

7.4.3.2.3 Suspended Sediment

Suspended sediment observations in Manitoba have been typically made at locations in the southern parts of the province or on very large rivers (e.g., the Saskatchewan River), and therefore, are not likely to provide data that are representative of conditions in the region of the proposed project site. Table 7.4-5 lists the sediment data stations with relatively small watersheds that are located near the Minago Project.

7.4.4 Hydrometric Results

7.4.4.1 Local Results

7.4.4.1.1 Streamflow and Water Level

The available local hydrometric data includes pressure, staff gauge and streamflow measurements for HRW1, MRW1, MRW2/2x, OCW1, OCW2, OCAWR and WRW1x. Pressure transducers were only recently installed at WRAOC and WRAR, and therefore no water level or streamflow were available for the hydrological assessment. As well, no concurrent pressure and staff gauge measurements were available to determine water levels or streamflow at WRW2x.

Table 7.4-3 Regional Streamflow Stations

Station Name [1]	Station ID	Distance from Site (km)	Latitude North	Longitude West	Drainage Area (km^2)	Period of Record	Years of Record
Sapochi River near Nelson House	005TG006	200 km to the North	55°54'	98°29'	391	1993-2007	15
Footprint River above Footprint Lake	005TF002	200 km to the North	55°56'	98°53'	643	1978-2007	30
Taylor River near Thompson	005TG002	180 km to the North East	55°29'	98°11'	886	1970-2007	38
Grass River at Wekusko Falls	005TB002	100 km to the North	54°47'	99°58'	3,260	1957-2007	51
Gunisao River at Jam Rapids	005UA003	100 km to the East	53°47'	97°40'	4,800	1971-2007	37
Burntwood River above Leaf Rapids	005TE002	160 km to the North	55°30'	99°13'	5,810	1985-2007	23
Odei River near Thompson	005TG003	250 km to the North East	56°00'	97°21'	6,110	1979-2007	29
Grass River above Standing Stone Falls	005TD001	240 km to the North East	55°45'	97°00'	15,400	1959-2007	49

1. Source: Golder Associates, 2009 (Secondary source: Water Survey Branch of Environment Canada (EC, 2008d)).

Table 7.4-4 Regional Long-Term Ice Data Stations

Station Name [1]	Water Body / Watercourse	Station Identification	Distance from Site (km)	Latitude North	Longitude West	Period of Record	Years of Record
Flin Flon	Schist Lake	FUBU-171	200 km to the North West	54°41'	101°41'	1956-1983	28
Norway House Forestry	Little Playgreen Lake	FUBU-354	90 km to the East	54°00'	97°48'	1956-1998	43
Norway House Forestry	Playgreen Lake	FUBU-356	90 km to the East	54°00'	97°48'	1986-1996	11
Norway House Forestry	Nelson River	FUBU-355	90 km to the East	54°00'	97°48'	1957-1962	6
Lynn Lake	Eldon Lake	FUBU-300	340 km to the North	56°52'	101°05'	1969-1994	26
Lynn Lake	Lynn Lake	FUBU-301	340 km to the North	56°52'	101°05'	1969-1985	17
Lynn Lake	West Lynn Lake	FUBU-302	340 km to the North	56°52'	101°05'	1987-1994	8
Gypsumville	Portage Bay	FUBU-231	270 km to the South	51°46'	98°38'	1969-1986	18

1. Source: Golder Associates, 2009 (Secondary source: Canadian Ice Database (Lenormand et al., 2002)).

Table 7.4-5 Sediment Data Stations

Station Name [1]	Station ID	Distance from Site (km)	Latitude North	Longitude West	Drainage Area (km^2)	Period of Record	Number of Years Available
Taylor River near Thompson	05TG002	180 km to the North East	55°29'	98°11'	886	1971-1979	7
Odei River near Thompson	05TG003	250 km to the North East	55°59'	97°21'	6,110	1979-1987	4
Burntwood river above Three Point Lake	05TE001	160 km to the North	55°27'	99°06'	6,670	1977-1983	6

1. Source: Golder Associates, 2009 (Secondary source: Water Survey Branch of Environment Canada (EC, 2008e)).

The steps used to derive water level and streamflow from the pressure measurement were:

- Establishment of a relationship between the pressure measurements and stream water levels based on water elevations measured from the reference staff gauge located at the site; and
- Establishment of a relationship between water elevations measured from the staff gauge and manual streamflow measurements made at the site.

The relationships determined for HRW1, MRW1, MRW2/2x, OCW1, OCW2, OCAWR and WRW1x are given in Appendix 7.4. These relationships were based on the observed water levels and streamflows at the stations. Confidence in the results of these relationships is greater within the ranges of the observations at the stations than outside these ranges. Water levels referenced to the staff gauge and corresponding streamflows at these stations are also graphed in Appendix 7.4. The graphs in Appendix 7.4 show the maximum observed water level and streamflow at the stations. A summary of derived streamflow characteristics for the period of record are provided in Table 7.4-6.

The record of pressure transducer measurements at the local hydrometric stations was limited to two periods: July to November 2007 and May to August 2008. Table 7.4-6 gives a summary of the streamflow characteristics for each of these periods. Based on the air temperature recorded from the regional stations, high streamflow levels recorded in early May 2008 are likely the result of the onset of the freshet. Streamflow variations for the other recorded months are attributed to rainfall runoff.

Long-term characterization of flow cannot be determined from this comparatively short period of record. Furthermore, confidence in the derived water level and streamflow at the local hydrometric stations are compounded by the following factors (Golder Associates, 2009):

- During high flow events, water in the Minago River could potentially be conveyed by two channels (i.e., the Wigle and Alloway Lake outlets at Highway 6). The MRW1 station monitors flow for only one of these channels (Alloway Lake outlet).

Table 7.4-6 Streamflow Characteristics at Local Stations for 2007 and 2008

Station [1]	Watershed	Flow from July to November 2007 (m^3/s)			Flow from May to August 2008 (m^3/s)		
	Area (km^2)	Minimum	Median	Maximum	Minimum	Median	Maximum
HRW1	1512	0.20	3.24	6.22	0.17	4.54	9.35
MWR1	716	0.058	1.54	6.70	0.27	1.71	5.79
MWR2/2x [2]	214	0.68	1.08	1.77	0.51	0.77	2.01
OCW1	123	0.28	0.61	1.14	0.24	0.54	1.42
OCW2	93	0.30	0.52	0.92	0.002	0.38	0.92
OCAWR [3]	303	1.12	1.71	1.90	0.13	1.20	7.09
WRW1x [4]	1139	2.15	5.05	6.50	1.92	5.74	7.29

1. Data source: Golder Associates, 2009 (Secondary source: Victory Nickel (2008)).
2. Monitoring at MRW2/2x could have been impacted by a beaver dam.
3. In 2007, streamflows were only available from October 17 to November 5 at OCAWR.
4. In 2008, streamflows were only available from May 8 to 18 and from August 3 to 15 at WRW1x.

- A beaver dam was observed after the installation of station MRW2. This station was eventually moved to a location downstream (i.e., MRW2x) of the beaver dam water impoundment. The impoundment has impacted pressure measurements at the original location.
- The stream at OCW2 has a very wide floodplain. High flows would likely be underestimated based on the staff gauge/streamflow relationship that was developed for that station.
- Station OCW1 is located roughly 100 m downstream from a culvert that conveys the water from Oakley Creek across Highway 6. Natural flows as a result of high rainfall events could be underestimated if water is stored or diverted upstream of that culvert.

Golder Associates recommended mitigation measures, which could include monitoring flow on the second channel of Minago River at Highway 6 (Wigle outlet) or moving station MRW1 upstream the split channels, and relocating stations OCW1 and OCW2 (Golder Associates, 2009).

7.4.4.1.2 Suspended Sediment

Analytical results from the water quality sampling program conducted by Victory Nickel (2008) for the Minago Project included the quantification of total suspended solids (TSS). The analytical results for TSS are summarized in Table 7.4-7 for each hydrometric station assuming that TSS is composed entirely of suspended sediment.

Measured TSS concentrations in the Minago River and upper reaches of Oakley Creek (OCW1, OCW2, and OCW3) were markedly lower than those in the Hargrave and William Rivers.

Table 7.4-7 Observed Total Suspended Solids at Local Stations between 2006 and 2008

Station [1]	Sampling Period	Sample Count		TSS (mg/L) [2]		
		Total	Below Detection Limits	Min	Median	Max
HRW1	May-Oct 2007; March and Aug 2008	8	0	8.0	28.5	42.0
MRW1	May-Oct 2006-2007; March and Aug 2008	14	4	1.0	<3.0	5.0
MRW2/2x	May-Oct 2007; May 2008	7	1	<3.0	4.0	12.5
MRW3	May-Oct 2007; May 2008	7	3	<3.0	3.0	5.7
OCW1	May-Oct 2006-2007; May 2008	14	10	<1.0	<3.0	23.0
OCW2	May-Oct 2006-2007; May 2008	13	8	<1.0	<3.0	11.0
OCW3	May-Oct 2006-2007; May 2008	13	11	<1.0	2.0	<3.0
OCWAR	Oct 2007 and May 2008	2	0	3.5	26.8	50
WRW1x	May-Oct 2007; May 2008	7	0	5.9	18.9	57.5
WRW2x	May-Sep 2007	5	0	6.9	29.9	65.0
WRAOC	Oct 2007 and May 2008	2	0	6.5	20.0	33.5
WRAR	May 2008 [3]	0	0	-	-	-
LLL1	Sep 2007	1	0	9.2	9.2	9.2
RL1	Sep 2007	1	0	14.2	14.2	14.2
WL1	May 2008	1	1	<3.0	<3.0	<3.0
WRALSB	Oct 2007	1	0	7.5	7.5	7.5
LBBWR	Oct 2007	1	0	6.5	6.5	6.5

1. Data source: Golder Associates, 2009 (Secondary source: Victory Nickel (2008)).
2. The < sign indicates a value below analytical detection limits. The detection limit for TSS was 1 mg/L for 2006 samples and 3 mg/L for 2007 and 2008 samples.
3. A water quality sample was taken at WRAR; however no analytical result for TSS was available.

7.4.5 Hydrometric Characteristics

This section summarizes the anticipated hydrologic processes occurring at the Minago project site, and within the Close Study Area (Figure 7.1-1) and Extended Study Area (Figure 7.1-2). The following components are addressed:

- Ice regime and snow on the ground;
- Surface water runoff;
- Peak and low flows; and
- Sediment yield.

7.4.5.1 Ice Regime and Snow on the Ground

The Canadian Ice Database (CID) was used to compile available ice data for lakes and rivers located between Latitudes 51 and 56 degrees north, and between Longitude 97 and 101 degrees west. An analysis of the data was conducted to provide a basis for estimating the following parameters in the vicinity of the Minago Project:

- Average maximum ice thickness;
- Average date for the first occurrence of permanent ice;
- Average date of complete freeze over;
- Average date of the first occurrence of ice deterioration; and
- Average date for water to be clear of ice.

Table 7.4-8 summarizes the available regional data. Mean ice thickness varies within a narrow range between 0.8 and 0.9 m, with only the northernmost stations (West Lynn Lake) having an ice smaller than the lower range value (0.8). The first occurrence of ice may be as early as mid-October; however, a complete freeze over is not observed until the end of October or early November. Deterioration of the ice cover is observed by late April and likely coincides with the freshet.

Similarly, the snow on the ground information from Environment Canada stations at Flin Flon, Norway House, Pasquia Project, The Pas and Thompson indicate that the snowpack becomes completely depleted by April 17 on average at these locations. The depletion can occur as early as March 1 or as late as May 9. Snow on the ground can vary significantly spatially, and therefore snow on the ground in a given area can be anticipated past the date of complete depletion at the climate stations.

Based on long-term air temperature data (Table 7.1-8), ice cover characteristics (Table 7.4-8) and snow on the ground depletion information, three distinct periods can be identified:

Table 7.4-8 Regional Ice Cover Characteristics

	Station Name [1]	Waterbody	Available Period of Record	Mean Maximum Ice Thickness (m)	Mean First Date of Occurrence of Permanent Ice [2]	Mean Date of Complete Freeze Over [2]	Mean First Date of Occurrence of Ice Deterioration	Mean Date for Water to be Clear of Ice
1	Flin Flon	Schist Lake	1956-1983	0.8	04-Nov	09-Nov	26-Apr	10-May
2	Norway House Forestry	Little Playgreen Lake	1956-1998	0.9	30-Oct	04-Nov	23-Apr	08-May
		Playgreen Lake	1986-1996	0.8	-	03-Nov	23-Apr	13-May
		Nelson River	1957-1962	0.9	-	-	22-Apr	02-May
3	Lynn Lake	Eldon Lake	1969-1994	0.8	15-Oct	25-Oct	01-May	16-May
		Lynn Lake	1969-1985	0.9	13-Oct	23-Oct	28-Apr	15-May
		West Lynn Lake	1987-1994	0.6	24-Oct	28-Oct	08-May	15-May
4	Gypsumville	Portage Bay	1969-1986	0.9	02-Nov	14-Nov	18-Apr	06-May
	Range of variation			**0.6 to 0.9**	**13-Oct to 04-Nov**	**23-Oct to 09-Nov**	**22-Apr to 08-May**	**02-May to 15-May**

1. Data source: Golder Associates, 2009 (Secondary source : Lenormand et al. (2002)).
2. Insufficient or no data available denoted by a – symbol.

- April to May: when the deterioration of the ice cover and the depletion of the snowpack is observed. This is the freshet period where rainfall and snowmelt produce surface runoff.
- June to October: when no winter processes such as ice cover or snowpack developments are observed. Surface runoff is generated from rain events only.
- November to March: when winter processes such as ice cover or snowpack developments are observed. Surface runoff is reduced during that period.

7.4.5.2 Annual Surface Water Runoff

The hydrometric stations listed in Table 7.4-3 were used in a regional analysis of annual runoff potential in the vicinity of the proposed project site. Table 7.4-9 provides the calculated seasonal runoff depths for each of these stations from April to May, June to October, November to March, and on an annual basis. Runoff is calculated by dividing the total streamflow observed

Table 7.4-9 Mean Annual Water Yield at Regional Stations

Station Name [1]	Watershed	Mean Streamflow (m^3/s)				Watershed Runoff (mm)				Percent of Annual Runoff (%)		
	Area (km^2)	Apr-May	Jun-Oct	Nov-Mar	Annual	Apr-May	Jun-Oct	Nov-Mar	Annual	Apr-May	Jun-Oct	Nov-Mar
Sapochi River near Nelson House	391	4.7	2.8	0.5	2.2	63	95	18	176	36	54	10
Taylor River near Thompson	886	8.6	6.4	1.6	4.8	51	96	24	171	30	56	14
Odei River near Thompson	6,110	60.4	46.1	10.1	33.6	52	100	22	173	30	57	12
Grass River at Wekusko Falls	3,260	10.2	13.6	9.2	11.2	16	55	37	108	15	51	34
Grass River above Standing Stone Falls	15,400	43.1	88.0	51.5	65.4	15	76	44	134	11	56	33
Footprint River above Footprint Lake	643	4.2	3.8	2.0	3.1	34	78	42	154	22	51	27
Gunisao River at Jam Rapids	4,800	27.8	22.8	8.6	17.8	31	63	24	117	26	54	20
Burntwood River above Leaf Rapids	5,810	35.1	31.1	9.0	22.6	32	71	20	123	26	58	16

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008d)).

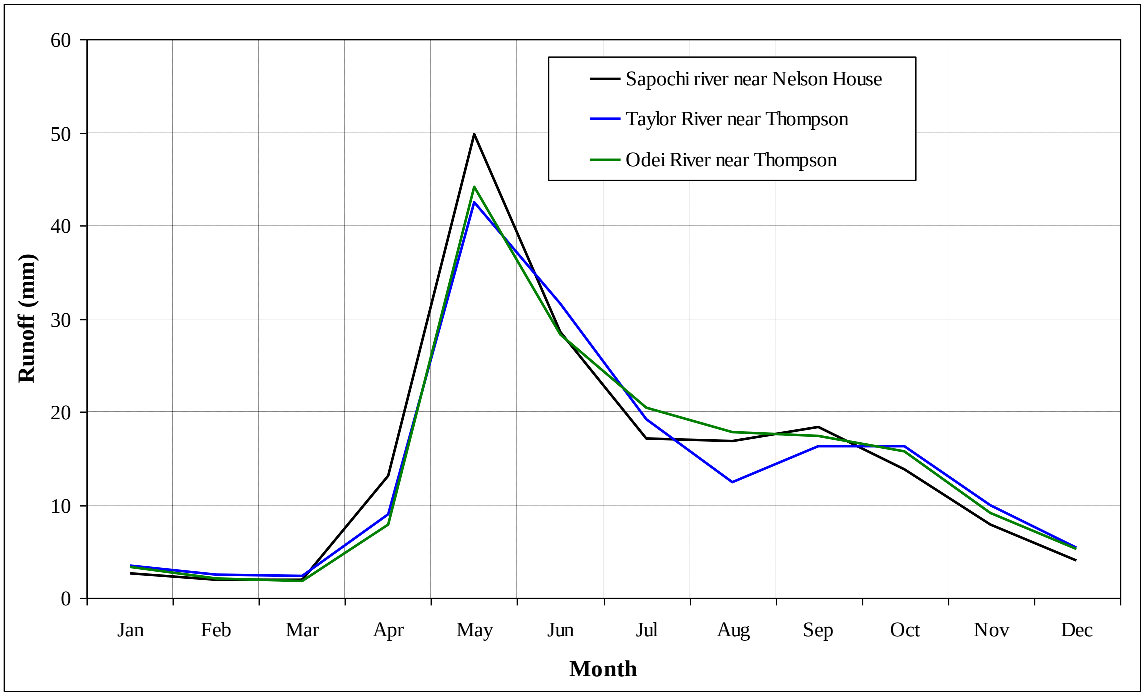
at the stations for a given period expressed in terms of volume by the watershed area at the corresponding stations. The runoff estimates represent:

- The water yield of the watershed at its outlet; and
- Total precipitation in the watershed minus total losses (evapotranspiration, infiltration, sublimation and snow redistribution) occurring within the watershed area.

The amount of runoff is dependent on precipitation input amount and on the characteristics of the watershed such as the proportion of lakes and wetland with respect to watershed area, vegetation and soils, which would impact evapotranspiration and infiltration. Based on the results of Table 7.4-9 and on the monthly water runoffs given in Figures 7.4-5 to 7.4-7, three groups of watersheds were identified:

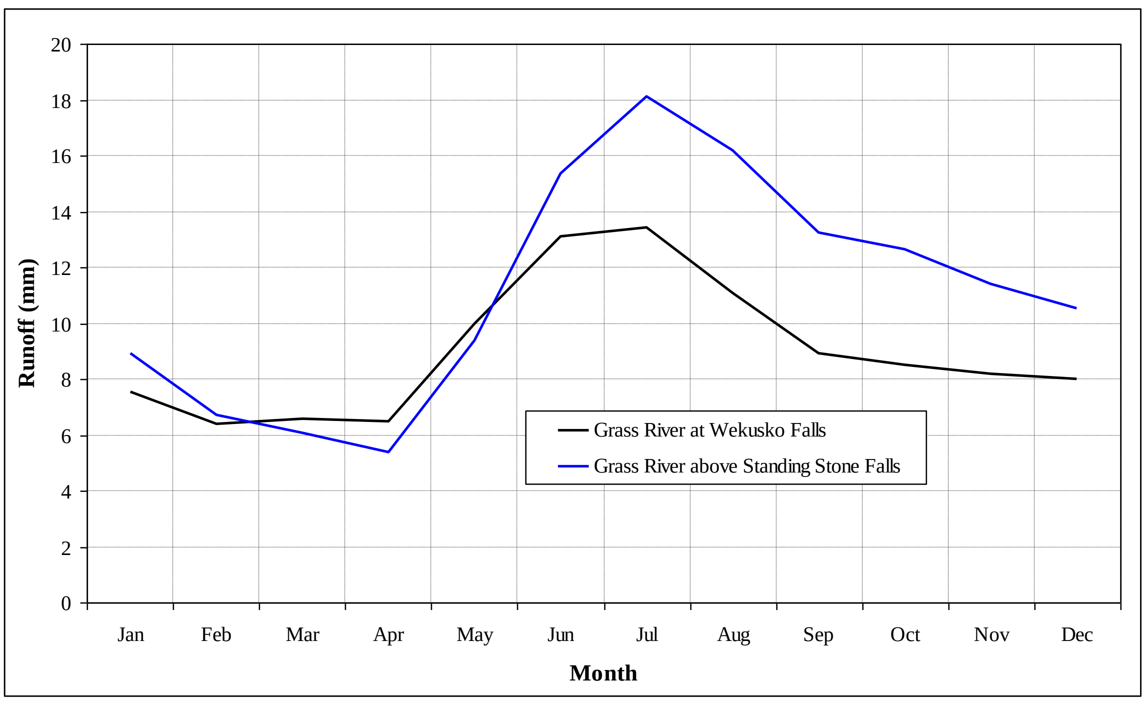
- **Sapochi, Taylor and Odei River Watersheds (Figure 7.4-5):** These watersheds are located further northeast from the project site, in a region of relatively higher precipitation, and covered with trees in relatively larger areas of the watersheds. Annual runoff (171 to 176 mm on average per year) is relatively higher from these watersheds than the others listed in Table 7.4-9. Their corresponding annual runoff coefficient, which is the ratio of mean annual runoff over mean annual total precipitation, ranges from 0.30 to 0.31 (Table 7.4-10).
- **Grass River Watersheds (Figure 7.4-6):** This river spans from the southwest to the northeast, north of the project site. The upstream watershed is in an area with moderate precipitation, and is dominated by fens and lakes and wetland, where evapotranspiration is potentially higher compared to forested areas. The result is a relatively low annual runoff (108 mm, for an annual runoff coefficient of 0.21). Further downstream, the Grass River traverses through a region of wooded areas and high precipitation, resulting in a comparatively higher water yield (133 mm, for an annual runoff coefficient of 0.24). The monthly distribution of runoff for the Grass River differs from those of the other regional stations listed in Table 7.4-9. Specifically, the peak occurs in July instead of May, as is the case for the other rivers.
- **Footprint, Gunisao and Burntwood River Watersheds (Figure 7.4-7):** These rivers are located in regions with moderate to high precipitation. However, their landscape is dominated by fens and wetland, resulting in comparatively low to moderate annual runoff varying between 117 and 154 mm (Table 7.4-10 for the Gunisao and Footprint Reivers, respectively). The monthly distribution of runoff is comparable for all three watersheds, with a peak runoff for the freshet occurring in May. Annual runoff coefficient for these watershed varies between 0.20 and 0.27 (Table 7.4-10 for the Gunisao and Footprint Rivers, respectively).

The hydrologic characteristics (in terms of vegetation, waterbody characteristics as well as peak runoff in May from the freshet) of the local watersheds near the project site would more likely resemble those of the third group of watersheds discussed above. Runoff coefficients for these



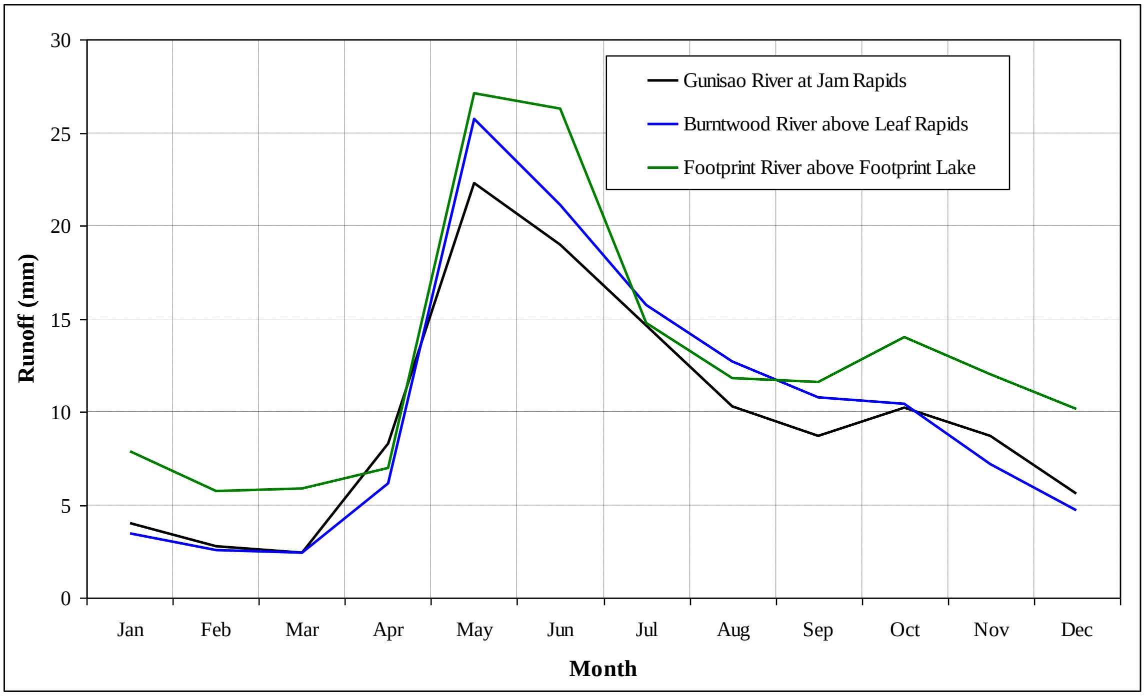
Source: Golder Associates, 2009

Figure 7.4-5 Average Monthly Runoff for the Sapochi, Taylor and Odei Rivers



Source: Golder Associates, 2009

Figure 7.4-6 Average Monthly Runoff for the Grass River



Source: Golder Associates, 2009

Figure 7.4-7 Average Monthly Runoff for the Gunisao, Burntwood and Footprint Rivers

Table 7.4-10 Regional Annual Runoff Coefficients

Station Name	Watershed Area (km^2)	Annual Runoff (mm) [1]	Total Annual Precipitation (mm) [2]	Runoff Coefficient
Sapochi River near Nelson House	391	176	573	0.31
Taylor River near Thompson	886	171	550	0.31
Odei River near Thompson	6,110	173	573	0.30
Grass River at Wekusko Falls	3,260	108	520	0.21
Grass River above Standing Stone Falls	15,400	134	550	0.24
Footprint River above Footprint Lake	643	154	573	0.27
Gunisao River at Jam Rapids	4,800	117	594	0.20
Burntwood River above Leaf Rapids	5,810	123	550	0.22

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008d)).
2. Data source: Golder Associates, 2009 (Secondary source: EC (2008b)).

local watersheds would also be assumed to be in the same range as those of the Footprint, Gunisao and Burntwood Rivers.

The average of the runoff coefficients at Footprint, Gunisao and Burntwood Rivers (Table 7.4-10) is considered in the present analysis as an adequate runoff coefficient for the local watersheds of the Minago Project. Based on an estimated average annual total precipitation of 510 mm (Table 7.1-10) and the assumed average runoff coefficient of 0.23, the corresponding annual water yield or mean annual runoff from the Oakley Creek and Hargrave, Minago and William River watersheds would be about 117 mm.

7.4.5.3 Annual Water Balance and Evapotranspiration/Infiltration

An annual water balance of the local project site watersheds was performed using the local watershed runoff estimated (117 mm), the estimated local precipitation (Table 7.1-10), and an assumed loss to sublimation and snow redistribution equal to 39% of the snowfall. The local annual water balance results are presented in Table 7.4-11.

It should be noted that losses due to ground infiltration and evapotranspiration could not be estimated from available local data and are therefore lumped together and are assumed equal to the total losses minus losses to sublimation and snow redistribution. The total watershed losses (i.e., evapotranspiration/infiltration, sublimation and snow redistribution) were computed as the total precipitation minus the runoff.

Table 7.4-11 Local Annual Water Balance

Component	Description	Value (mm)
Precipitation	Rainfall	369
	Snowfall	141
	Total Precipitation	510
Losses	Evapotranspiration / Infiltration	338
	Snow Losses [1]	55
	Total Losses	393
Water Runoff	Runoff [2]	117

Source: Golder Associates, 2009

1. Snow losses are the result of sublimation and snow redistribution and assumed to be about 39% of the snowfall.
2. Total losses are equal to the total precipitation minus runoff.

Estimates of the evapotranspiration losses for the local watersheds are functions of the regional variability in lake area, wetland area, and vegetation and terrain types. In particular, additional evaporative loss and resulting reduced runoff could occur from the presence of a significantly sized lake in a watershed. Table 7.4-12 lists the proportions of lake areas within the Hargrave,

Table 7.4-12 Ratio of Lake Areas to Total Watershed Area

<table>
<tr><th>Watershed</th><th>Lakes Considered [1]</th><th>Lake Area (km^2)</th><th>Watershed Area (km^2) at Monitoring Station</th><th>Ratio of Lake over Watershed Area (%)</th></tr>
<tr><td>Footprint River</td><td>Leftrook and Ugik Lakes</td><td>77</td><td>643</td><td>12%</td></tr>
<tr><td>Gunisao River</td><td>Gunisao, Bennett, Lebris and Costes Lakes</td><td>147</td><td>4,800</td><td>3%</td></tr>
<tr><td>Burnwood River</td><td>Apeganau, File, Loonhead, Batty, Limestone Point, Hassett, Guttrie and Burntwood Lakes</td><td>259</td><td>5,810</td><td>4%</td></tr>
<tr><td>Hargrave River</td><td>Hargrave Lake</td><td>80</td><td>1,512 at HRW1</td><td>5%</td></tr>
<tr><td rowspan="3">Minago River</td><td rowspan="3">None</td><td rowspan="3">Negligible</td><td>214 at MRW2</td><td rowspan="3">Negligible</td></tr>
<tr><td>716 at MRW1</td></tr>
<tr><td>785 at MRW3</td></tr>
<tr><td rowspan="3">Oakley Creek</td><td rowspan="3">None</td><td rowspan="3">Negligible</td><td>93 at OCW2</td><td rowspan="3">Negligible</td></tr>
<tr><td>123 at OCW1</td></tr>
<tr><td>303 at OCAWR</td></tr>
<tr><td rowspan="4">William River</td><td rowspan="4">William and Little Limestone Lakes</td><td rowspan="4">151</td><td>654 at WRAR</td><td>23%</td></tr>
<tr><td>815 at WRW2x</td><td>19%</td></tr>
<tr><td>836 at WRAOC</td><td>18%</td></tr>
<tr><td>1,139 at WRW1x</td><td>13%</td></tr>
</table>

Source: Golder Associates, 2009

1. Only significantly sized lakes on 1:250,000 scale topographic maps were considered.

William, Minago and Oakley watersheds, and compares them to those of the Footprint, Gunisao and Burntwood River watersheds. The proportions are limited to significantly sized lakes within the watersheds, with all other waterbodies considered as negligible.

As indicated in Table 7.4-12, proportions of lakes are appreciably higher in the William River watershed compared to those of the Footprint, Gunisao and Burntwood River watersheds. Consequently, evapotranspiration/infiltration losses from the William River watershed may be potentially higher, or runoff may be comparatively less, than is assumed in the water balance results presented in Table 7.4-11.

7.4.5.4 Monthly Water Balance

In addition to the average annual watershed balance presented above, an average monthly water balance was also completed for the Hargrave, William, Minago and Oakley watersheds. The calculation of the monthly water balance was completed in the same manner as for the annual balance with the additional assumption that the monthly distribution for evapotranspiration/infiltration is similar to that of lake evaporation (Table 7.1-16). Evapotranspiration/infiltration and lake evaporation rates are, in general, similarly influenced by the seasonal variation in precipitation and energy fluxes. Furthermore, it was also assumed that the monthly runoff distribution for the Hargrave, William, Minago and Oakley watersheds would be equal to that of the Burntwood River (Figure 7.4-7). The Burntwood River watershed is located in close proximity to the project site with precipitation and temperature regimes that are expected to be similar to that of the local watersheds. The resulting monthly water balance is presented in Table 7.4-13.

7.4.5.5 Peak and Low Flows

7.4.5.5.1 Regional Area Peak Discharges

A frequency analysis of flood flows was performed using peak discharge data during the freshet period from April to May and during the summer/fall period from June to October that were available at the regional hydrometric stations. Any high flow event from November to March was of lower magnitude than those of the freshet or summer/fall periods. Freshet events are expected to generate higher peaks than summer/fall events for all watersheds, with the exception of those on the Grass River.

The three groups of watersheds identified in Surface Water Runoff Section for watershed runoff assessments are also applicable to the evaluation of peak discharges. Peak discharges from a watershed are dependent upon precipitation and on the characteristics of the watershed such as the proportion of lakes and wetland, and the vegetation and soil types. Productivity (i.e., the peak discharge divided by the watershed area and expressed in $L/s/km^2$) is relatively high for the Sapochi, Taylor and Odei River watersheds due to the higher precipitation amounts and lower proportions of wetland areas compared to other watersheds (Tables 7.4-14 and 7.4-15). Alternatively, lakes would act to route flood flows and consequently dampen peaks. This is assumed to occur on the Grass River watersheds and, to some extent, on the Footprint, Gunisao and Burntwood River watersheds as well.

Flow routing through the drainage system of a watershed would typically dampen peaks. As a result it is expected that the ratio of flood peaks to the watershed area (i.e., productivity) would be higher for smaller watersheds (Sapochi, Taylor and Odei River in Tables 7.4-14 and 7.4-15, for example).

It is expected that peak discharge characteristics for watersheds in the area of the project site would be similar to those of the Footprint, Gunisao and Burntwood River watersheds because of similar responses to wetlands. However, the smallest watershed within this group is the Footprint River watershed (643 km^2) and it is anticipated that smaller watersheds, such as those of the Minago River (MRW2) and Oakley Creek (OCW2, OCW1 and OCAWR), would have higher peak productivity than those observed for the group as a whole.

Estimated peak productivity for the Footprint, Gunisao and Burntwood River watersheds are 17, 28 and 43 $L/s/km^2$ for the 2-, 10- and 100-year freshet peaks, and 11, 19 and 31 $L/s/km^2$ for 2-, 10- and 100-year summer/fall peaks, respectively. These values are assumed to be applicable for watersheds in the vicinity of the proposed project site that are larger than 643 km^2

Table 7.4-13 Local Monthly Water Balance

Month	Precipitation			Losses			Runoff [2]
	Rainfall	Snowfall	Total Precipitation	Evapotranspiration/ Infiltration	Snow Losses [1]	Total Losses	
Jan	0.2	20.1	20.2	0.0	7.8	7.8	3.3
Feb	0.2	17.5	17.8	0.0	6.8	6.8	2.4
Mar	1.6	20.9	22.4	0.0	8.1	8.1	2.3
Apr	11.0	15.8	26.8	10.5	6.2	16.7	5.9
May	38.6	4.2	42.8	66.8	1.6	68.4	24.6
Jun	74.2	0.2	74.4	72.0	0.1	72.1	20.2
Jul	78.3	0.0	78.3	75.6	0.0	75.6	15.0
Aug	69.6	0.0	69.6	64.1	0.0	64.1	12.1
Sep	64.6	1.1	65.8	38.2	0.4	38.6	10.3
Oct	27.5	11.5	39.0	10.5	4.5	15.0	9.9
Nov	2.9	25.3	28.2	0.0	9.9	9.9	6.8
Dec	0.2	24.8	25.0	0.0	9.7	9.7	4.5
Annual	369	141	510	338	55	393	117

Source: Golder Associates, 2009

1. Snow losses are the result of sublimation and snow redistribution and equal 39% of the snowfall.
2. Total losses are equal to the total precipitation minus runoff.

Table 7.4-14 Regional Flood Frequency Estimates during Freshet

Station Name [1]	Watershed	Peak Discharge (m^3/s)			Peak Productivity ($L/s/km^2$)		
	Area (km^2)	2-Year	10-Year	100-Year	2-Year	10-Year	100-Year
Sapochi River near Nelson House	391	14	30	42	35.3	77.1	107.6
Taylor River near Thompson	886	25	45	62	27.9	50.4	70.2
Odei River near Thompson	6,110	173	293	396	28.3	47.9	64.8
Grass River at Wekusko Falls	3,260	18	31	45	5.7	9.7	13.9
Grass River above Standing Stone Falls	15,400	106	171	229	6.9	11.1	14.8
Footprint River above Footprint Lake	643	11	17	22	17.0	26.5	34.5
Gunisao River at Jam Rapids	4,800	50	104	183	10.4	21.7	38.1
Burntwood River above Leaf Rapids	5,810	89	164	249	15.4	28.2	42.8

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008d)).

Table 7.4-15 Regional Flood Frequency Estimates during Summer/Fall

Station Name [1]	Watershed Area (km²)	Peak Discharge (m^3/s)			Peak Productivity ($L/s/km^2$)		
		2-Year	10-Year	100-Year	2-Year	10-Year	100-Year
Sapochi River near Nelson House	391	6	16	40	14.6	40.3	101.8
Taylor River near Thompson	886	14	29	55	15.7	33.2	62.6
Odei River near Thompson	6,110	83	187	354	13.6	30.6	57.9
Grass River at Wekusko Falls	3,260	19	34	51	5.8	10.3	15.5
Grass River above Standing Stone Falls	15,400	117	180	236	7.6	11.7	15.3
Footprint River above Footprint Lake	643	7	12	15	11.1	19.2	23.8
Gunisao River at Jam Rapids	4,800	36	80	149	7.5	16.6	31.1
Burntwood River above Leaf Rapids	5,810	54	101	151	9.3	17.4	26.0

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008d)).

Table 7.4-2). Estimating the productivity of the smaller watersheds in the vicinity of the project site is addressed in the following section.

7.4.5.5.2 Runoff and Peak Discharge from Smaller (<643 km^2) Watersheds

The surfaces of the smaller watersheds in the vicinity of the project site are composed largely of wetland vegetation (fens, bogs and peat). These surfaces are typically highly absorbent, usually poorly drained and have a high groundwater table that is at, or near the ground surface following the spring freshet or major storm events. Watershed runoff from these watersheds is anticipated to be comprised of surface runoff, as well as interflow and groundwater contributions. The relative magnitude of the interflow and groundwater contributions to the runoff would be dependent on the retention capacity of the watershed.

Event-based models, which are typically used for determining peak flows, would generally not be suitable for these watershed characteristics because they generally consider surface runoff only. Instead, a continuous model is required to account for the retention capacity of the watersheds.

In this report, a simple daily water balance was used as a continuous model to obtain an initial and preliminary estimate of runoff from the smaller watersheds in the vicinity of the Minago Project. Water inputs to the daily water balance model include rainfall and snowmelt water, while snow losses from sublimation and potential redistribution of snow out of the watershed were accounted for by assuming a reduction in the calculated snowpack snow water equivalent (SWE) by 39%. Losses from evapotranspiration and infiltration were incorporated in the model through runoff production rates.

The snowmelt module assumed for the daily water balance model was based on the degree-day method and considers the daily mean air temperature, rainfall and snowfall series generated for the project site (discussed in Section 7.1). The limited climate data available for the study area prevented the use of more physically-based snowmelt simulation models. It is expected that modelling results based on the water balance model approach contain some degree of uncertainty.

The degree-day model uses the following equation to calculate the daily snowmelt:

$$M = M_f \, (T_i - T_b)$$

where:
- M - daily snowmelt (mm)
- M_f - melt factor (mm/^{o}C/day)
- T_b - base air temperature above which melt begins (^{o}C)
- T_i - air temperature (°C).

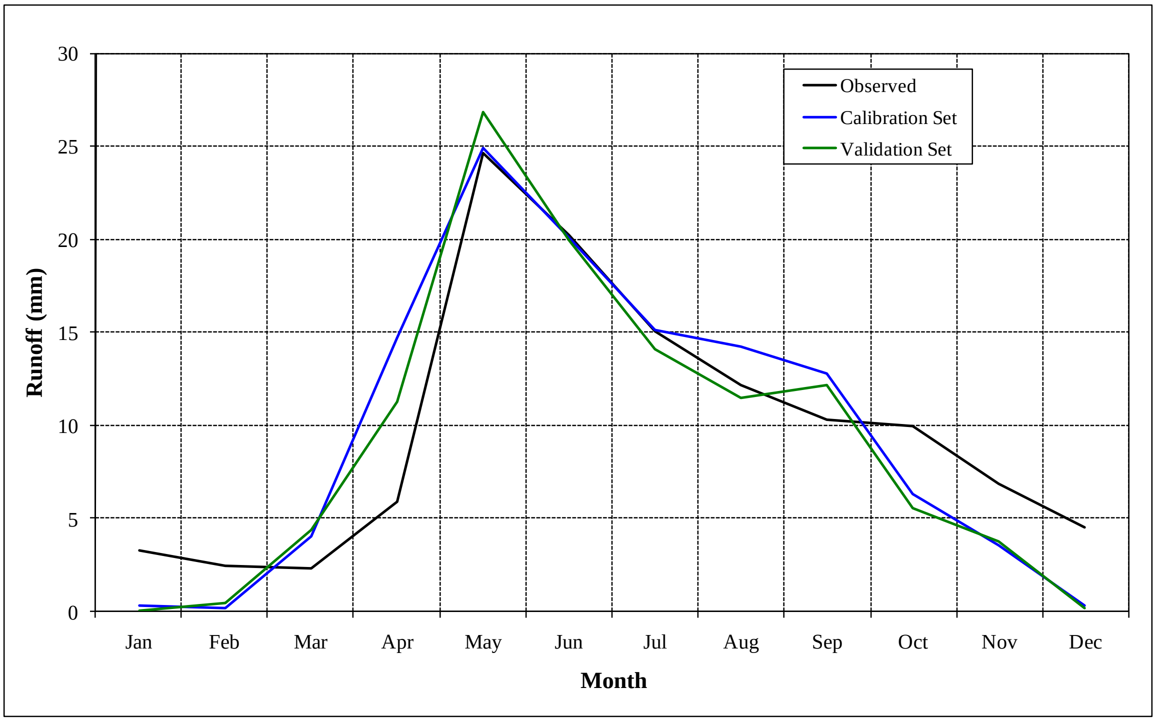
The runoff production rate is the ratio of water depth from rainfall or snowmelt that generates a runoff. This rate is a calibration parameter that is indicative of the retention capacity of that watershed. A low runoff production rate would suggest a longer retention time because of the larger losses from evapotranspiration and infiltration. Runoff production rates, P_m, for use in the daily water balance model were established on a monthly basis (m = 1 to 12).

Runoff production rates for the winter period (November to March) were assumed equal to 1, since the ground is presumed frozen and has therefore no retention. This implies that all of the rainfall in these months would contribute to runoff, even though some of the water would likely be retained by the snowpack. From April to October, the rates were assumed to be roughly equivalent to a runoff coefficient. Runoff production rates during the freshet were assumed to be higher than those of the summer/fall months due to the presumed saturated conditions of the soil, which would be indicative of a lower retention capacity.

The model did not account for overland and channel routing. The model also neglects the storage of melt in the snowpack, micro-topography, and small lakes.

The daily water balance model estimates maximum daily runoff rates based on daily air temperature, rainfall and snowfall data collected at The Pas station from 1951 to 2007, adjusted to the Minago Project site location. A total of 60% of the data were employed for the calibration of the model, while the remaining 40% were used as a validation set. Model calibration consisted of adjusting the assumed values for M_f, T_b and P_m until computed watershed monthly runoff depths were in general agreement with those presented for the Minago River and Oakley Creek watersheds in Table 7.4-13.

Figure 7.4-8 compares the observed and predicted (calibration and validation sets) watershed runoff on a monthly basis. The predicted runoffs were obtained by setting M_f and T_b equal to 0.9 mm/°/day and 2.5 ^{o}C, respectively. The runoff production rates, P_m, were set equal to 1 from November to March, 0.26 from April to June, and 0.19 from July to October. The estimated annual runoff for the Minago and Oakley watersheds is 117 mm, while the model predicted values were 117 mm and 110 mm, respectively for the calibration and validation data sets.



Source: Golder Associates, 2009

Figure 7.4-8 Comparison of Predicted and Observed Water Yield in the Degree-Day Model

The developed degree-day model is limited in its capacity to predict runoff from December to March. Only runoff from rainfall is accounted for; however, groundwater flow would be a significant contributor to runoff during the winter. It is also understood that applying monthly runoff production rates represent a simplified formulation of runoff generation processes. Production rates may vary significantly on a daily basis. In subsequent stages of the mine project, the predictions of runoff from this model should be confirmed with the use of a continuous watershed runoff model that includes a comprehensive formulation of hydrologic processes for the generation of flows (i.e., surface, interflow and groundwater) (Golder Associates, 2009).

Following model calibration, the annual maximum daily runoff depths, which are the water depths from rainfall and snowmelt weighted by the runoff production rates, were obtained from the model for the freshet and summer/fall periods. The runoff depths were then used in a frequency analysis to determine runoff depths for selected return periods for small watersheds (Table 7.4-16). As indicated, the resulting productivity estimates are higher than those from the regional analysis of peaks presented in Tables 7.4-14 and 7.4-15.

Table 7.4-16 Flood Frequency Estimates for Smaller Study Area Watersheds

Period	Peak Daily Runoff (mm)			Peak Daily Productivity (L/s/km^2)		
	2-Year	10-Year	100-Year	2-Year	10-Year	100-Year
Freshet (Apr-May)	4.1	7.7	15.6	48	89	181
Summer/Fall (Jun-Oct)	2.8	5.4	10.4	33	62	120

Source: Golder Associates, 2009

7.4.5.5.3 Local Area Peak Discharges

The estimation of peak discharges for watersheds in the vicinity of the proposed project site combine the result of the regional analysis (larger watersheds) and daily water balance model (smaller watersheds) as follows:

- The productivity obtained from the frequency analysis of daily runoff (Table 7.4-16) was considered applicable to the smallest monitored watershed in the vicinity of the proposed project site (Oakley Creek at OCW2; 93 km^2);
- Peak productivity for watersheds in the vicinity of the project site that are larger than the Footprint River watershed (643 km^2) were assumed to be equal to the maximum values observed at Footprint, Gunisao and Burntwood River;
- Peak productivity for intermediate watersheds was obtained through linear interpolation as a function of surface area; and
- Peak discharges were then obtained by multiplying the resulting productivity by the watershed area.

The corresponding peak discharges and productivities for the watersheds in the vicinity of the proposed project site are provided in Tables 7.4-17 and 7.4-18 for the freshet and summer/fall periods, respectively.

Table 7.4-17 Flood Frequency Estimates for Local Study Area Watersheds during the Freshet Period

Station Name	Watershed Area (km^2)	Peak Discharge (m^3/s)			Peak Productivity ($L/s/km^2$)		
		2-Year	10-Year	100-Year	2-Year	10-Year	100-Year
OCW2	93	4.4	8.3	16.7	47.7	89.2	180.7
OCW1	123	5.8	10.6	21.4	47.0	85.9	173.1
OCAWR	303	11.0	20.1	39.1	36.2	66.4	129.0
MRW2	214	8.8	16.3	32.3	41.0	76.1	151.0
MRW1	716	12.2	20.1	30.6	17.0	28.2	42.8
MRW3	785	13.3	22.1	33.6	17.0	28.2	42.8
WRAR	654	11.1	18.4	28.0	17.0	28.2	42.8
WRW2x	815	13.8	22.9	34.9	17.0	28.2	42.8
WRAOC	836	14.2	23.5	35.8	17.0	28.2	42.8
WRW1x	1,139	19.3	32.1	48.7	17.0	28.2	42.8
HRW1	1,512	25.7	42.6	64.7	17.0	28.2	42.8

Source: Golder Associates, 2009

Table 7.4-18 Flood Frequency Estimates for Local Study Area Watersheds during the Summer/Fall Period

Station Name	Watershed Area (km^2)	Peak Discharge (m^3/s)			Peak Productivity ($L/s/km^2$)		
		2-Year	10-Year	100-Year	2-Year	10-Year	100-Year
OCW2	93	3.1	5.8	11.1	33.0	62.5	120.2
OCW1	123	4.0	7.4	14.2	32.5	60.1	115.4
OCAWR	303	7.5	14.0	26.3	24.8	46.3	86.9
MRW2	214	6.0	11.4	21.6	28.2	53.2	101.0
MRW1	716	7.9	13.8	22.3	11.1	19.2	31.1
MRW3	785	8.7	15.1	24.4	11.1	19.2	31.1
WRAR	654	7.2	12.6	20.4	11.1	19.2	31.1
WRW2x	815	9.0	15.7	25.4	11.1	19.2	31.1
WRAOC	836	9.2	16.1	26.0	11.1	19.2	31.1
WRW1x	1,139	12.6	21.9	35.4	11.1	19.2	31.1
HRW1	1,512	16.7	29.1	47.1	11.1	19.2	31.1

Source: Golder Associates, 2009

7.4.5.5.4 Low Flows

A frequency analysis was performed on the 7-day low flow series observed at the regional hydrometric stations during the ice-cover period from November to March and open water period from April to October. The results of the frequency analysis are given in Tables 7.4-19 (ice-cover period) and 7.4-20 (open water period).

Low flow characteristics are typically indicative of the watershed contribution from interflow and groundwater flow. These two types of flows would be a function of the water retention in a watershed, based on the amount of lake, wetland and absorbing vegetation. Watersheds with significant amount of wetland (Grass, Footprint, Gunisao and Burntwood Rivers)) generally show higher productivity in Tables 7.4-19 and 7.4-20 for the 2- and 10-year events than those with lesser amount of wetland area (Sapochi, Taylor and Odei Rivers). Productivity is more variable for the 100-year events.

Table 7.4-19 Seven-Day Low Flows at Regional Stations during the Ice-Cover Period

Station Name	Watershed Area (km^2)	7-Day Low Flow (m^3/s)			Productivity ($L/s/km^2$)		
		2-Year	10-Year	100-Year	2-Year	10-Year	100-Year
Sapochi River near Nelson House	391	0.23	0.13	0.09	0.59	0.34	0.23
Taylor River near Thompson	886	0.7	0.33	0.12	0.74	0.38	0.13
Odei River near Thompson	6,110	3.1	1.2	0.22	0.51	0.19	0.04
Grass River at Wekusko Falls	3,260	7.8	3.2	0.001	2.40	0.99	0.0003
Grass River above Standing Stone Falls	15,400	44.0	22.2	10.5	2.85	1.44	0.68
Footprint River above Footprint Lake	643	1.3	0.66	0.11	2.02	1.02	0.18
Gunisao River at Jam Rapids	4,800	3.9	1.8	0.77	0.81	0.37	0.16
Burntwood River above Leaf Rapids	5,810	4.0	2.5	2.0	0.69	0.43	0.35

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008d)).

Table 7.4-20 Seven-Day Low Flows at Regional Stations during the Open-Water Period

Station Name	Watershed Area (km^2)	7-Day Low Flow (m^3/s)			Productivity ($L/s/km^2$)		
		2-Year	10-Year	100-Year	2-Year	10-Year	100-Year
Sapochi River near Nelson House	391	0.37	0.19	0.15	0.95	0.49	0.38
Taylor River near Thompson	886	0.75	0.084	0.015	0.84	0.10	0.02
Odei River near Thompson	6,110	14.7	6.6	4.0	2.40	1.07	0.66
Grass River at Wekusko Falls	3,260	7.3	3.1	0.23	2.25	0.95	0.07
Grass River above Standing Stone Falls	15,400	36.0	19.0	7.9	2.34	1.24	0.51
Footprint River above Footprint Lake	643	1.3	0.42	0.001	2.02	0.66	0.00
Gunisao River at Jam Rapids	4,800	8.1	2.7	0.59	1.70	0.55	0.12
Burntwood River above Leaf Rapids	5,810	11.5	3.6	1.1	1.98	0.62	0.18

1. Data source: Golder Associates, 2009 (Secondary source: EC (2008d)).

Based on wetland and vegetation characteristics, it was assumed that the low flow conditions in the Footprint, Gunisao and Burntwood River watersheds are similar to those in the area of the Minago Project. Productivity in that area was assumed to be equal to the average productivity estimated for the Footprint, Gunisao and Burntwood River watersheds. These average productivity values are respectively 1.17, 0.61 and 0.23 $L/s/km^2$ for the 2-, 10- and 100-year ice-cover low flow, and 1.90, 0.61 and 0.10 $L/s/km^2$ for 2-, 10- and 100-year open water low flow (Tables 7.4-19 and 7.4-20).

Local low flows may be obtained by multiplying productivity by the watershed area. The corresponding low flows are provided in Tables 7.4-21 and 7.4-22, respectively for the ice-cover and open water periods.

7.4.5.6 Sediment Yield

Sediment yield from a watershed is affected by climatic, hydrologic, and geomorphic characteristics including precipitation, vegetation cover (especially wetlands), basin runoff, land use, topography, drainage density, sediment storage, sediment transport capacity, and soil erodibility. Accurate determination of basin sediment yield requires rigorous and continuous measurements of the bed load, suspended load, and the amount of dissolved sediment in a receiving stream.

Table 7.4-21 Seven-Day Low Flows at Local Stations during the Ice-Cover Period

Station Name	Watershed Area (km^2)	7-Day Low Flow (m^3/s)		
		2-Year	10-Year	100-Year
OCW2	93	0.11	0.057	0.021
OCW1	123	0.14	0.075	0.028
MRW2	214	0.25	0.13	0.049
OCAWR	303	0.36	0.18	0.069
WRAR	654	0.8	0.40	0.15
MRW1	716	0.8	0.44	0.16
MRW3	785	0.9	0.48	0.18
WRW2x	815	1.0	0.50	0.19
WRAOC	836	1.0	0.51	0.19
WRW1x	1,139	1.3	0.69	0.26
HRW1	1,512	1.8	0.9	0.34

Source: Golder Associates, 2009

Table 7.4-22 Seven-Day Low Flows at Local Stations during the Open-Water Period

Station Name	Watershed Area (km^2)	7-Day Low Flow (m^3/s)		
		2-Year	10-Year	100-Year
OCW2	93	0.18	0.057	0.010
OCW1	123	0.23	0.075	0.013
MRW2	214	0.41	0.13	0.022
OCAWR	303	0.58	0.18	0.031
WRAR	654	1.2	0.40	0.07
MRW1	716	1.4	0.44	0.07
MRW3	785	1.5	0.48	0.08
WRW2x	815	1.5	0.50	0.08
WRAOC	836	1.6	0.51	0.09
WRW1x	1,139	2.2	0.69	0.12
HRW1	1,512	2.9	0.9	0.16

Source: Golder Associates, 2009

However, such rigorous measurement programs are rare, and most of the basin sediment yields are approximated based on discontinuous (spot) measurements of the suspended sediment load.

Table 7.4-23 presents an estimate of sediment yield over a 6-month period for the local (i.e., Hargrave, Minago and William Rivers and Oakley Creek) and regional watersheds. The estimate considers the following:

- The yield is estimated from May to October, which was the sampling period at the local watersheds in 2006 and 2007;
- The annual yield is considered to be similar to the calculated semi-annual yield because very little sediment is generated during the winter months;
- The TSS samples below the detection limits were set equal to half the detection limit value;
- The TSS yield in mg/L is equal to the average of the water samples; and
- Sediment density has been assumed to be 2,650 kg/m^3.

Table 7.4-23 Estimates of Semi-Annual Sediment Yield

River	Station Name	Drainage Area (km^2)	Number of Years of Data Available	Estimated Annual Yield ~ Calculated Semi-annual Sediment Yield	
				(mg/L)	(mm)
Regional Rivers	Taylor River near Thompson	886	6	39.1	0.0019
	Odei River near Thompson	6,110	4	47.2	0.0024
	Burntwood River above Three Point Lake	6,670	6	32.4	0.0011
Oakley Creek	OCW3	43	2	1.1	<0.0001
	OCW2	93	2	2.0	0.0001
	OCW1	123	2	3.0	0.0001
Minago River	MRW2/2x	214	1	4.0	0.0001
	MRW1	716	2	2.0	0.0001
	MRW3	785	1	3.0	0.0001
William River	WRW2x	815	1	30.4	0.0009
	WRW1x	1,139	1	17.6	0.0005
Hargrave River	HRW1	1,512	1	26.6	0.0007

Source: Golder Associates, 2009

From Table 7.4-23, the following observations may be made:

- The low yields at Oakley Creek and Minago River are indicative of lower land erosion in their watersheds compared to the watersheds of the other local and regional rivers.
- The lower yield at WRW1x than that at WRW2x would likely result from the low loadings coming from Oakley Creek. WRW1x is downstream of the confluence of Oakley Creek and William River.

7.4.6 Minago's Wetlands and some of their Characteristics

The study area is a relatively flat, low-lying region with extensive wetlands. The poorly drained bogs located within the study area consist essentially of treed bogs (Figure 7.4-9). The tree stratum is dominated by black spruce (*Picea mariana*) and tamarack (*Larix laricina*). The shrub stratum is dominated by shrub birch (*Betula glandulosa*) and bog rosemary (*Andromeda glaucophylla*). Bog sedge (*Carex magellanica*) and swamp horsetail (*Equisetum fluviatile*) are among the dominant herbs. The nonvascular stratum is dominated by peat moss (*Sphagnum* spp.) and feather mosses (*Helodium blandowii*, *Pleurozium schreberi*, etc.) (URS, 2008d).

Source: Roche, 2008a

Figure 7.4-9 Treed Bog

Other than being one of the most important components of the regional landscape, wetlands play a role that no other ecosystem can since they act as natural water treatment plants. Wetlands tend to slow down the force of water, encouraging the deposition of sediments carried in the water. This is beneficial further downstream where deposition of sediments may block waterways. Nutrients are often associated with sediments and can be deposited at the same time. These nutrients may accumulate in the sub-soil, be transformed by chemical and biological processes or be taken up by wetland vegetation. Moreover, by storing the water in the soil or retaining it in the surface waters of lakes, marshes, etc., wetlands reduce the need for expensive engineered structures. Wetland vegetation also plays a role in slowing down the flow of water and may reduce the thermal impact that discharge of relatively warm water would have on stream habitats (Roche, 2010).

Many wetland plants have the capacity to remove toxic substances that have come from pesticides, industrial discharges and/or mining activities. Some wetland plants have been found to accumulate heavy metals in their tissues at 100,000 times the concentration in the surrounding water and can detoxify certain kinds of effluent (Ramsar, 2000). Some *Typha* and *Phragmites* species have been used to treat effluents from mining areas that contain high concentrations of heavy metals such as cadmium, zinc, mercury, nickel, copper and vanadium (Higgins and Mattes, 2003) and to treat waters running off roads and highways (Sérodes et al., 2003).

Indeed, wetlands have several functions that aid in the removal of metals in waters. These characteristics are required for certain processes to occur: adsorption and ion exchange, bioaccumulation, bacterial and abiotic oxidation, sedimentation, neutralization, reduction, and dissolution of carbonate minerals (Perry and Kleinmann, 1991; Kadlec and Wallace, 2008).

Wetlands have organic-rich substrates, which exchange dissolved metals. This exchange occurs between the dissolved metals and abundant humic and fulvic acids contained within the substrate (Wildeman et al., 1991). Moreover, especially in bogs, *Sphagnum*'s cation exchange capacity (CEC) is one of the most important mechanisms by which dissolved metals are adsorbed and represents the capacity of a soil to exchange and retain positively charged ions (cations). *Sphagnum* mosses, the main components of peat deposit, are essentially made of polysaccharides (many saccharide units linked by glycosidic bonds) which provide a high CEC and, by the way, a high acidifying capacity (van Breeman, 1995). The high CEC enables an efficient retention of nutrients from the surrounding environment (air and plant decomposition) coupled with the release of H^+ ions. CEC is also an indicator of a soil's capacity to prevent potential contamination of groundwater and surface water since cations such as arsenic, copper, iron, nickel, lead and zinc may also be retained within the peat deposit (Roche, 2010).

Wetland sediments are generally anoxic or anaerobic below a thin oxidized surface layer and contain organic carbon for microbial growth. The anoxic zone of the sediments provides conditions, which favour microbial and chemical reducing processes. Soluble metals are converted to insoluble forms by the anoxic conditions of wetland sediments. Settling of suspended solids occurs from water velocity control by the wetland's vegetation (Ramsar, 2000).

Processes within natural wetlands have been found to remediate contaminants contained in acid rock drainage (ARD). Kleinmann (1985) found that iron concentrations dropped from 20-25 mg/L to 1 mg/L, manganese concentrations dropped from 30-40 mg/L to 2 mg/L in a *Typha* wetland. *Sphagnum* spp. may also have a significant effect on concentrations of iron, manganese, sulfate, and other mineral concentrations (Kleinmann, 1985; Weider et al., 1985). Plant roots will retain arsenic and other metals (Sobolewski, 1997). Plants also generate microenvironments that assist in the reduction and oxidation processes (Wildeman et al., 1991).

Gabor et al. (2004) and others have demonstrated that wetlands can efficiently remove contaminants from runoff water. Gabor et al. (2004) reported that artificial wetlands have reduced total nitrogen (by 30 to 87%), total phosphorous (by 4 to 90%), suspended solids (by 45 to 99%) and pathogen contents (by 61 to 99%) in waters passing through them. Halverson (2004) reported that wetlands to reduced metal contents by 36 to 98% in runoff waters that contained Ag, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, and Zn.

7.4.7 Effects Assessment Methodology

7.4.7.1 Scope of Assessment

Issues and Selection of Valued Ecosystem and Cultural Components (VECCs)

The open pit mine and the industrial complex will be located in the headwaters of Oakley Creek.

It is VNI's intention to concentrate the project footprint and associated effects on hydrology, as much as possible, within the Oakley Creek and Minago River drainages and to manage impacts to minimize downstream effects.

The surface water hydrology was identified as a VECC for the project assessment as it is a key factor with respect to both project design and operation and associated environmental effects. Issues of concern with respect to hydrology include:

- water availability for project use (domestic and process water uses);
- input to project water balance during all project phases including closure (such as long-term saturation of ultramafic rock for ARD management);
- design of site water management facilities (sizing of diversion and drainage ditches, settling ponds, culverts);
- assimilative capacity of surface waters for project-related discharges; and
- availability of physical instream habitat for fish and aquatic life.

Based on the above, Environmental Baseline Studies were conducted and presented to government agencies and Communities of Interest (COI) and the following factors, detailed in Table 7.4-24, were selected for further analysis to characterize and assess project effects on the surface water hydrology VECC.

Table 7.4-24 Hydrologic Processes Analyzed, VECC Selection Rationale, and Data Sources

Parameter	Rationale for Selection	Linkage to Regulatory Drivers	Baseline Data for EIS
Runoff (mean annual and mean monthly stream flow)	• Key input to stream flow analysis • Influences sediment	• Identified in Environmental Baseline Studies (EBS)	• Project field manual and automated data collection • Water Survey of Canada regional hydrology data • Climate data and climatic modeling of precipitation
Peak/flood flows (magnitude and timing)	• Required for water management facility and stream crossing designs • Affects stream channels (stability and morphology) and sediment transport • Floods are a natural hazard that must be considered in project design	• Identified in EBS Work plan	• Field data • Regional data • Flood frequency modeling
Low flows (magnitude and timing)	• Affects water quality and assimilative capacity of streams for project effluents • Affects instream habitat for fish and aquatic life • Affects availability of water for processing and camp use	• Identified in EBS Work plan	• Field data • Regional data • Low flow modeling
Evaporation	• Affects water levels in TWRMF and other storage facilities • Evaporation affects site water balance	• Identified in EBS Work	• Regional data • Modeling
Snowmelt rate	• Together with rainfall, snowmelt forms the principal hydrologic inputs to the system	• Identified in EBS Work	• Regional data • Field data • Modeling

Temporal Boundaries

Baseline data collection in the project area began in 2006 with the identification of drainages of interest. Regional hydrometric data from Water Survey of Canada was also used to supplement this data.

The assessment timeframe includes the period of record for applicable baseline data collection stations; project construction, operation and decommissioning, and the closure period up to the time when the groundwater table in the pit area will have been reestablished and contributions to stream base flows will have stabilized. It is planned that additional manual and automated data collection will be installed throughout the project life, using the established station network.

Study Area

With respect to surface water hydrology, there are three scales of interest: site-specific, local and regional. The site-specific scale covers areas directly affected or potentially directly affected by the mine and associated infrastructure. This includes the headwaters of Oakley Creek.

The local scale includes the entire drainages of Oakley Creek, and the Minago and William Rivers. The local scale covers an area that is larger area than the site-specific area. The site-specific scale and local scale together comprise the Local Study Area (LSA), in which hydrology will affect and be affected by the project design. The Regional Area includes the headwaters of William River and Hargrave Rivers.

7.4.7.2 Determination of Effects Significance

The significance of residual project and cumulative effects will be determined based on the defined effects attributes. An effect will be considered significant, if it is:

- an adverse effect of high likelihood, moderate magnitude and that is far future in duration or irreversible;
- an adverse effect of high likelihood and high magnitude, unless it is local in geographic extent and short- to long-term in duration;
- an adverse effect of high likelihood and high magnitude, that is local in geographic extent and far future in duration or irreversible.

Otherwise, effects will be rated as not significant.

7.4.8 Project Effects

Effect attributes for the assessment of the surface water hydrology are summarized in Table 7.4-25. There are several ways in which the project can potentially affect surface water hydrology throughout the life of the project:

Table 7.4-25 Effect Attributes for Surface Water Hydrology

Attribute	Definition
	Direction
Positive	Condition of VECC is improving.
Adverse	Condition of VECC is worsening or is not acceptable.
Neutral	Condition of VECC is not changing in comparison to baseline conditions and trends.
	Magnitude
Low	Effect occurs that might or might not be detectable, but is within the range of natural variability and does not compromise ecological, economic or social/cultural values.
Moderate	Clearly an effect but unlikely to pose a serious risk to the VECC or represent a management challenge from an ecological, economic or social/cultural standpoint.
High	Effect is likely to pose a serious risk to the VECC and represents a management challenge from an ecological, economic or social/cultural standpoint.
	Geographic Extent
Site-specific	Effect on VECC confined to a single small area within the Local Study Area (LSA).
Local	Effect on VECC within Local Study Area (LSA).
Regional	Effect on VECC extends into the Regional Study Area (RSA).
	Duration [1]
Short term	Effect on VECC is limited to the <1 year.
Medium term	Effect on VECC occurs between 1 and 4 years.
Long term	Effect on VECC lasts longer than 4 years but does not extend more than 10 years after decommissioning and final reclamation.
Far future [2]	Effect on VECC extends >10 years after decommissioning and abandonment.
	Frequency (Short Term duration effects that occur more than once)
Low	Effect on VECC occurs infrequently (< 1 day per month).
Moderate	Effect on VECC occurs periodically (seasonal or several days per month).
High	Effect on VECC occurs frequently throughout the year (weekly).
	Reversibility
Reversible	Effect on VECC will cease to exist during or after the project is complete.
Irreversible	Effect on VECC will persist during and/or after the project is complete.
	Likelihood of Occurrence
Unknown	Effect on VECC is not well understood and based on potential risk to the VECC, effects will be monitored and adaptive management measures taken, as appropriate.
High	Effect on VECC is well understood and there is a high likelihood of effect on the VECC as predicted.

Notes:

1 Reclamation goals are to approximate original (pre-mine) climate and hydrology within the range of natural variability or to approximate regional climate, if post-operational regional climate differs from pre-operational regional climate.

2 Effects to some VECCs may be permanent (see reversibility).

- **Water Use for Domestic and Industrial Purposes** – There will be no direct extraction of water from surface water bodies for project use during the operations phase. Potable water will be supplied from deep aquifer wells. The majority of water for ore processing will come from pit dewatering wells and reclaim water originating from the Polishing Pond (PP). The PP, in turn, will be fed by discharge from the Tailings and Waste Rock Management Facility (TWRMF), dewatering wells and other point sources. Water supplied from deep aquifers for the project will not result in a drawdown or dewatering of the Oakley Creek or the Minago River and thus will not affect the surface water hydrology (Golder Associates, 2008b). Additional information is provided in Section 7.6.
- **Project Site and Transportation Corridors Clearing and Soil Compaction** – Removal of vegetation and site development causes reduced transpiration, increased soil moisture and decreased infiltration leading to increased site runoff. The potential effect of increased runoff on stream flows will be minimal as the disturbed area is very small in comparison to the total drainage areas and site water management will further minimize potential of effects (see below).
- **Project Site Water Management** – Clean water diversions around facility sites, site drainage collection ditches and settling ponds will minimize potential effects of ground surface disturbance on runoff and stream flows in the project area.
- **Transportation Corridors Development** – Transportation corridor (Road) ditches will intercept shallow subsurface flow and will bring it to the surface. Road surfaces become compacted and relatively impermeable, reducing infiltration of precipitation. Road ditches and drainage structures form preferred pathways for drainage, hastening runoff. The density of roads that will be built is low (far less than 1 km of road length per square kilometre of drainage area), which indicates that the overall contribution of the road drainage network to watershed runoff will not be significant. Increased runoff from road development is not expected to affect peak flows in local streams. Road drainage structures and stream crossings will be appropriately sized for passing design flows and will be capable of passing bed load sediment of the size range normally transported by the streams.
- **Snow plowing** – Piling up of snow, compaction by vehicle travel, and introduction of sediment, particularly dust, to the snowpack in the vicinity of the project site and transportation corridors, will result in both more rapid snowmelt (in the case of dirty snow) and slower snowmelt (in the case of compacted or piled snow). Localized changes in the snowpack melt rate resulting from more rapid melting, and slower melting, will be small and should cancel each other out. No measurable effects on peak flows during spring freshet are expected.
- **Mine dewatering affecting flows in the Minago River and Oakley Creek** – Open pit mine development will intercept groundwater flows, primarily in the Oakley Creek basin. The process waters will be conveyed to the TWRMF, and subsequently, the TWRMF discharge and excess dewatering well water will be collected in the Polishing Pond (PP). Water from the PP will either be recycled to the process plant or discharged to Oakley Creek and Minago River in the spring, summer and fall months (May – October) and discharged to the Minago River watershed in the winter months (November to April). VNI does not

contemplate to discharge PP water to Oakley Creek during the winter months, because the creek is frozen solid during those months. At full development, Polishing Pond discharges could potentially result in measurable flow increases in Oakley Creek and the Minago River.

- **Polishing Pond Discharges to the Minago River and Oakley Creek** – Excess water accumulated in the PP will be discharged into Oakley Creek and Minago River. This stream is termed as final effluent. Therefore, its flow is the one at which water will be entering the discharge pipeline. From May to October, the final effluent will be discharged to both the Minago River (70%) and the Oakley Creek (30%). From November to April, water will only be discharged to the Minago River.

  From May to October, the final effluent will first be discharged in a treed bog before being collected by the Oakley Creek or the Minago River. The receiving treed bog will be upstream of the Minago River Bridge for the case of the Minago River discharge point and the discharge point for the Oakley Creek watershed will be through an existing discharge ditch. From November to April, the final effluent will be discharged in a rock-filled channel before being released to the Minago River.

7.4.8.1 Seasonal Issues

As water will not be discharged consistently in one place over the year, there might be some impacts on the receiving environment. The following sections describe those impacts and provide an evaluation of their potential and importance.

7.4.8.1.1 Impacts on Hydrological Conditions

The boreal region, which encompasses the study area, has a subarctic climate that is subject to considerable inter-annual variability. Climate influences the seasonal stream flow regime, which typically exhibits winter low flow, terminated by spring freshet, followed by summer flow recession. Therefore, three periods of time have been considered for this analysis: the winter low flow period, from November to April, the spring freshet, in May, and the summer flow period, from June to October. Water flows were measured in the Oakley Creek and the Minago River for these three periods as part of the Environmental Baseline Studies.

In terms of hydrology, the impact of discharging a significant volume of water every day in a stream can be quite important, especially if the volume of water being discharged causes an increase in the stream flow that exceeds the stream's natural capacity, i.e. the stream high-water flow associated with the spring freshet.

Table 7.4-26 details the predicted flow increases as the final effluent will be discharged in the receiving Oakley Creek and Minago River while Table 7.4-27 presents the associated increases in water depth. Figures 7.4-10 and 7.4-11 illustrate the relation between those two parameters for both receiving watercourses.

For the Minago project, water being discharged in the Oakley Creek and the Minago River from June to April will not increase the stream flow up to a level exceeding the high-water flow, which,

Table 7.4-26 Projected Flow Rates (m^3/s) as the Final Effluent will be Discharged in the Receiving Watercourses

Flow (m^3/s)	Year 1			Year 2			Year 3			Year 4		
	November - April	May	June - October	November - April	May	June - October	November - April	May	June - October	November - April	May	June - October
Minago River - Upstream	0.80	10.00	1.90	0.80	10.00	1.90	0.80	10.00	1.90	0.80	10.00	1.90
Discharge to Minago River	0.24	0.97	0.36	0.29	1.04	0.36	0.29	1.02	0.36	0.29	1.00	0.36
Minago River - Downstream	1.04	10.97	2.26	1.09	11.04	2.26	1.09	11.02	2.26	1.09	11.00	2.26
Oakley Creek - Upstream	0.00	4.00	0.50	0.00	4.00	0.50	0.00	4.00	0.50	0.00	4.00	0.50
Discharge to Oakley Creek	0.00	0.41	0.15	0.00	0.45	0.15	0.00	0.44	0.15	0.00	0.43	0.15
Oakley Creek - Downstream	0.00	4.41	0.65	0.00	4.45	0.65	0.00	4.44	0.65	0.00	4.43	0.65
Increase in Minago River	31%	10%	19%	36%	10%	19%	36%	10%	19%	36%	10%	19%
Increase in Oakley Creek	0%	10%	31%	0%	11%	31%	0%	11%	31%	0%	11%	31%

Flow (m^3/s)	Year 5			Year 6			Year 7			Year 8		
	November - April	May	June - October	November - April	May	June - October	November - April	May	June - October	November - April	May	June - October
Minago River - Upstream	0.80	10.00	1.90	0.80	10.00	1.90	0.80	10.00	1.90	0.80	10.00	1.90
Discharge to Minago River	0.29	0.97	0.36	0.29	0.95	0.36	0.29	0.92	0.36	0.29	0.91	0.36
Minago River - Downstream	1.09	10.97	2.26	1.09	10.95	2.26	1.09	10.92	2.26	1.09	10.91	2.26
Oakley Creek - Upstream	0.00	4.00	0.50	0.00	4.00	0.50	0.00	4.00	0.50	0.00	4.00	0.50
Discharge to Oakley Creek	0.00	0.42	0.15	0.00	0.41	0.15	0.00	0.40	0.15	0.00	0.39	0.15
Oakley Creek - Downstream	0.00	4.42	0.65	0.00	4.41	0.65	0.00	4.40	0.65	0.00	4.39	0.65
Increase in Minago River	36%	10%	19%	36%	9%	19%	36%	9%	19%	36%	9%	19%
Increase in Oakley Creek	0%	10%	31%	0%	10%	31%	0%	10%	31%	0%	10%	31%

Flow (m^3/s)	Year 9			Year 10			Closure			Year 12		
	November - April	May	June - October	November - April	May	June - October	November - April	May	June - October	November - April	May	June - October
Minago River - Upstream	0.80	10.00	1.90	0.80	10.00	1.90	0.80	10.00	1.90	0.80	10.00	1.90
Discharge to Minago River	0.04	0.12	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Minago River - Downstream	0.84	1.12	1.97	0.80	10.00	1.90	0.80	10.00	1.90	0.80	10.00	1.90
Oakley Creek - Upstream	0.00	4.00	0.50	0.00	4.00	0.50	0.00	4.00	0.50	0.00	4.00	0.50
Discharge to Oakley Creek	0.00	0.00	0.00	0.00	0.37	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Oakley Creek - Downstream	0.00	4.00	0.50	0.00	4.37	0.57	0.00	4.00	0.50	0.00	4.00	0.50
Increase in Minago River	5%	1%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Increase in Oakley Creek	0%	0%	0%	0%	9%	14%	0%	0%	0%	0%	0%	0%

Flow (m^3/s)	Year 13		
	November - April	May	June - October
Minago River - Upstream	0.80	10.00	1.90
Discharge to Minago River	0.00	0.00	0.00
Minago River - Downstream	0.80	10.00	1.90
Oakley Creek - Upstream	0.00	4.00	0.50
Discharge to Oakley Creek	0.00	0.00	0.00
Oakley Creek - Downstream	0.00	4.00	0.50
Increase in Minago River	0%	0%	0%
Increase in Oakley Creek	0%	0%	0%

Table 7.4-27 Projected Water Depths (m) as the Final Effluent will be Discharged in the Receiving Watercourses

Water level (m)	Year 1			Year 2			Year 3			Year 4		
	November - April	May	June - October	November - April	May	June - October	November - April	May	June - October	November - April	May	June - October
Minago River - Upstream	0.44	1.76	0.72	0.44	1.76	0.72	0.44	1.76	0.72	0.44	1.76	0.72
Discharge to Minago River	0.22	0.49	0.28	0.24	0.52	0.28	0.24	0.51	0.28	0.24	0.50	0.28
Minago River - Downstream	0.52	1.84	0.80	0.53	1.85	0.80	0.53	1.85	0.80	0.53	1.85	0.80
Oakley Creek - Upstream	0.00	1.24	0.41	0.00	1.24	0.41	0.00	1.24	0.41	0.00	1.24	0.41
Discharge to Oakley Creek	0.00	0.37	0.21	0.00	0.39	0.21	0.00	0.38	0.21	0.00	0.38	0.21
Oakley Creek - Downstream	0.00	1.30	0.48	0.00	1.31	0.48	0.00	1.31	0.48	0.00	1.31	0.48
Increase in Minago River	17%	5%	10%	19%	5%	10%	19%	5%	10%	19%	5%	10%
Increase in Oakley Creek	0%	5%	16%	0%	5%	16%	0%	5%	16%	0%	5%	16%

Water level (m)	Year 5			Year 6			Year 7			Year 8		
	November - April	May	June - October	November - April	May	June - October	November - April	May	June - October	November - April	May	June - October
Minago River - Upstream	0.44	1.76	0.72	0.44	1.76	0.72	0.44	1.76	0.72	0.44	1.76	0.72
Discharge to Minago River	0.24	0.50	0.28	0.24	0.49	0.28	0.24	0.48	0.28	0.24	0.48	0.28
Minago River - Downstream	0.53	1.84	0.80	0.53	1.84	0.80	0.53	1.84	0.80	0.53	1.84	0.80
Oakley Creek - Upstream	0.00	1.24	0.41	0.00	1.24	0.41	0.00	1.24	0.41	0.00	1.24	0.41
Discharge to Oakley Creek	0.00	0.37	0.21	0.00	0.37	0.21	0.00	0.36	0.21	0.00	0.36	0.21
Oakley Creek - Downstream	0.00	1.30	0.48	0.00	1.30	0.48	0.00	1.30	0.48	0.00	1.30	0.48
Increase in Minago River	19%	5%	10%	19%	5%	10%	19%	5%	10%	19%	5%	10%
Increase in Oakley Creek	0%	5%	16%	0%	5%	16%	0%	5%	16%	0%	5%	16%

Water level (m)	Year 9			Year 10			Closure			Year 12		
	November - April	May	June - October	November - April	May	June - October	November - April	May	June - October	November - April	May	June - October
Minago River - Upstream	0.44	1.76	0.72	0.44	1.76	0.72	0.44	1.76	0.72	0.44	1.76	0.72
Discharge to Minago River	0.08	0.15	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Minago River - Downstream	0.46	1.77	0.74	0.44	1.76	0.72	0.44	1.76	0.72	0.44	1.76	0.72
Oakley Creek - Upstream	0.00	1.24	0.41	0.00	1.24	0.41	0.00	1.24	0.41	0.00	1.24	0.41
Discharge to Oakley Creek	0.00	0.00	0.00	0.00	0.35	0.13	0.00	0.00	0.00	0.00	0.00	0.00
Oakley Creek - Downstream	0.00	1.24	0.41	0.00	1.30	0.44	0.00	1.24	0.41	0.00	1.24	0.41
Increase in Minago River	3%	1%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Increase in Oakley Creek	0%	0%	0%	0%	4%	7%	0%	0%	0%	0%	0%	0%

Water level (m)	Year 13		
	November - April	May	June - October
Minago River - Upstream	0.44	1.76	0.72
Discharge to Minago River	0.00	0.00	0.00
Minago River - Downstream	0.44	1.76	0.72
Oakley Creek - Upstream	0.00	1.24	0.41
Discharge to Oakley Creek	0.00	0.00	0.00
Oakley Creek - Downstream	0.00	1.24	0.41
Increase in Minago River	0%	0%	0%
Increase in Oakley Creek	0%	0%	0%

Figure 7.4-10 Relationship between Flow Rate and Water Depth in the Minago River with Discharge

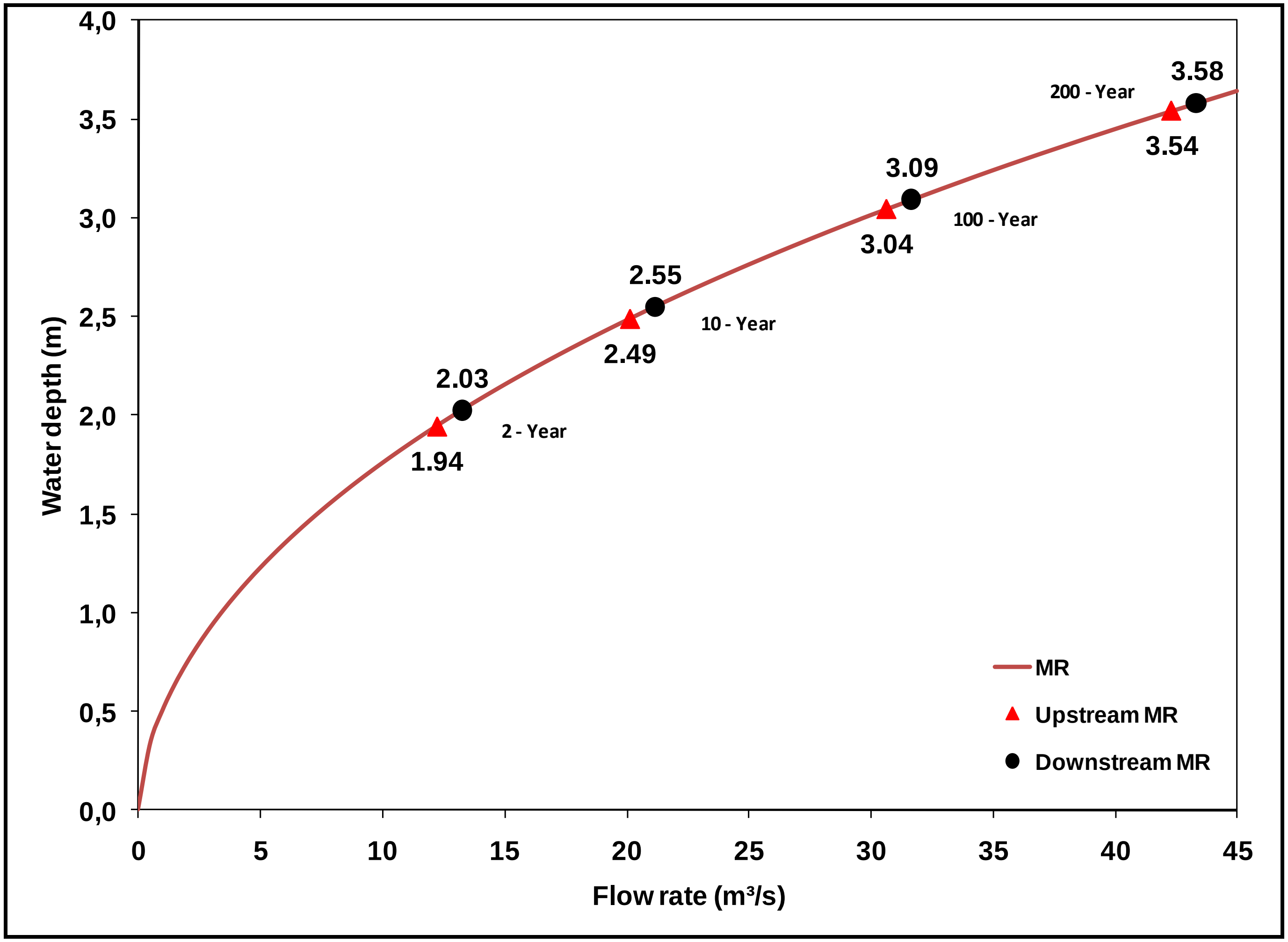
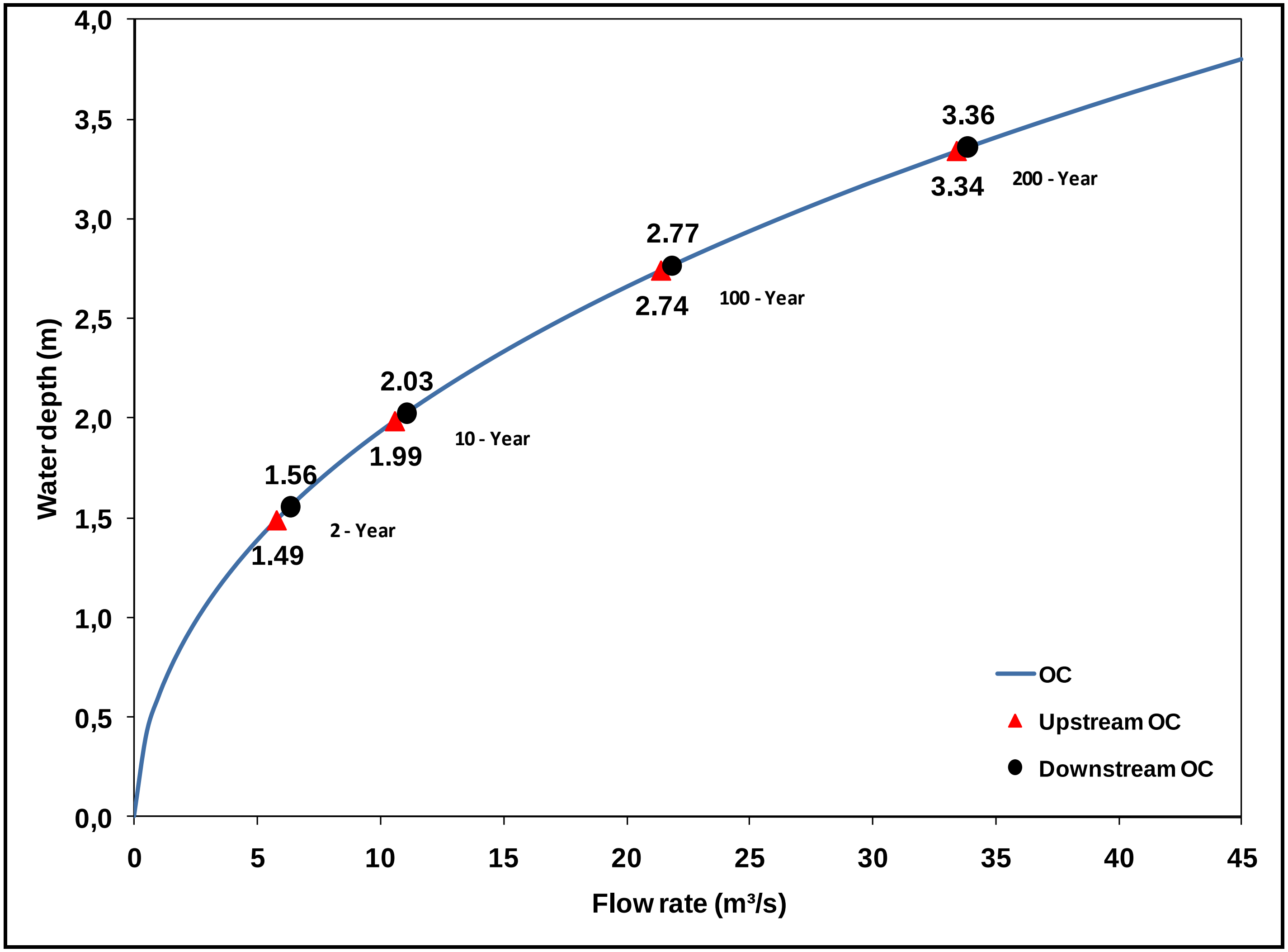


Figure 7.4-11 Relationship between Flow Rate and Water Depth in the Oakley Creek with Discharge



in this area, occurs in May (Table 7.4-26). This means that these streams have the natural capacity to receive the discharged water. On the other hand, in May, i.e. at the high-water level, increases in terms of flow rate, while the discharge of the final effluent will be at its maximum rate (year 2), will be about 10% for the Minago River and 11% for the Oakley Creek (Table 7.4-26). These increased flow rates will result in a projected increase in water depth of 5% for both watercourses (Table 7.4-27). The estimation of those related increases in water depth due to the discharge of the final effluent in the receiving watercourses were calculated using URS (2008a) channel-description data for reaches directly impacted by the final effluent, i.e. where it will be discharged. Table 7.4-28 details these channel parameters, measured by URS (2008a).

Table 7.4-28 Channel Characteristics for Minago River and Oakley Creek

Parameters	Minago River (From J3 to MRW1)	Oakley Creek (From OCW1 to WRW1x)
Channel bottom width (m)	7.2	4.3
Slope ratio	3:1	3:1
Channel slope (m/m)	0.0008	0.0017
Manning's Roughness Coefficient	0.07	0.09

The boreal region is sensitive to variations in the climate. It is also an area where many rivers have been regulated (Ye et al., 2003), notably for hydroelectric power generation. Both natural and human factors cause variations and changes in the timing and magnitude, hence the seasonal rhythm of river discharge. Therefore, such small variations in the stream flow at the high-water level are within the natural variation occurring in such boreal conditions and should not have any significant impact on the receiving hydrological environment. Figures 7.4-10 and 7.4-11 illustrates how small those flow increases will be for the Minago River and the Oakley Creek when compared to 1:10, 1:100 and 1:200 peak flow discharges. It is also important to note that the increased flows during a normal year (1:2) at the high water level are not high enough to correspond to a 1:10 peak flow event, to which the river system is well-adapted.

Moreover, from May to October, the final effluent will first be discharged in a vast treed bog so that its flow will be reduced before being released in the receiving streams. This means that values shown in Table 7.4-26 should be considered as maximum values since they represent a situation in which water is being directly discharged in the Oakley Creek or the Minago River without passing through a wetland before. Moreover, Table 7.4-27 also presents data that must be considered as maximum values since those were estimated based on a trapezoidal-shape channel which represents a situation that does not account for vegetation on riverbanks, which attenuate flows and other topographical/bathymetrical features that could help in reducing the potential effects of the final effluent on natural flow rates.

The potential negative impacts of the final effluent (total suspended solids, heavy metals content) on water quality will be mitigated, since water will run through a treed bog before reaching the receiving streams. The bog's capacity to receive discharged water can be easily demonstrated based on relatively simple observations. First, the presence of trees and the absence of ponds within a bog indicate that drainage is not as limited as it would be in large open bogs with several ponds (Thibault, 2006). This means that these bogs still have the capacity to store additional water by creating ponds (Tremblay and Garneau, 2008).

An adaptative monitoring program will be implemented to monitor flows in the receiving watercourses upstream and downstream of the discharge points. The final effluent flow will also be monitored and signs of change within the watercourses will be documented (photographs will be taken annually during similar flow periods or times of year).

7.4.8.1.2 Impacts on Biological Aspects

Two main components of the receiving environment could be impacted by how the final effluent will be managed, namely wetlands and stream habitats.

Impacts on Wetlands

From May to October, the final effluent will first be discharged in a vast treed bog before being released to the receiving streams. These bogs still have the capacity to store additional water by creating ponds.

A small marsh will certainly be created where the final effluent will be discharged. However, it would be quite surprising to see such a significant transformation over the entire bog's surface (creation of ponds and reduction of the tree cover) given that:

- no ponds at all have been observed within these bogs;
- they cover significant areas and are parts of a vast complex of wetlands that are hydrologically connected together and form one of the most important ecosystem in the region.

Still, if a significant transformation of the bog's surface were to occur, it is important to note that it is widely accepted that open bogs with ponds represent more attractive habitats for many wildlife species such as waterfowl and amphibians. Ducks Unlimited Canada, as well as *Québec's ministère du Développement durable, de l'Environnement et des Parcs* (Department of Sustainable Development, Environment and Parks), has recognized this general concept and use it to evaluate the ecological value of a bog. Poulin (2002) has also proposed a set of criteria to assess a bog's ecological value, including the area covered by ponds.

A diffuser will be installed to reduce erosion at the point where the final effluent will be released in the bog. Rocks (riprap) will also be installed at this same location.

Impacts on Stream Habitats

The fact that water will first be discharged in a bog before being released in the receiving streams means that the increases shown in Table 7.4-26 should be considered as maximum values since they represent a situation in which water is being directly discharged in the Oakley Creek or the Minago River without passing through a wetland before. Given the capacity of wetlands, such as those bogs, to slow the water flow coming to the receiving streams, the impact on stream habitats should be low, or not significant, particularly in May. However, if an increase in the amount of water flowing in those streams should occur, the impact on stream habitat quality would likely be positive, especially in winter low flow conditions.

Low flows are defined as those typical during a prolonged dry period (Smakhtin, 2001), or more precisely in the Canadian context, those that occur during periods without significant rainfall or snowmelt input. During low flows, most stream habitat types are reduced in extent and changes in water quality can occur, which can be stressful for fish and other biota (IFC, 2004).

Therefore, especially from November to April, higher water flows and thus water levels would help maintaining the existing stream habitat types and limit changes in water quality that can occur, therefore limiting seasonal stresses for some fish species and other biota. Such positive impacts of higher winter flow have been observed in northern Québec by Hydro-Québec along rivers regulated for hydroelectric power generation purposes.

Water coming out of a mine is usually not at the same temperature than water flowing in the surrounding streams. However, before being released as the final effluent, that water will have to flow through the TWRMF and the Polishing Pond, therefore being exposed to rainfall and ambient temperatures for some days. Based on these facts, the thermal impact of the water being discharged to the receiving environment is considered to be not significant.

Finally, to avoid any erosion of the riverbed in the Minago River while water will not pass through a bog first (from November to April), a rock-filled channel will be implemented between the river and where the final effluent will be released (end of the pipeline). However, aerial surveys will be performed during the summer of 2010 to evaluate if some other small unmapped stream, located in the immediate vicinity of the Minago River where the final effluent is to be discharged, could be used in order to avoid the implementation of a rock-filled channel and to reduce the potential footprint of the project.

An adaptative monitoring program will be implemented to monitor flows in the receiving watercourses upstream and downstream the discharge points. The final effluent flow will also be monitored and signs of change within the watercourses will be documented (photographs will be taken annually during similar flow periods or times of year).

7.4.8.2 Closure Issues

As it was the case for transitional period (seasonal) issues, the potential impacts of ending the discharge of the final effluent to the receiving environment affect two main components, namely hydrological conditions (river and creek) and biological aspects (wetlands and stream habitats).

As discussed in the previous sections, the impacts of increasing or decreasing the water flow in the Minago River and the Oakley Creek will be low, or not significant, in terms of hydrology since they are within the natural variation occurring in this region.

These impacts will also be low on wetlands since these vast ecosystems are quite resilient. Indeed, mosses, sedges and ericaceous shrubs are among the most widespread species in the region and can easily acclimatize themselves to a wide variety of conditions (Campbell and Rochefort, 2001). Gradually, vegetation cover is expected to change back to what it was before if no other change in climatic conditions occurs; otherwise, it will adapt itself to the prevailing climatic conditions. Bogs are not as sensitive as forest stands to climatic conditions, especially rainfall, since they are already wet ecosystems that have the capacity to store additional water. In fact, the development of a bog is mainly due to a combination of factors, such as temperature and precipitation favouring, a positive net annual water balance.

The impacts of a reduction in the water flow on stream habitats could however be potentially significant. Indeed, especially in winter low flow conditions, lower water flows and thus water levels reduce stream habitat types and increase the risk of changes in water quality, increasing seasonal stresses for fish and other biota.

Therefore, mitigation measures will have to be implemented in order to limit the potential impacts of such a change in water level conditions, meaning that water will have to be stored in the PP in such a way that the final effluent flow will be gradually reduced and not drastically. This would enable a comeback to pre-mining (natural) conditions.

The areas on which the pipeline, the rock-filled channel, if needed, and the diffuser will be implemented will have to be rehabilitated, meaning that they will be re-vegetated with indigenous species.

7.4.8.2.1 Open Pit Closure

A common extraction method for metal mining is open pit mining, which results in (a) residual pit(s) being left on the landscape. The excavated pits will be of various depths and sizes, but all will require environmental reclamation. One possible reclamation endpoint could be the creation of end-pit lakes, which will be formed by water filling the open pit left upon the completion of mining operations. These pits can be filled by artificially flooding or allowing the pits to fill naturally through hydrological processes such as precipitation and/or groundwater infiltration. Depending on water quality, it may also be possible to modify or enhance pits to create aquatic habitat for fish and wildlife.

At Minago, it has been decided not to create a fish habitat using the pit once it will have been flooded. Therefore, it will be necessary to create obstacles to fish circulation between the Oakley Creek and the pit since water from the pit will be flowing towards the Oakley Creek using a network of drainage ditches.

To that effect, residual waste rock wil be used to block the ditches since such coarse material would allow the free movement of water while preventing fish from swimming through them.

However, fish may be introduced into a pit lake during or after flooding by waterfowl and other fish-eating bird species, which could drop fishes while passing over the pit or simply stopping by. Species such as the Northern pike or Walleye could therefore be observed in the pit lake.

Based on the magnitude of the project footprint in the affected drainage basins and site water management to minimize effects of increased runoff, no measurable effects on surface water hydrology are expected from surface disturbances. The main issue with respect to project effects on hydrology is groundwater interception due to pit dewatering, which will be managed through the Polishing Pond. This effect would occur primarily during operations, decommissioning and initial years of closure, when the groundwater table will be re-established in the mine area. Effects and mitigation are described in detail below.

Oakley Creek

The effect of pit dewatering on groundwater contributions to stream flow will be insignificant in Oakley Creek. No reductions in flows are expected to occur (Golder Assoicates, 2008b) in Oakley Creek as there is no recorded hydraulic connection between the open pit dewatering activities and Oakley Creek. Furthermore, under current conditions, Oakley Creek freezes solid at times during the winter when it has a net discharge of zero.

Following closure of the mine, the restoration of the groundwater regime will proceed in two phases: the refilling of the pit itself will take approximately eleven years (pit volume = 156.7M m^3 at a recharge rate of 40,000 cubic metres per day). The flow from the pit will be directed to the Oakley Creek watershed. Fisheries and benthic community in the Oakley Creek will not be impacted by open pit dewatering operations. Therefore, there are no concerns regarding impacts on productive instream habitat for benthic communities and fish. Flow monitoring in Oakley Creek will continue during operations to confirm the no effects phenomena as a result of pit dewatering and assess the related effects on fish habitat in the lower reaches.

Minago River

Based on the Golder Associates (2008b) report, the Minago groundwater regime will not be affected by the pit dewatering operations. Therefore, there will be no negative impacts on the Minago watershed groundwater flows.

7.4.8.3 Residual Project Effects

There are no predicted residual effects of mine dewatering on low flow conditions in both Oakley Creek and the Minago River and therefore, open pit dewatering will not be of a concern during the operational and closure phases. Accordingly, residual effects of mine dewatering on the Minago River and Oakley Creek will be insignificant or non existent. Predicted residual effects of Polishing Pond discharges on flows in the Minago River and Oakley Creek are positive or neutral, low, local and reversible. The likelihood of effects as predicted is low. No mitigation measures will be required, because the predicted effects are not a concern with respect to hydrologic conditions or aquatic habitat.

7.4.8.4 Cumulative Effects

The residual project effects identified in the previous section are site-specific to local in geographic extent. No additional projects are currently planned within the area, which would overlap with predicted project effects. Therefore, there will be no significant adverse cumulative or residual cumulative effects in the project area. The likelihood of occurrence of effects as predicted is high.

Mitigation measures pertaining to project effects on surface water hydrology are summarized in Table 7.4-29.

7.4.8.5 Monitoring and Follow-up

Follow-up Studies

Existing water quality monitoring sites established for the project will continue to be used during project construction, operations and decommissioning phases. Additionally, automated monitoring equipment will be installed at various sites (stations) on the Minago River, William River and Oakley Creek to better quantify flows. Moreover, more a detailed description of the watercourses along reaches directly impacted by the final effluent will also be undertaken to be able to more precisely estimate the associated increases in water depth. Data collected will also be used to improve and refine stage-discharge curves and estimated peak and low flow magnitudes for specified return periods. Improved values will lead to a more accurate understanding of the project hydrology and the range of natural variability. Due to potential fisheries concerns related to discharges to the Oakley Creek and the Minago River, stream flows will be monitored on an ongoing basis in conjunction with observations of effects on fish habitat to define minimum instream flow requirements for fish habitat.

Monitoring Programs

Selected manual and automated monitoring sites will be installed and will be used for monitoring surface water flow, in conjunction with planned monitoring for fisheries and water quality (Table 7.4-30). The final effluent flow will also be monitored and signs of change within the watercourses will be documented (photographs will be taken annually during similar flow periods or times of year).

Table 7.4-29 Mitigation Measures for Effects on Surface Water Hydrology

Potential Project Effect	Mitigation Measures
Effects of clearing and construction on runoff and stream flows	• See Site Water Management Plan • See Erosion and Sediment Control Plan
Effects of stream crossings on stream flows	• Design flow specifications to allow unobstructed passage of flows and bed load • See Erosion and Sediment Control Plan

Improved values will lead to a more accurate understanding of the project hydrology and the range of natural variability. Due to potential fisheries concerns related to discharges to the Oakley Creek and the Minago River, stream flows will be monitored on an ongoing basis in conjunction with observations of effects on fish habitat to define minimum instream flow requirements for fish habitat.

7.4.8.6 Summary of Effects

Table 7.4-31 provides a tabular summary of the project effects on surface water hydrology.

Table 7.4-30 Monitoring and Follow-up Programs for Hydrology

Potential Project Effect	Program Objectives	General Methods	Reporting	Implementation
Follow-Up and Monitoring Programs				
Site water management	• Develop stage discharge curves and refine peak and low flow projections for water management purposes	• Ongoing operation of recording pressure transducers • Continued monthly manual monitoring • Install new manual monitoring stations	• Internal	Proponent
Increased flows in Minago River and Oakley Creek from Polishing Pond discharges	• Define maximum instream flow requirements for aquatic habitat • Maintain flows that are less than or equal to the identified maximum by monitoring effects and implementing mitigation measures as required	• Installation of automated monitoring equipment in Oakley Creek and the Minago River (both upstream and downstream of the Polishing Pond Discharge points) • Develop stage/discharge relationship to assess effects on wetted stream habitat	• Internal for adaptive management purposes • to the MB Gov.'t as required • to DFO as required	Proponent
Monitoring Programs				
Project effects on flows in Oakley Creek and the Minago River	• Monitor flows to check effects predictions and support interpretation of water quality monitoring results	• Ongoing operation of recording pressure transducers on Oakley Creek and Minago River • Monthly summer manual monitoring at stations on Oakley Creek and Minago River (upstream and downstream of the Minago Project discharges) • Manual discharge measurements in conjunction with water quality sampling • Annual taking of photographs during similar flow periods or times of year	• to DFO as required for compliance with the *Metal Mining Effluent Regulations* (MMER)	Proponent

Table 7.4-31 Summary of the Project Effects on Surface Water Hydrology

Potential Effect	Level of Effect						Effect Rating	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Construction, Operations and Decommissioning								
Increased flows in Oakley Creek and Minago River due to Polishing Pond Discharges	Positive	Moderate	Local	Long-term	Reversible	High	Not significant	Not significant
Closure								
Reduced low flows in Oakley Creek and Minago River to base flow due to discontinued discharges to the watersheds	Adverse	Moderate	Site specific	Long-term	Reversible	High	Not significant	Not significant

7.5 Surface Water Quality

This section summarizes the monitoring program of surface water quality. The objectives of the surface water quality program were to:

- establish pre-mining baseline surface water quality conditions for the Minago Project Area;
- provide baseline surface water quality data required to complete an Environmental Impact Assessment of the Minago Project under the Manitoba *Environmental Assessment Act*;
- provide baseline surface water quality data required to complete bankable Feasibility Study on the Minago Project; and
- provide baseline surface water quality data for water quality modeling, engineering design, water management and determining impacts to aquatic resources.

No known historical records were found for surface water quality data for the Minago Project Area.

7.5.1 Relevant Water Quality Guidelines

Relevant water quality guidelines and regulations for the Minago Project include:

- *Manitoba Water Quality Standards, Objectives and Guidelines* (Williamson, 2002);
- Canadian *Guidelines for the Protection of Aquatic Life* (CCME, 2007); and
- *Metal Mining Effluent Regulations* (Environment Canada, 2002a).

The intent and applications of these regulations and guidelines are summarized below whereas their detailed concentration limits are listed in subsection 7.5.3 as part of the discussion of surface water quality results obtained for Minago watercourses.

7.5.1.1 Manitoba Tier I Water Quality Standards, Tier II Water Quality Objectives, and Tier III Water Quality Guidelines

Manitoba Tier I Water Quality Standards identify minimum standards for common classes of discharges in Manitoba. These standards form the basis for the technology-based approach to the prevention of pollution. The *Manitoba Tier I Water Quality Standards* may also contain Canada-Wide Standards developed and negotiated by the Canadian Council of Ministers of the Environment (CCME) under the Canada-Wide Accord on Environmental Harmonization (Williamson, 2002).

Manitoba Tier II Water Quality Objectives are defined for a limited number of common pollutants (such as dissolved metals and nutrients) in Manitoba that are routinely controlled through licencing under the Manitoba *Environment Act. Manitoba Tier II Water Quality Objectives* typically form the basis for the water quality base approach when additional restrictions need to be developed to protect important uses of ground or surface waters beyond those defined in Tier I Water Quality Standards or other controls to which discharges are subject (Williamson, 2002).

Manitoba Tier III Water Quality Guidelines contain guidelines developed by the federal Canadian Council of Ministers of the Environment (CCME), which were developed to ensure that the most sensitive species in the aquatic receiving environment are protected at all times along with an adequate margin of safety (Williamson, 2002).

7.5.1.2 Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 2007)

Canadian Water Quality Guidelines for the Protection of Aquatic Life define acceptable levels for substances or conditions that affect water quality such as toxic chemicals, temperature and acidity. As long as conditions are within the levels established by the guidelines, one would not expect to see negative effects in the environment (CCME, 2007). These guidelines are based on toxicity data for the most sensitive species of plants and animals found in Canadian waters and act as science-based benchmarks.

7.5.1.3 Metal Mining Effluent Regulations (MMER)

The *Metal Mining Effluent Regulations* (MMER) were registered on June 6, 2002, under subsections 34(2), 36(5), and 38(9) of the *Fisheries Act*. The MMER replaced the MMLER and the associated Metal Mining Liquid Effluent Guidelines, which came into force in February 1977.

The MMER prescribe authorized concentration limits for deleterious substances in mine effluents that discharge to waters frequented by fish. The regulated parameters are arsenic, copper, cyanide, lead, nickel, zinc, total suspended solids (TSS), Radium 226, and pH.

The MMER apply to all Canadian metal mines (except placer mines) that exceeded an effluent flowrate of 50 m^3 per day at any time after the Regulations were registered. Mines are defined as facilities where ore is mined or milled and include mines under development, new mines, and reopened mines.

The MMER apply to effluent from all final discharge points (FDPs) at a mine site. A FDP is defined in the Regulations as a point beyond which the mine no longer exercises control over the quality of the effluent.

7.5.2 Scope of Surface Water Quality Assessment

7.5.2.1 Introduction

Surface water quality in watercourses surrounding the Minago Project was assessed by Wardrop (2007) from May to October 2006, URS (2008g) from May to August 2007, and KR Design Inc. from September 2007 to May 2008. Wardrop (2007) monitored water quality in Oakley Creek and Minago River while URS (2008g) and KR Design Inc. regularly monitored water quality in Oakley Creek, Minago River, William River, and Hargrave River. One-time assessments of surface water quality were also completed for William Lake, Little Limestone Lake, Russell Lake, and two locations near the confluence of William River and Limestone Bay on Lake Winnipeg (Figure 7.5-1, Table 7.5-1). The selected locations for surface water sampling stations were based on:

- a review of topographic maps, orthophoto and drainage features at and surrounding the Minago Project Site;
- considerations associated with the simultaneous collection of hydrological data, stream sediment and benthic samples during one or more of the surface water sampling events;
- considerations associated with the selection of representative stations both upstream and downstream of the Minago Project Site for the development of long-term sampling stations to monitor long-term trends in surface water quality during the exploration phase of the Minago Project and during potential development, operation and post-closure phases of the Minago Project mine life.

Water samples were analyzed for field parameters (pH, temperature, conductivity, oxidation-reduction potential (ORP), and dissolved oxygen (DO)), nutrients, major ions, metals, Radium-226 and other physicochemical parameters. Collection methods conformed to the guidelines outlined in the federal *Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring* (MMER-EEM; Environment Canada 2002b).

7.5.2.2 Scope of Assessment – 2006 Program

Wardrop established the following four water quality sampling stations on Oakley Creek and Minago River (Wardrop, 2007):

- OCW-1 is located on the west-side of Highway 6 and receives drainage from Oakley Creek and the ditches along Highway 6;
- OCW-2 is located 2.2 km upstream of OCW-1 and receives the drainage from forks of Oakley Creek;
- OCW-3 is located 550 m upstream of OCW-2 and receives drainage from the southwest forks of Oakley Creek;

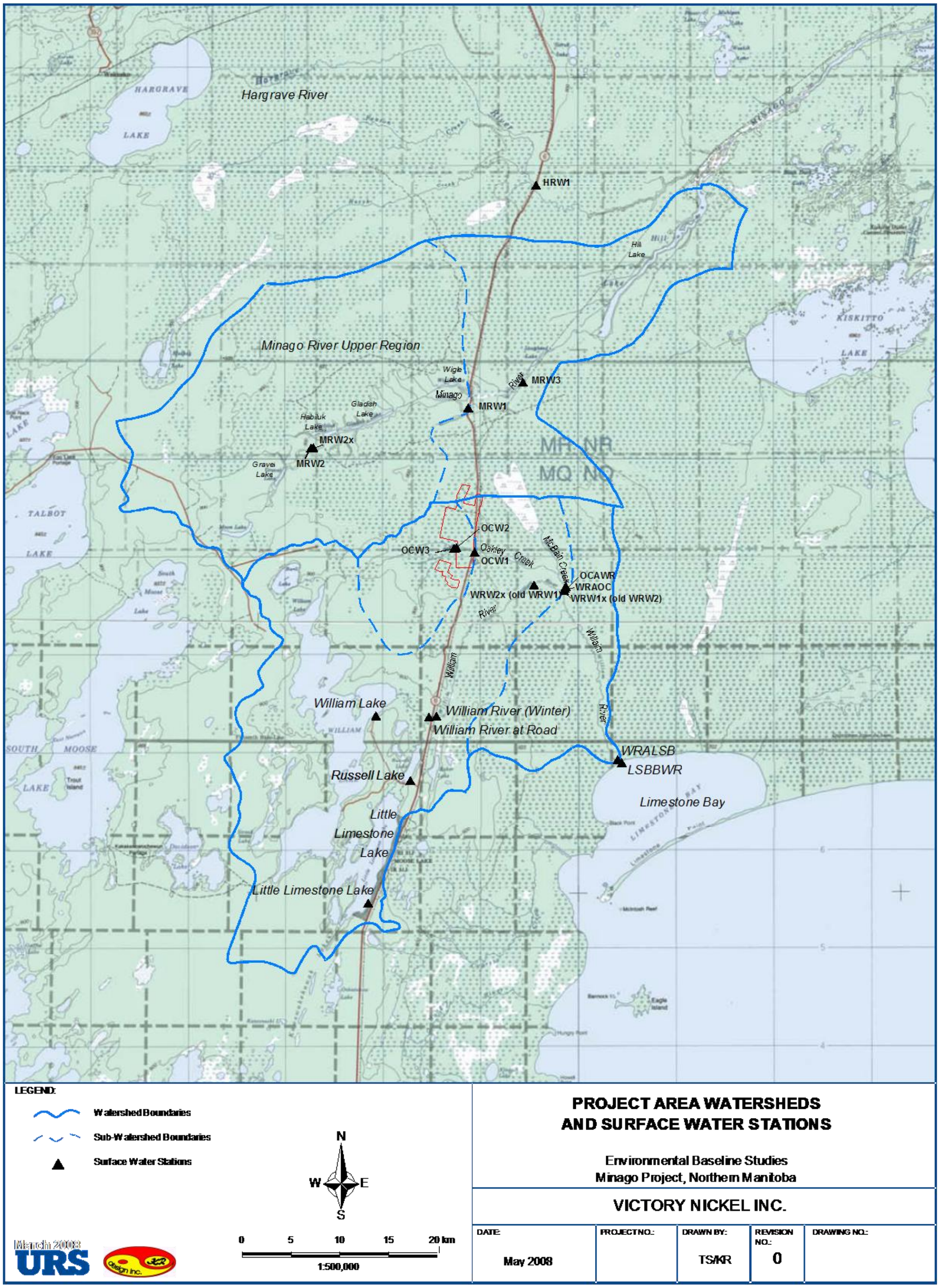


Figure 7.5-1 Locations of the Surface Water Monitoring Stations at Minago

Table 7.5-1 Nomenclature and Coordinates of Minago Surface Water Monitoring Stations

VNI Sample Location	UTM (NAD 83)		UTM (NAD 83)		
(as of Sept. 15, 2007)	Northing	Easting	Latitude	Longitude	Description
HRW1	6028072	495606	54°24.041' N	99°04.051' W	Hargrave River immediately west of Highway 6
MRW1	6005277	488671	54°11.721' N	99°10.420' W	Minago River immediately west of Highway 6
MRW2	6001212	472476	54°09.494' N	99°25.290' W	Minago River near Habiluk Lake
MRW2x	6001166	472571	54°09.470' N	99°25.206' W	Minago River near Habiluk Lake (~ 100 m downstream of MRW2)
MRW3	6007895	494274			Minago River downstream of Highway 6 near powerline cut
OCW1	5990510	489322	54°03.762' N	99°09.786' W	Oakley Creek immediately east of Highway 6
OCW2	5990961	487463	54°04.002' N	99°11.492' W	Oakley Creek immediately downstream of north tributary
OCW3	5990892	487230	54°03.965' N	99°11.707' W	Oakley Creek immediately upstream of north tributary
WRW2x	5987162	495416	54°01.963' N	99°04.199' W	William River approx. 6 km upstream of the Oakley Creek confluence
WRW1x	5986554	498523	54°01.637' N	99°01.350' W	William River approx. 100 m downstream of the Oakley Creek confluence
WRAOC	5986647	498452	54°01.685' N	99°01.416' W	William River approx. 50 m upstream of the Oakley Creek
OCAWR	5986744	498457	54°01.738' N	99°01.414' W	Oakley Creek approx. 50 m above William River
WRALSB	5969206	503935	53°52.278' N	98°56.410' W	William River approx. 100 m above Limestone Bay
LSBBWR	5968889	504092	53°52.107' N	98°56.262' W	Limestone Bay approx. 250 m below William River
Little Limestone Lake	5954922	478725			Little Limestone Lake (at end of road)
Russell Lake	5967117	482571			Russell Lake (at end of road)
William River (Winter)	5973774	485141	53°54.730' N	99°13.574' W	William River east of Highway 6
William River at Road	5973791	485078			William River west of Highway 6
William Lake	5973831	479083			William Lake at end of access road

- MRW-1 was established on the Minago River at the Highway 6 crossing, approximately 15 km north of Oakley Creek.

Coordinates for all stations were recorded using a handheld Trimble GeoXM-2005 series GPS with 1 m horizontal resolution (Table 7.5-2).

Table 7.5-2 Coordinates – Wardrop (2007) Surface Water Monitoring Locations

Monitoring Station	Northing (m)	Easting (m)
OCW-1	5990528	489238
OCW-2	5990974	487559
OCW-3	5990931	487048
MRW-1	6005275	488684

In the field, Wardrop (2007) measured water temperature, dissolved oxygen (DO) concentration and percent oxygen saturation, conductance, oxidation-reduction potential (ORP), total dissolved solids (TDS), salinity, and pH once per month from May to October, 2006 using a YSI 600 QS Multiparameter Sampling System. All measurements were made at mid-water column depth.

Water samples for laboratory analyses were collected at all sampling stations once a month from May to October 2006. Samples were analysed for nutrients, major ions, metals, Radium-226, and other physicochemical parameters. Maxxam Analytics Inc., of Burnaby, BC, conducted the analyses for all parameters, except Radium-226, which was analyzed at Becquerel Laboratories Inc. in Mississauga, Ontario. Wardrop's (2007) field sampling protocol for their surface water quality sampling program is given in Appendix 7.5.

7.5.2.3 Scope of Assessment - URS (2008g)

URS (2008g) collected monthly surface water quality samples from the Minago River, William River, Hargrave River and Oakley Creek between May and August 2007 (Figure 7.5-1 and Table 7.5-1).

Surface water quality sampling at each sampling station included measurement of field parameters (pH, temperature, conductivity, oxidation-reduction potential (ORP), and dissolved oxygen (DO)) and the collection of surface water samples for laboratory analysis. Laboratory analysis included:

- **Physical Tests:** pH, conductivity, hardness, total dissolved solids, total suspended solids and turbidity;
- **Anions and Nutrients:** ammonia, acidity, alkalinity, bromide, chloride, fluoride, sulphate, nitrate, nitrite, total kjeldahl nitrogen and total nitrogen;

- **Metals:** total and dissolved; and
- **Other Parameters**: total cyanide and Radium-226.

ALS Laboratory Group, of Vancouver, BC, conducted the analyses for all parameters, except Radium-226, which was analyzed at SRC Analytical, of Saskatoon, SK. URS' (2008g) field protocol for water quality sampling is given in Appendix 7.5.

7.5.2.4 Scope of Assessment – KR Design Inc.

KR Design Inc. collected surface water quality samples from the Minago River, William River, Hargrave River and Oakley Creek in September and October 2007 and March and May 2008. One-time surface water quality samples were also collected from William Lake, Little Limestone Lake, Russell Lake, and two locations near the confluence of William River and Limestone Bay on Lake Winnipeg (Figure 7.5-1, Table 7.5-1).

Surface water quality sampling at each sampling station included measurement of field parameters (pH, temperature, conductivity, oxidation-reduction potential (ORP), Total Dissolved Solids, dissolved oxygen (DO), and barometric pressure) and the collection of surface water samples for laboratory analysis. Field parameters were assessed with a YSI 600QS multiparameter probe. This probe was calibrated prior to every field sampling event. The probe's pH meter was calibrated with pH 7.0 and pH 10.0 standard solutions. The dissolved oxygen and depth sensors were calibrated immediately before every field measurement.

Laboratory analysis included:

- **Physical Tests:** pH, conductivity, hardness, total dissolved solids, total suspended solids and turbidity;
- **Anions and Nutrients:** ammonia, acidity, alkalinity, bromide, chloride, fluoride, sulphate, nitrate, nitrite, total kjeldahl nitrogen and total nitrogen, dissolved and total organic carbon;
- **Metals:** total and dissolved; and
- **Other Parameters**: weak acid dissociable cyanide and Radium-226.

ALS Laboratory Group, of Vancouver, BC, conducted the analyses for all parameters, except Radium-226, which was analyzed at SRC Analytical, of Saskatoon, SK. KR Design Inc.'s field protocol for water quality sampling is given in Appendix 7.5.

7.5.3 Baseline Conditions – Surface Water Quality

In this document, water quality results were compared to the Final Draft Manitoba Water Quality Standards, Objectives and Guidelines (Williamson, 2002). For the purposes of assessing baseline surface water quality for the Minago Project Area, the Tier III Water Quality Guidelines were applied. The Tier III Water Quality Guidelines contain guidelines developed by the federal Canadian Council of Ministers of the Environment (CCME), which were developed to ensure that the most sensitive species in the aquatic receiving environment are protected at all times along with an adequate margin of safety. Where specific parameters are not available under the Tier III Water Quality Guidelines, Tier II Water Quality were applied to assess baseline surface water quality conditions, and in anticipation of the further assessment of potential impacts on surface water quality from the Minago Project mine development plan. For completeness, summaries of Minago surface water quality results also list guideline limits for the *Canadian Water Quality Guidelines for the Protection of Aquatic Life* (CCME, 2007) and the *Metal Mining Effluent Regulations* (MMER).

7.5.3.1 Data Validity

The vast majority of surface water quality results were judged to be valid based on results obtained for monitoring stations and quality control and assurance samples (travel blanks, field blanks and field duplicates). However, a few data validity issues were encountered. These included slight contamination of field and travel blanks, replicate duplicate analyses for which the relative percent difference (RPD) was greater than 20%, and higher dissolved versus total element concentrations.

Slight contamination in some of the quality control samples was encountered and analytical results for these samples are summarized in Appendix 7.5. Results for replicate duplicate analyses ranged from an RPD of 0.03 to 189% for element concentrations, compared to the typically accepted and mandated 20%. In general, Maxxam laboratory data had higher RPD values than ALS Laboratory Group data. Details of replicate analyses are given in Appendix L7.5 as part of the presentation of analytical laboratory certified results.

Higher dissolved versus total element concentrations were measured on numerous occasions. In theory, dissolved element concentrations are never higher than the total element concentrations. As part of the investigation of this finding, error bounds were calculated for all of the Minago water quality data based on the Data Quality Objectives (DQO) for precision provided by the ALS Laboratory Group. Precision was assumed to be the absolute value of the Relative Percent Difference (RPD) for laboratory duplicate samples plus/minus the additional value of square root of 2 multiplied by the detection limit (DL) to deal with variability of the two results near the detection limit. Thus, the difference between results was assumed to be:

$$\leq \left| RPD \times mean \right| + (\sqrt{2} \times DL) .$$

A sample calculation of the error bounds is given in Appendix L7.5.

For water samples for which the reported dissolved element concentrations were higher than the total element concentrations further data analysis was undertaken to determine whether those differences were actually significant based on the calculated error bounds. For the vast majority of water samples, the differences between the measured total and dissolved element concentrations were not significant. However, for some of the water samples the differences were significant. Table 7.5-3 summarizes the number of test results for which the differences were significantly different and could not solely be explained with the error bounds. Details of the element concentrations for these water samples and their error bounds are presented at the end of each of the monthly water quality data presented in Appendix L7.5.

For samples for which the differences were significant, the error might have been due to laboratory method variability as well as other factors such as:

- field sampling method variability;
- bias introduced during general handling, storage, transportation and/or analysis of the sample; and
- field sample grab bias - where separate grab samples are processed to produce total and dissolved samples.

Table 7.5-3 Number of Test Results with Significant Higher Dissolved versus Total Concentrations

Sampling Date	Number of Results that could not be fully explained with the error bounds assuming RPD as measured or 20% for which no RPD existed	Number of Results that could not be fully explained with the error bounds assuming RPD was 20%	Consultant / Lab
03-May-06	1	1	Wardrop / Maxxam
16-May-06	5	0	Wardrop / Maxxam
20-Jun-06	0	0	Wardrop / Maxxam
18-Jul-06	18	0	Wardrop / Maxxam
22-Aug-06	3	0	Wardrop / Maxxam
19-Sep-06	6	0	Wardrop / Maxxam
12-Oct-06	3	0	Wardrop / Maxxam
15-May-07	5	3	URS / ALS Vancouver
12-Jun-07	1	0	URS / ALS Vancouver
15-Jul-07	4	0	URS / ALS Vancouver
15-Aug-07	6	5	URS / ALS Vancouver
12-Sep-07	3	2	KR Design / ALS Vancouver
15-Oct-07	0	0	KR Design / ALS Vancouver
11-Mar-08	1	0	KR Design / ALS Vancouver
6-9 May-08	32	0	KR Design / ALS Vancouver

7.5.3.2 Summary of Water Quality Results

The following summary of water quality results is indicative of baseline conditions in watercourses in the vicinity of the Minago Project. Detailed water quality results, tabulated by sampling station and compared to Manitoba Water Quality Objective and Guidelines and CCME Water Quality Guidelines, are given in Appendix 7.5. All certified analytical laboratory reports for the water quality analyses, inclusive water quality control results, are provided in Appendix L.7.5.

Table 7.5-4 presents an overview of water quality results in terms of average, median, minimum and maximum concentrations for all surface water sampling stations, monitored between May 2006 and May 2008. These water quality results are tabulated alongside Manitoba Water Quality Objective and Guidelines, *Canadian Water Quality Guidelines for Protection of Aquatic Life* (CCME, 2007), and Metal Mining Effluent Regulations (Environment Canada, 2002a). Detailed results for each and every sampling station, including a listing of minimum and maximum concentrations, are presented in Appendix 7.5.

Overall, water quality was good at the Minago Project and its vicinity with only some of the parameters exceeding Manitoba and/or CCME limits. These exceedances are discussed and illustrated below after a general description of the water quality surrounding the Minago Project.

Considering all stations and all sampling events, most of the elements for which and total and dissolved concentrations were assessed had similar dissolved and total concentrations. For those elements, the ratio (expressed as percent) of dissolved to total concentrations was 93% or greater. Exceptions to this finding, detailed in Table 7.5-5, were for aluminum, iron, cobalt, manganese, lead, nickel, and chromium. On average, the ratio of dissolved to total element concentration was 32% for aluminum, 46% for iron, 64% for cobalt, 70% for manganese, 78% for lead and nickel, and 82% for chromium.

7.5.3.2.1 pH and Alkalinity

To date, all water samples collected were alkaline with a pH ranging from 7.01 to 8.84. All pH measurements met the *Manitoba Tier II Water Quality Objectives*. The average and median field pH were 7.82 and and 7.81, respectively (Table 7.5-4). The alkaline pH in the area may be attributed to the limestone prevalent in the area. An illustration of pH levels in the surface waters surrounding the Minago site can be found in Appendix 7.5.

Considering all sampling stations and events, the total alkalinity ranged from 56.6 to 703.0 mg/L (as $CaCO_3$) with average and median concentrations of 166.3 mg/L and 161.5 mg/L, respectively (Table 7.5-4). Most of the alkalinity was likely due to bicarbonate, because whenever both total and bicarbonate alkalinity were assessed, those two parameter concentrations were equal (Appendix 7.5).

Table 7.5-4 Overview of Surface Water Quality at Minago

	Units	AVERAGE[1] May-Oct. All stations	MEDIAN[1] May-Oct. All stations	MINIMUM May-Oct. All stations	MAXIMUM May-Oct. All stations	REGULATIONS: Manitoba Water Quality Standards, Objectives and Guidelines (Williamson, 2002) – TIER II Water Quality Objectives	Manitoba – TIER III - Water Quality Guidelines: DRINKING MAC	Manitoba – TIER III - Water Quality Guidelines: Freshwater Aquatic Life	Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 2007)
Field Properties									
Temperature	°C	12.8	11.6	**1.0**	**25.6**			Tier II	**narrative [s]**
Specific Conductance	uS/cm at 25°C	291.3	300.8	**127.0**	**580.0**	1000			
Conductance	uS/cm	214.2	215.5	**69.3**	**346.0**				
Total dissolved solids	g/L	0.191	0.202	**0.083**	**0.266**				
Diss. oxygen (% saturation)	sat %	90.3	92.3	**61.4**	**109.2**				
Dissolved oxygen	mg/L	9.6	9.6	**5.7**	**13.4**	varies with life-stages & temperature; 6.5 mg/L (30-Day, 3-Year if temp. > 5°C); Instantaneous Minimum 5 mg/L (if T>5°C)			
Depth		0.075	0.069	**0.002**	**0.242**				
pH	pH Units	7.82	7.81	**7.01**	**8.84**			6.5-9	**6.5-9**
ORP	mV	210.1	207.8	**115.8**	**309.0**				
Barometric pressure	kN/m^2	97.0	98.6	**14.4**	**99.6**				
Salinity	ppt	0.2	0.2						
Physical Tests									
Hardness (as CaCO3)	mg/L	173.9	170.0	**61.5**	**715.0**				
Conductivity (in laboratory)	uS/cm	284.5	282.0	**109.0**	**1170.0**	1000			
pH	pH Units	8.07	8.07	**7.71**	**8.56**				**6.5-9**
Total Dissolved Solids	mg/L	189.2	186.0	**60.0**	**739.0**	700			
Total Suspended Solids	mg/L	11.5	5.0	**0.5**	**65.0**	Dependent on background TSS (5 mg/L (30-Day, 3 Year) or 25 mg/L (1-Day, 3-Year) or 10% (1-Day, 3-Year) of induced change from background)		Tier II	**narrative**
Turbidity	NTU	6.0	1.5	**0.2**	**38.1**		1.0	Tier II	**narrative**
True Colour	Col. Unit	46.9	50.0	**10.0**	**70.0**				
Anions and Nutrients									
Ammonia (NH4)	mg/L	0.023	0.020	**0.005**	**0.155**	pH and temperature dependent (lowest concentration for all categories = 1.17 mg/L for pH 7.8)		Tier II	**see factsheet**
Acidity (as CaCO3)	mg/L	2.6	2.4	**1.0**	**10.7**				
Alkalinity, Total (as CaCO3)	mg/L	166.3	161.5	**56.6**	**703.0**				
Alkalinity (PP as CaCO3) **	mg/L	0.3	0.3						
Alkalinity, Carbonate (as CaCO3)	mg/L	1.0	1.0	**<2.0**	**<2.0**				
Alkalinity, Hydroxide (as CaCO3)	mg/L	1.0	1.0	**<2.0**	**<2.0**				
Alkalinity, Bicarbonate (as CaCO3)		184.0	141.5	**56.6**	**703.0**				
Bromide (Br)	mg/L	0.025	0.025	**<0.050**	**<0.050**				
Chloride (Cl)	mg/L	0.90	0.70	**0.52**	**11.10**				
Fluoride (F)	mg/L	0.087	0.073	**0.036**	**0.590**		1.5		
Sulphate (SO4)	mg/L	1.19	0.73	**0.52**	**10.90**				
Nitrate (NO3-N)	mg/L	0.22	0.003	**0.01**	**1.35**		10		2.93 [c,u]
Nitrate (NO3)	mg/L	0.011	0.010	**0.020**	**0.030**		45		13 [c,u,y]
Nitrite (NO2-N)	mg/L	0.042	0.001	**<0.0010**	**0.29**		0.97	CCME	0.06 [z]
Nitrite (NO2)	mg/L	0.006	0.003	**0.005**	**0.049**		3.2	CCME	0.197
Nitrate-N plus Nitrite-N						10			
Total Kjeldahl Nitrogen (Calc)	mg/L	0.515	0.500	**0.153**	**1.440**				
Total Nitrogen	mg/L	0.566	0.512	**0.184**	**2.590**				
Diss. Organic Carbon	mg/L	13.66	13.65	**1.86**	**35.10**				
Diss. Inorganic Carbon (C)	mg/L	42.5	43.9	**31.8**	**60.0**				
Total Organic Carbon	mg/L	13.74	13.65	**2.41**	**35.80**				
Tot. Inorganic Carbon (C)	mg/L	43.1	42.5	**25.3**	**61.0**				
Cyanides									
Cyanide, **Total**	mg/L	0.0097	0.0095	**0.0056**	**0.0140**		0.2		
Cyanide, **Weak Associable Cyanide**	mg/L	0.0025	0.0025	**<0.0050**	**<0.0050**	0.0052 mg/L (4-Day, 3-Year)		Tier II	0.005 (as free CN)
Radiological Parameters									
Radium-226	Bq/L	0.005	0.003	**0.005**	**0.050**		0.6		

NOTE:
1 If the sample concentration was less than the detection limit, half the detection limit was used to compute the average and median.

Table 7.5-4 (Cont.'d) Overview of Surface Water Quality at Minago

		AVERAGE[1]	MEDIAN[1]	MINIMUM	MAXIMUM	REGULATIONS				
		May - Oct. All stations	May - Oct. All stations	May - Oct. All stations	May - Oct. All stations	Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 2007)	Manitoba Water Quality Standards, Objectives (Williamson, TIER III - Water Quality Guidelines			Metal Mining Effluent Regulations (MMER) (2002)
							Drinking			
Matrix	Units	Water	Water	Water	Water	(see Footness for details)	MAC	IMAC	Freshwater	(Monthly Mean)
Physical Tests										
Hardness (as CaCO3)	mg/L	173.9	170.0	**61.5**	**715.0**					
Conductivity (in laboratory)	uS/cm	284.5	282.0	**109.0**	**1170.0**					
pH	pH Units	8.07	8.07	**7.71**	**8.56**	**6.5-9**				6.0-9.5
Total Elements										
Aluminum (Al)-Total	mg/L	0.197	0.053	**0.001**	**1.94**	**0.005 - 0.1**			0.005 - 0.1	
Antimony (Sb)-Total	mg/L	0.00009	0.00003	**0.000051**	**0.00110**			0.006		
Arsenic (As)-Total	mg/L	0.00066	0.00060	**0.00014**	**0.00452**	**0.005**[k]		0.025	0.15 mg/L (4-Day, 3-Year) [A]	0.5
Barium (Ba)-Total	mg/L	0.020	0.019	**0.008**	**0.066**		1			
Beryllium (Be)-Total	mg/L	0.0001	0.0001	**<0.00020**	**<0.00050**					
Bismuth (Bi)-Total	mg/L	0.00020	0.00025	**0.00008**	**0.00020**					
Boron (B)-Total	mg/L	0.01183	0.01000	**0.0035**	**0.128**			5		
Cadmium (Cd)-Total	mg/L	0.00003	0.00001	**0.00001**	**0.00118**	**0.000017**[c,l]	0.005			
Calcium (Ca)-Total	mg/L	36.4	34.7	**10.8**	**142.0**					
Chromium (Cr)-Total	mg/L	0.00065	0.00044	**0.00013**	**0.00298**		0.05			
Trivalent Chromium (Cr-III)	mg/L					**0.0089**[c,k]				
Hexavalent Chromium (Cr-VI)	mg/L					**0.001**[k]				
Cobalt (Co)-Total	mg/L	0.00014	0.00005	**0.00002**	**0.00095**					
Copper (Cu)-Total	mg/L	0.00070	0.00037	**0.00010**	**0.00643**	**0.002-0.004**[m]				0.3
Iron (Fe)-Total	mg/L	0.271	0.137	**0.025**	**1.89**	**0.3**[d]			0.3	
Lead (Pb)-Total	mg/L	0.00017	0.00007	**0.00002**	**0.00221**	**0.001-0.007**[o]	0.01			0.2
Lithium (Li)-Total	mg/L	0.00283	0.00250	**0.00190**	**0.01800**					
Magnesium (Mg)-Total	mg/L	20.0	18.8	**7.5**	**81.6**					
Manganese (Mn)-Total	mg/L	0.0294	0.0145	**0.0007**	**0.9730**					
Mercury (Hg)-Total	mg/L	0.00002	0.00003	**0.00006**	**0.00007**		0.001		0.0001	
Inorganic Mercury	mg/L					**0.000026**				
Methylmercury	mg/L					**0.000004**[c,w]				
Molybdenum (Mo)-Total	mg/L	0.00014	0.00009	**0.00005**	**0.00094**				0.073	
Nickel (Ni)-Total	mg/L	0.00076	0.00040	**0.00011**	**0.00641**	**0.025-0.15**[p]				0.5
Phosphorus (P)-Total	mg/L	0.113	0.150	**0.003**	**0.027**	**narrative** [x]				
Potassium (K)-Total	mg/L	1.07	1.00	**0.19**	**12.2**					
Selenium (Se)-Total	mg/L	0.00045	0.00025	**0.00011**	**0.00135**	**0.001**[d]	0.01		0.001	
Silicon (Si)-Total	mg/L	4.06	3.95	**0.92**	**18.8**					
Silver (Ag)-Total	mg/L	0.00002	0.00001	**0.00001**	**0.00083**	**0.0001**[d]			0.0001	
Sodium (Na)-Total	mg/L	2.88	2.44	**0.51**	**21.2**					
Strontium (Sr)-Total	mg/L	0.04539	0.04020	**0.0113**	**0.2640**		5 Bq/L			
Thallium (Tl)-Total	mg/L	0.00003	0.00003	**<0.000050**	**<0.00010**	**0.0008**[j]			0.0008	
Tin (Sn)-Total	mg/L	0.00010	0.00005	**0.00005**	**0.00060**					
Titanium (Ti)-Total	mg/L	0.01001	0.00500	**0.0005**	**0.06500**					
Uranium (U)-Total	mg/L	0.00017	0.00015	**0.00002**	**0.00098**			0.02		
Vanadium (V)-Total	mg/L	0.00066	0.00050	**0.00006**	**0.00440**					
Zinc (Zn)-Total	mg/L	0.00152	0.00100	**0.0007**	**0.0060**	**0.03**[d]				0.5

NOTE:

1 If the sample concentration was less than the detection limit, half the detection limit was used to compute the average and median.

Table 7.5-4 (Cont.'d) Overview of Surface Water Quality at Minago

	Units	AVERAGE[1] May-Oct. All stations	MEDIAN[1] May-Oct. All stations	MINIMUM May-Oct. All stations	MAXIMUM May-Oct. All stations	REGULATIONS: Manitoba Water Quality Standards, Objectives, and Guidelines (Williamson, 2002) — TIER II Water Quality Objectives	TIER III - Water Quality Guidelines — DRINKING MAC	TIER III — DRINKING IMAC	TIER III — Freshwater Aquatic Life
Physical Tests									
Hardness (as CaCO3)	mg/L	173.9	170.0	**61.5**	**715.0**				
pH	pH Units	8.07	8.07	**7.71**	**8.56**				
Dissolved Elements									
Aluminum (Al)-Dissolved	mg/L	0.026	0.005	**0.001**	**0.319**				0.005 - 0.1
Antimony (Sb)-Dissolved	mg/L	0.00009	0.00003	**0.00005**	**0.00114**			0.006	
Arsenic (As)-Dissolved	mg/L	0.00064	0.00060	**0.00014**	**0.00456**	0.15 mg/L (4-Day, 3-Year)[A]		0.025	Tier II
Barium (Ba)-Dissolved	mg/L	0.01915	0.01855	**0.00721**	**0.06300**		1		
Beryllium (Be)-Dissolved	mg/L	0.00014	0.00010	**<0.00020**	**<0.00050**				
Bismuth (Bi)-Dissolved	mg/L	0.00019	0.00025	**<0.00050**	**<0.00050**				
Boron (B)-Dissolved	mg/L	0.0122	0.0100	**0.0034**	**0.1970**			5	
Cadmium (Cd)-Dissolved	mg/L	0.00004	0.00001	**0.00001**	**0.00218**	Hardness dependent [B] (e.g. 0.00163 mg/L chronic; 0.00267 mg/L acute at hardness 65 mg/L $CaCO_3$)	0.005		Tier II
Calcium (Ca)-Dissolved	mg/L	36.5	35.6	**10.9**	**151.0**				
Chromium (Cr)-Dissolved	mg/L	0.00031	0.00025	**0.00015**	**0.00199**	Hardness dependent [C] (e.g.,0.052 mg/L Cr-III chronic at hardness 65 mg/L; 0.011 mg/L Cr-VI 4-Day, 3-Year)	0.05		Tier II
Cobalt (Co)-Dissolved	mg/L	0.00006	0.00005	**0.00002**	**0.00084**				
Copper (Cu)-Dissolved	mg/L	0.00049	0.00032	**0.00010**	**0.00630**	Hardness dependent [D] (e.g.,0.0062 mg/L chronic at hardness 65 mg/L $CaCO_3$)			Tier II
Iron (Fe)-Dissolved	mg/L	0.088	0.052	**0.010**	**1.190**				0.3
Lead (Pb)-Dissolved	mg/L	0.00008	0.00003	**0.00002**	**0.00212**	Hardness dependent [E] (e.g., 0.00157 mg/L chronic at hardness 65 mg/L $CaCO_3$)	0.01		Tier II
Lithium (Li)-Dissolved	mg/L	0.00284	0.00250	**0.00210**	**0.01800**				
Magnesium (Mg)-Dissolved	mg/L	20.05	19.00	**7.17**	**82.10**				
Manganese (Mn)-Dissolved	mg/L	0.02054	0.00697	**0.00025**	**0.90600**				
Mercury (Hg)-Dissolved	mg/L	0.00002	0.00003	**<0.000010**	**<0.00010**		0.001		0.0001
Molybdenum (Mo)-Dissolved	mg/L	0.00010	0.00009	**0.00005**	**0.00067**				0.073
Nickel (Ni)-Dissolved	mg/L	0.00041	0.00025	**0.00010**	**0.00585**	Hardness dependent [F] (e.g., 0.036 mg/L chronic at hardness 65 mg/L $CaCO_3$)			Tier II
Phosphorus (P)-Dissolved	mg/L	0.112	0.150	**0.002**	**0.015**				
Potassium (K)-Dissolved	mg/L	8.10	1.00	**0.18**	**705.00**				
Selenium (Se)-Dissolved	mg/L	0.00021	0.00025	**0.00014**	**0.00081**		0.01		0.001
Silicon (Si)-Dissolved	mg/L	3.77	3.43	**0.76**	**18.30**				
Silver (Ag)-Dissolved	mg/L	0.00002	0.00001	**0.00001**	**0.00058**				0.0001
Sodium (Na)-Dissolved	mg/L	2.87	2.41	**0.52**	**21.30**				
Strontium (Sr)-Dissolved	mg/L	0.0448	0.0393	**0.0112**	**0.2680**		5 Bq/L		
Thallium (Tl)-Dissolved	mg/L	0.00003	0.00003	**<0.000050**	**<0.00010**				0.0008
Tin (Sn)-Dissolved	mg/L	0.00011	0.00005	**0.00010**	**0.00134**				
Titanium (Ti)-Dissolved	mg/L	0.004	0.005	**0.012**	**0.026**				
Uranium (U)-Dissolved	mg/L	0.00017	0.00015	**0.00001**	**0.00102**			0.02	
Vanadium (V)-Dissolved	mg/L	0.00037	0.00029	**0.00005**	**0.00428**				
Zinc (Zn)-Dissolved	mg/L	0.00095	0.00050	**0.00060**	**0.00580**	Hardness dependent [G] (e.g., 0.082 mg/L chronic at hardness 65 mg/L $CaCO_3$)			Tier II

NOTE:

1 If the sample concentration was less than the detection limit, half the detection limit was used to compute the average and median.

Notes:

MAC - Maximum Acceptable Concentration
IMAC Interim Maximum Acceptable Concentration

A Arsenic limits: 0.15 mg/L for averaging duration 4 days (4-Day, 3-Year or 7Q10 Design Flow); 0.34 mg/L for averaging duration 1 hr (1-Day, 3-Year or 1Q10 Design Flow)

B Cadmium limits: [e{0.7852[ln(Hardness)]-2.715}]×[1.101672-{ln(Hardness)(0.041838)}] for 4 days averaging duration.
[e{1.128[ln(Hardness)]-3.6867}]×[1.136672-{ln(Hardness)(0.041838)}] for 1 hour averaging duration.

C Chromium limits: Chromium III: [e{0.8190[ln(Hardness)]+0.6848}]×[0.860] for 4 days averaging duration.
Chromium III: [e{0.8190[ln(Hardness)]+3.7256}]×[0.316] for 1 hour averaging duration.
Chromium VI: 0.011 mg/L for averaging duration 4 days (4-Day, 3-Year or 7Q10 Design Flow); 0.016 mg/L for averaging duration 1 hr (1-Day, 3-Year or 1Q10 Design Flow)

D Copper limits: [e{0.8545[ln(Hardness)]-1.702}]×[0.960] for 4 Days hour averaging duration.
[e{0.9422[ln(Hardness)]-1.700}]×[0.960] for 1 hour averaging duration.

E Lead limits: [e{1.273[ln(Hardness)]-4,705}]×[1.46203 -{ln(Hardness)(0.145712)}] for 4 Days averaging duration.
[e{1.273[ln(Hardness)]-1.460}]×[1.46203 -{ln(Hardness)(0.145712)}] for 1 hour averaging duration.

F Nickel limits: [e{0.8460[ln(Hardness)]+0.0584}]×[0.997] for 4 Days averaging duration.
[e{0.8460[ln(Hardness)]+2.255}]×[0.998] for 1 hour averaging duration.

G Zinc limits: [e{0.8473[ln(Hardness)]+0.884}]×[0.976] for 4 Days averaging duration.
[e{0.8473[ln(Hardness)]+0.884}]×[0.978] for 1 hour averaging duration.

Footnotes for the CCME (Canadian Council of Ministers of the Environment) Aquatic Guidelines. 2006. (= Canadian water quality guidelines for the protection of aquatic life).

c Interim guideline.
d No fact sheet created.
g Aluminium guideline= 5 $\mu g \cdot L^{-1}$ at pH <6.5
= 100 $\mu g \cdot L^{-1}$ at pH = 6.5 or greater
h Ammonia guideline: Expressed as µg unionized ammonia$\cdot L^{-1}$. This would be equivalent to 15.2 µg ammonia-nitrogen$\cdot L^{-1}$. Guideline for total ammonia is temperature and pH dependent, please consult factsheet for more information.
j The technical document for the guideline is available from the Ontario Ministry of the Environment.
k Substance has been re-evaluated since CCREM 1987 + Appendixes. Either a new guideline has been derived or insufficient data existed to derive a new guideline.
l Cadmium guideline = 10{0.86[log(hardness)] - 3.2}.
m Copper guideline = 2 $\mu g \cdot L^{-1}$ at [CaCO3] = 0–120 $mg \cdot L^{-1}$
= 3 $\mu g \cdot L^{-1}$ at [CaCO3] = 120–180 $mg \cdot L^{-1}$
= 4 $\mu g \cdot L^{-1}$ at [CaCO3] >180 $mg \cdot L^{-1}$
n Dissolved oxygen for warm-water biota: early life stages = 6000 $\mu g \cdot L^{-1}$
other life stages = 5500 $\mu g \cdot L^{-1}$
for cold-water biota: early life stages = 9500 $\mu g \cdot L^{-1}$
other life stages = 6500 $\mu g \cdot L^{-1}$
o Lead guideline = 1 $\mu g \cdot L^{-1}$ at [CaCO3] = 0–60 $mg \cdot L^{-1}$
= 2 $\mu g \cdot L^{-1}$ at [CaCO3] = 60–120 $mg \cdot ^{L-1}$
= 4 $\mu g \cdot L^{-1}$ at [CaCO3] = 120–180 $mg \cdot L^{-1}$
= 7 $\mu g \cdot L^{-1}$ at [CaCO3] = >180 $mg \cdot L^{-1}$
p Nickel guideline = 25 $\mu g \cdot L^{-1}$ at [CaCO3] = 0–60 $mg \cdot L^{-1}$
= 65 $\mu g \cdot L^{-1}$ at [CaCO3] = 60–120 $mg \cdot L^{-1}$
= 110 $\mu g \cdot L^{-1}$ at [CaCO3] = 120–180 $mg \cdot L^{-1}$
= 150 $\mu g \cdot L^{-1}$ at [CaCO3] = >180 $mg \cdot L^{-1}$
s Temperature: (for more information, see CCREM 1987)
Thermal Stratification: Thermal additions to receiving waters should be such that thermal stratification and subsequent turnover dates are not altered from those existing prior to the addition of heat from artificial origins.
Maximum Weekly Average Temperature: Thermal additions to receiving waters should be such that the maximum weekly average temperature is not exceeded.
Short-term Exposure to Extreme Temperature: Thermal additions to receiving waters should be such that the short-term exposures to maximum temperatures are not exceeded. Exposures should not be so lengthy or frequent as to adversely affect the important species.
u For protection from direct toxic effects; the guidelines do not consider indirect effects due to eutrophication.
w May not protect fully higher trophic level fish; see factsheet for details.
x Canadian Trigger Ranges (for further narrative see factsheet), Total Phosphorus (ug$\cdot$.L^{-1}):
ultra-oligotrophic <4
oligotrophic 4-10
mesotrophic 10-20
meso-eutrophic 20-35
eutrophic 35-100
hyper-eutrophic >100
y Guidelines are expressed in µg nitrate$\cdot L^{-1}$. These values are equivalent to 2900 µg nitrate-nitrogen$\cdot L^{-1}$, and 3600 µg nitrate-nitrogen$\cdot L^{-1}$, for freshwater and marine respectively.
z Guideline is expressed as µg nitrite-nitrogen$\cdot L^{-1}$. This value is equivalent to 197 µg nitrite$\cdot L^{-1}$.

Table 7.5-5 Average Ratio of Dissolved versus Total Element Concentrations

Element	Average Ratio of Dissolved versus Total Element Concentrations [1]
Aluminum (Al)	32%
Iron (Fe)	46%
Cobalt (Co)	64%
Vanadium (V)	65%
Titanium (Ti)	67%
Manganese (Mn)	70%
Lead (Pb)	78%
Nickel (Ni)	78%
Chromium (Cr)	82%
all other elements	93% or greater

NOTE: If the dissolved or total element concentration was less than the detection limit, half the detection limit was used to compute the average.

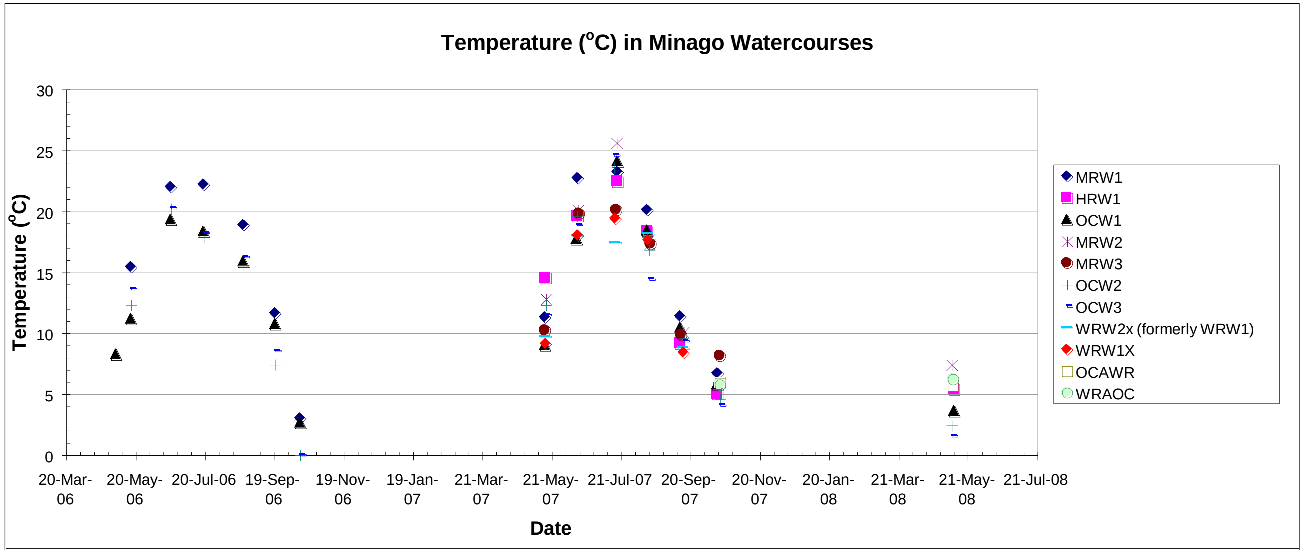
7.5.3.2.2 Hardness

Water in watercourses surrounding the Minago site is relatively hard. The recorded hardness ranged from 61.5 to 715 mg/L (as $CaCO_3$). The average and median hardness was 173.9 mg/L and 170 mg/L (as $CaCO_3$), respectively (Table 7.5-4). At these levels of hardness, all recorded dissolved metal concentrations met the *Manitoba Tier II Water Quality Objectives*.

7.5.3.2.3 Temperature and Dissolved Oxygen

The temperature, recorded between May and October of 2006, 2007, and 2008 varied seasonally in the Minago surface watercourses (Figure 7.5-2). Creeks and streams warmed quickly in the spring and cooled off in the fall. Seasonal variations in the water termperatures occurred as a response to ambient air temperatures. Recorded water temperatures ranged from a minimum of 2.7^{o}C to a maximum of 22.2^{o}C in 2006 and from a minimum of 4.7^{o}C to a maximum of 25.6^{o}C in 2007. The maximum temperature was recorded on July 19 at station MRW1 in 2006 and on July 17 at station MRW2 in 2007.

The dissolved oxygen concentration ranged from a minimum of 5.8 mg/L (recorded on Jul. 19, 2006 at OCW3) to a maximum of 12.6 mg/L in 2006 and from a minimum of 5.7 mg/L (recorded on Jun. 13, 2007 at MRW1) to a maximum of 13.4 mg/L in 2007. In percent saturation, the reported dissolved oxygen concentrations ranged from 61.4 to 106.3% in 2006 and from 83.6 to 109.2% in 2007 (Figure 7.5-3). Dissolved oxygen concentrations were lowest in the summer



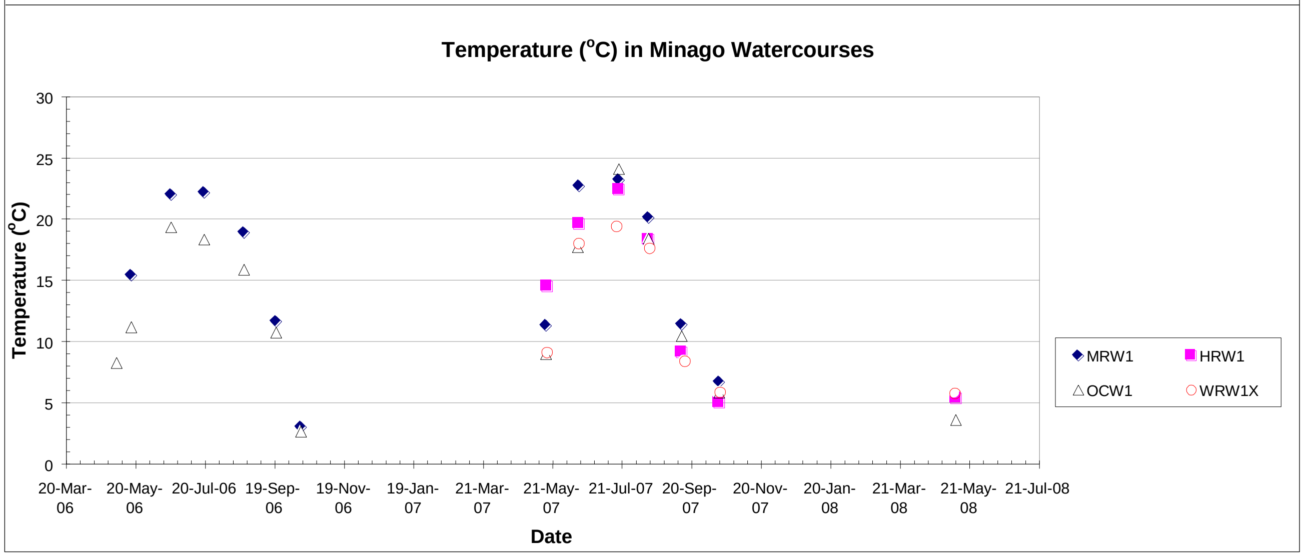


Figure 7.5-2 Temperature in Minago Surface Watercourses

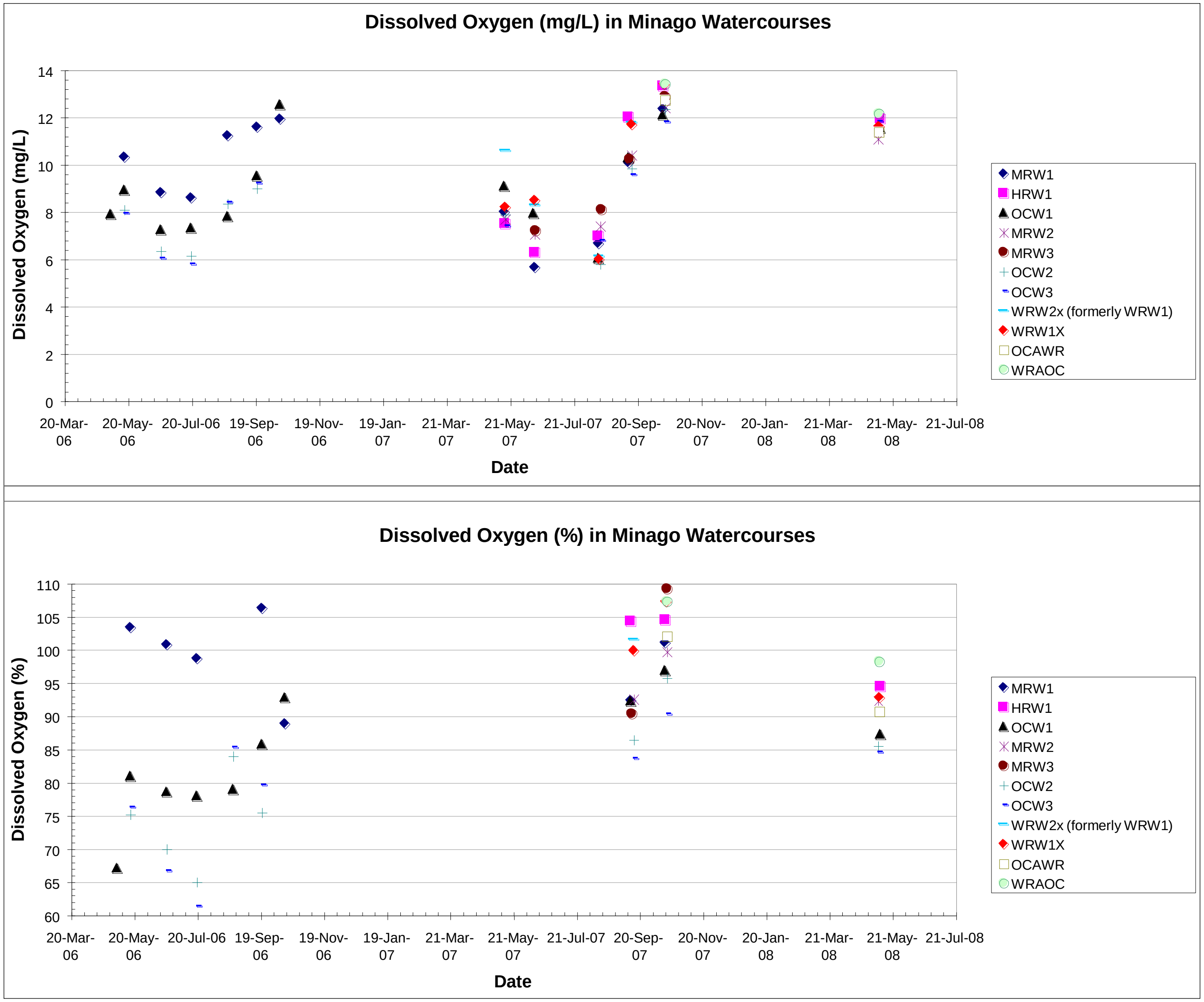


Figure 7.5-3 Dissolved Oxygen in Minago Surface Watercourses

months corresponding with the higher water temperatures recorded in the summer (Figure 7.5-3). This was expected as dissolved oxygen in water is governed by Henry's Law (higher temperature results in lower dissolved oxygen) if all other environmental conditions are the same. At Minago, all measured dissolved oxygen concentrations met the *Manitoba Tier II Water Quality Objectives* (Table 7.5-4).

7.5.3.2.4 Conductivity and Oxidation-Reduction Potential

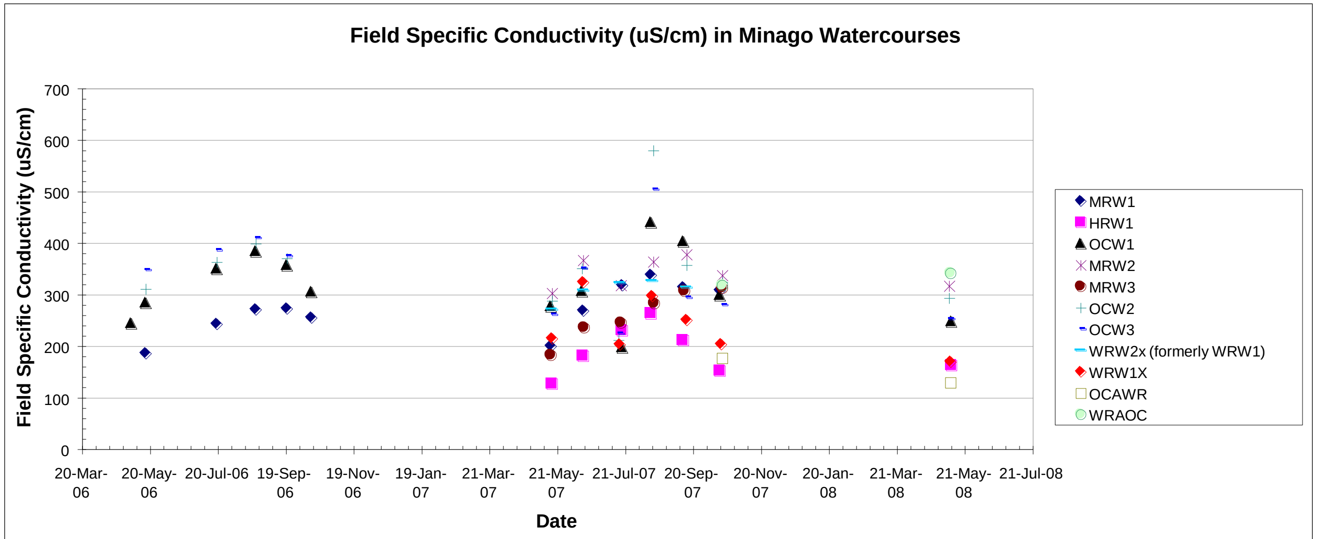
The field specific conductivity (conductivity measured at *in situ* water temperature corrected to 25^oC) ranged from 127 to 580 μS/cm with average and median values of 214.2 and 215.5 μS/cm, respectively (Table 7.5-4 and Figure 7.5-4). Conductivities, measured in the laboratory after sample shipment, ranged from 129 to 467 μS/cm in all but one sample. That sample, collected on Mar. 11, 2008 from the Hargrave River sampling station HRW1, had a conductivity of 1,170 μS/cm. To date, all conductivity measurements met the *Manitoba Tier II Water Quality Objective* of 1,000 μS/cm with the exception of the Mar. 11, 2008 conductivity recorded at HRW1. The average and median values for conductivities, measured in the laboratory, were 284.5 and 282.0 μS/cm, respectively.

The Oxidation-Reduction Potential (ORP or redox potential) is an important characteristic of natural waters. The ORP is a measure of the oxidizing or reducing power of water. The ORP measures the ability of the aquatic system to supply electrons to an oxidizing agent (for example, oxygen) and to take up electrons from a reducing agent. Reduction-oxidation (redox) reactions occur simultaneously (Radojevic and Bashkin, 2006; Manahan, 2005). In redox reactions, the substance that is reduced accepts electrons and the substance that supplies electrons is oxidized. For example, the reduction of oxygen (O_2) by organic matter (represented by $\{CH_2O\}$),

$$\{CH_2O\} + O_2 \rightarrow CO_2 + H_2O$$

results in oxygen depletion in the water that can potentially kill fish, if the depletion is severe enough.

At Minago, the ORP ranged from 116 to 309 mV with average and median values of 210 mV and 208 mV, respectively (Table 7.5-4). In typical surface water, ORP ranges from 100 to 500 mV (Radojevic and Bashkin, 2006; Manahan, 2005). Thus, the ORP of surface watercourses in the vicinity of the Minago site is on the lower (more reducing) side of the normal range. ORP measurements at Minago are illustrated in Appendix 7.5.



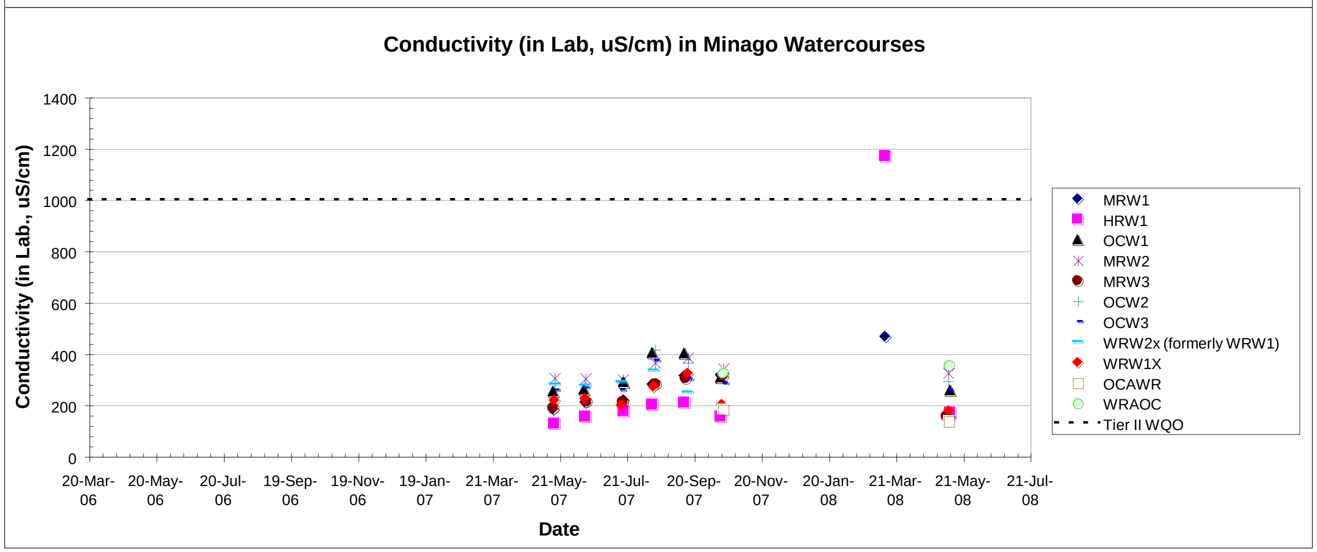


Figure 7.5-4 Conductivity (µS/cm) in Minago Surface Watercourses

7.5.3.2.5 Exceedances of Water Quality Guidelines and Objectives

Overall, the water quality was good in the vicinity of the Minago Project with only some parameters exceeding Manitoba and/or CCME (Canadian Council of Ministers of the Environment) limits for the protection of freshwater aquatic life. The most common exceedances of Manitoba water quality guidelines occurred for aluminum (Figure 7.5-5) and iron (Figure 7.5-6) followed by Nitrite-N (Figure 7.5-8), copper (Figure 7.5-9), Total Dissolved Solids (TDS) (Figure 7.5-10), and selenium and silver (Figure 7.5-11). These exceedances are discussed below.

Aluminum, Iron and Turbidity

In watercourses surrounding the Minago site, the total aluminum concentration ranged from 0.001 to 1.94 mg/L with average and median values of 0.197 mg/L and 0.053 mg/L, respectively (Table 7.5-4, Figure 7.5-5). In comparison, the maximum guideline level for aluminum, defined in the *Manitoba Tier III Freshwater Quality Guidelines* and the CCME (2007) guidelines for the protection of Aquatic Life, is 0.1 mg/L for a pH greater than 6.5. Thus, average total aluminum levels were significantly above guideline levels. Generally, the total aluminum concentration was higher for rivers and reaches with larger flow volumes (at the Hargrave River station and William River WRW2x and WRW1x; Figure 7.5-5).

At Minago, the dissolved aluminum concentration ranged from 0.001 to 0.319 mg/L with average and median values of 0.026 and 0.005 mg/L, respectively (Table 7.5-4). In comparison, the maximum guideline level defined in the *Manitoba Tier III Freshwater Quality Guidelines* is 0.1 mg/L if pH is greater than 6.5. To date, the dissolved aluminum concentrations exceeded *the Manitoba Tier II Water Quality Objectives* on 4 occasions (Figure 7.5-5).

Total iron concentration ranged from 0.025 to 1.89 mg/L in watercourses surrounding the Minago site. The average and median total iron concentrations were 0.271 mg/L and 0.137 mg/L, respectively (Table 7.5-4, Figure 7.5-6). In comparison, the maximum guideline level for iron, defined in the *Manitoba Tier III Freshwater Quality Guidelines* and the CCME (2007) guidelines for the protection of Aquatic Life, is 0.3 mg/L. To date, this guideline value was exceeded on 20 occasions at Minago. Generally, the total iron concentration was higher for rivers and reaches with larger flow volumes (at the Hargrave River station and William River WRW2x and WRW1x; Figure 7.5-6).

At Minago, the dissolved iron concentration ranged from 0.01 to 1.19 mg/L with average and median values of 0.088 and 0.052 mg/L, respectively (Table 7.5-4). In comparison, the maximum guideline levels set in the *Manitoba Tier III Freshwater Quality Guidelines* is 0.3 mg/L. This guideline level was exceeded on 4 occasions in the Minago water samples collected to date.

The elevated concentrations of aluminum and iron, in light of complete absence of any type of industrial or domestic development in the vicinity of the Minago site, are likely due to eroded clay particles and leaching from the muskegs in the area. As previously mentioned, surficial soils at the Minago site consist of 1.0 to 2.1 m of peat that is underlain by

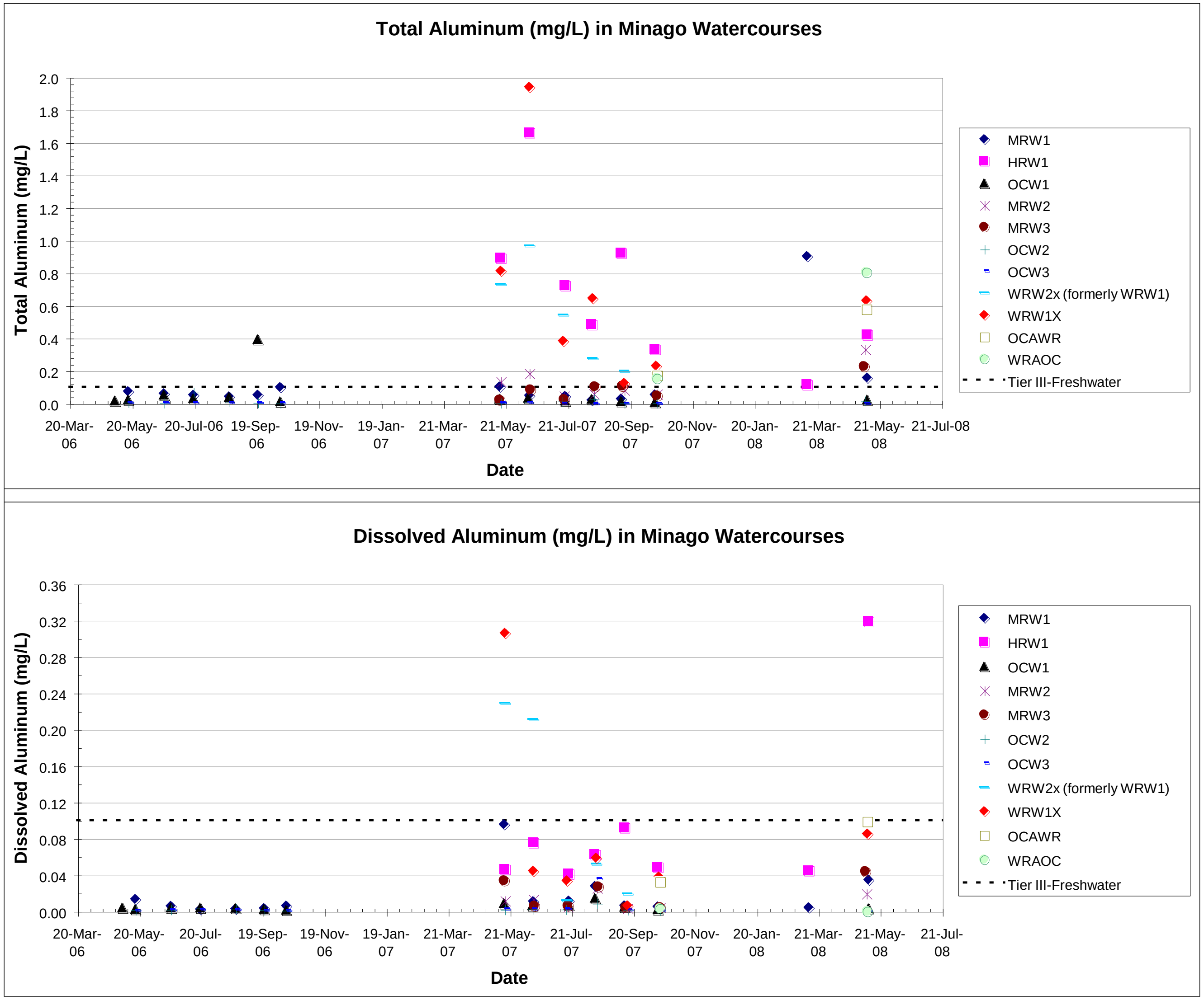
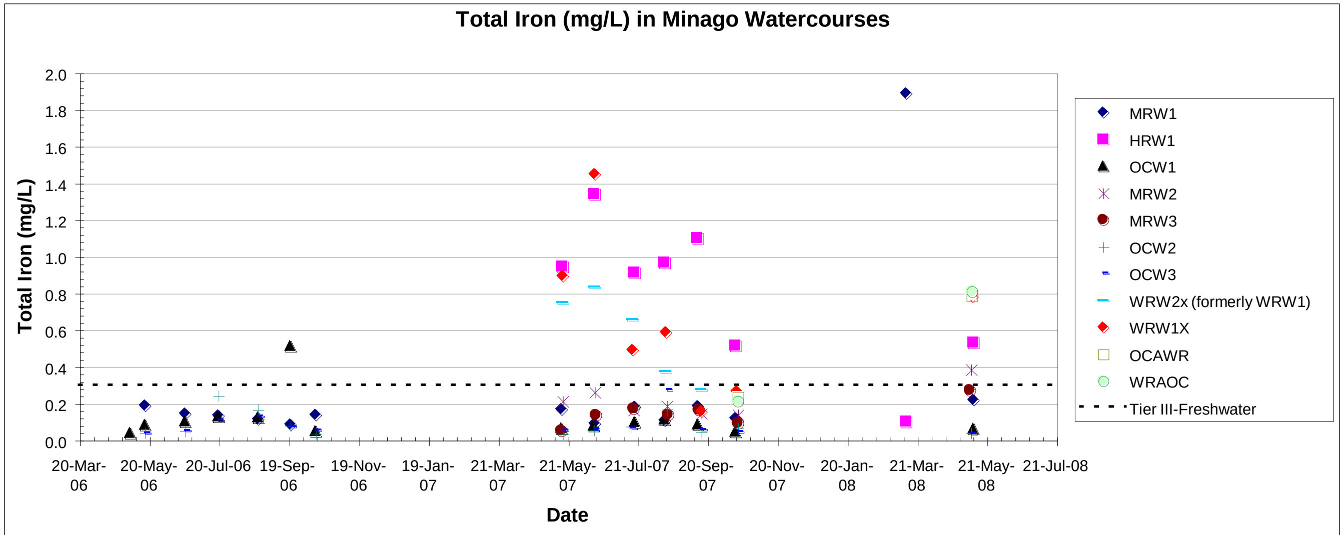


Figure 7.5-5 Total and Dissolved Aluminum (mg/L) in Minago Surface Watercourses



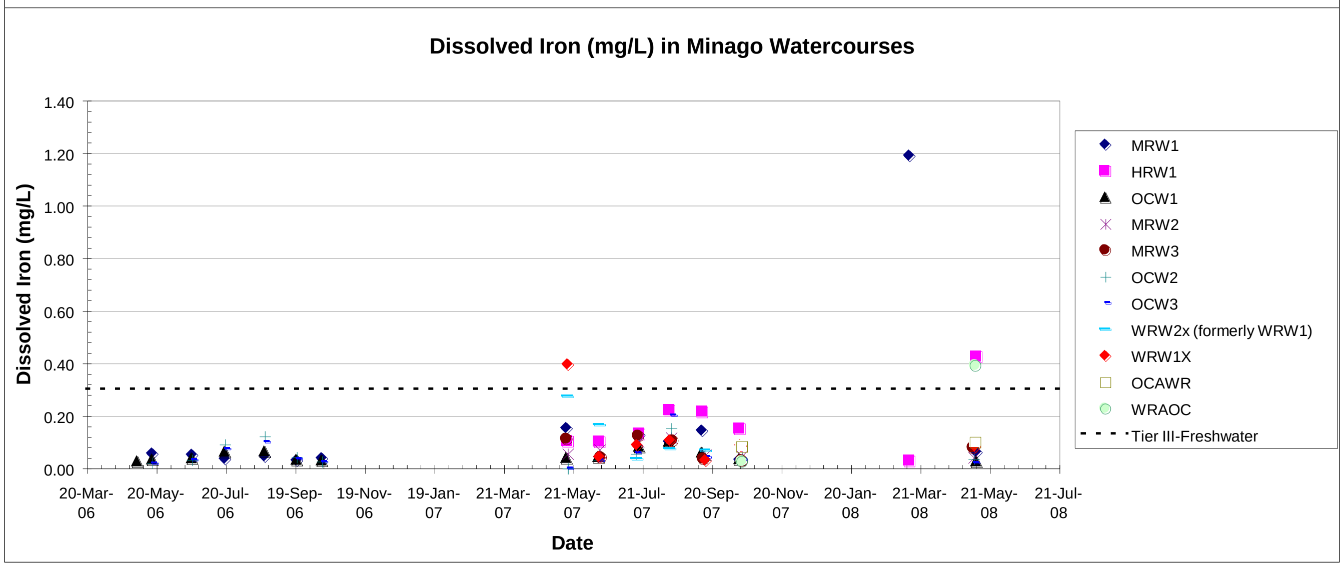


Figure 7.5-6 Total and Dissolved Iron (mg/L) in Minago Surface Watercourses

1.5 to 10.7 m of impermeable compacted glacial lacustrine clays. Many clays contain large amounts of aluminum, sodium, potassium, magnesium, calcium, and iron, as well as trace quantities of other metals. They are also readily suspended in water as colloidal particles may be leached from soil (Manahan, 2005).

All clays contain silicate and most contain aluminum and water (Manahan, 2005). All clay minerals are very small colloidal-sized crystals (diameter less than 1 μm). Chemically, they are hydrous aluminosilicates plus other metallic ions (Holtz and Kovacs, 1981). Physically, clays consist of very fine grains having sheet-like structures. There are only two fundamental crystal sheets, the silica (or tetrahedral) and the alumina (or octahedral) sheets. The particular way in which these sheets are stacked, together with different bonding and different metallic ions in the crystal lattice, constitute the different clay minerals (Holtz and Kovacs, 1981). Clay minerals differ in their general chemical formula, structure, and chemical and physical properties. For example the structural formula for the clay minerals montmorillonite and illite are $Al_2(OH)_2Si_4O_{10}$ and $K_{0-2}Al_4(Si_{8-6}\ Al_{0-2})O_{20}(OH)_4$, respectively (Manahan, 2005).

Turbidity results for the watercourses surrounding the Minago site also point to suspended colloidal matter and soil particles (Figure 7.5-7). Recorded turbidity ranged from 0.2 to 38.1 NTU and the average and median turbidity were 6.0 and 1.5 NTU (Table 7.5-4), respectively. To date, turbidity was greater than 1 on 59 occasions at Minago. Generally, turbidity was higher for the rivers and reaches with larger flow volumes (at the Hargrave River station and William River WRW2x and WRW1x; Figure 7.5-7).

To shed some light on the connection between elevated total aluminum and total iron concentrations and turbidity, correlation analyses were conducted. For a perfect correlation, the correlation coefficient R is 1 and R^2 is equal to 1. Based on the water quality results obtained to date, total aluminum concentrations correlated very well ($R^2 > 0.86$) with turbidity for stations OCW1, WRW2x and MRW1 while total iron concentrations correlated well ($R^2 > 0.81$) with turbidity for stations WRW2x, OCW1, HRW1, and MRW1. Results of the correlation analyses are presented in Table 7.5-6. Detailed correlation graphs for these analyses are given in Appendix 7.5.

Table 7.5-6 Results of Correlation Analyses – Total Aluminum and Total Iron versus Turbidity

		Total Alumimum versus Turbidity	**Total Iron versus Turbidity**
Stream / Creek	**Sampling Station**	R^2	R^2
Oakley Creek	**OCW1**	**0.958**	**0.912**
William River	**WRW2x**	**0.941**	**0.958**
	WRW1x	0.162	0.366
Minago River	**MRW1**	**0.867**	**0.813**
	MRW2	0.685	0.584
Hargrave River	**HRW1**	0.434	**0.820**

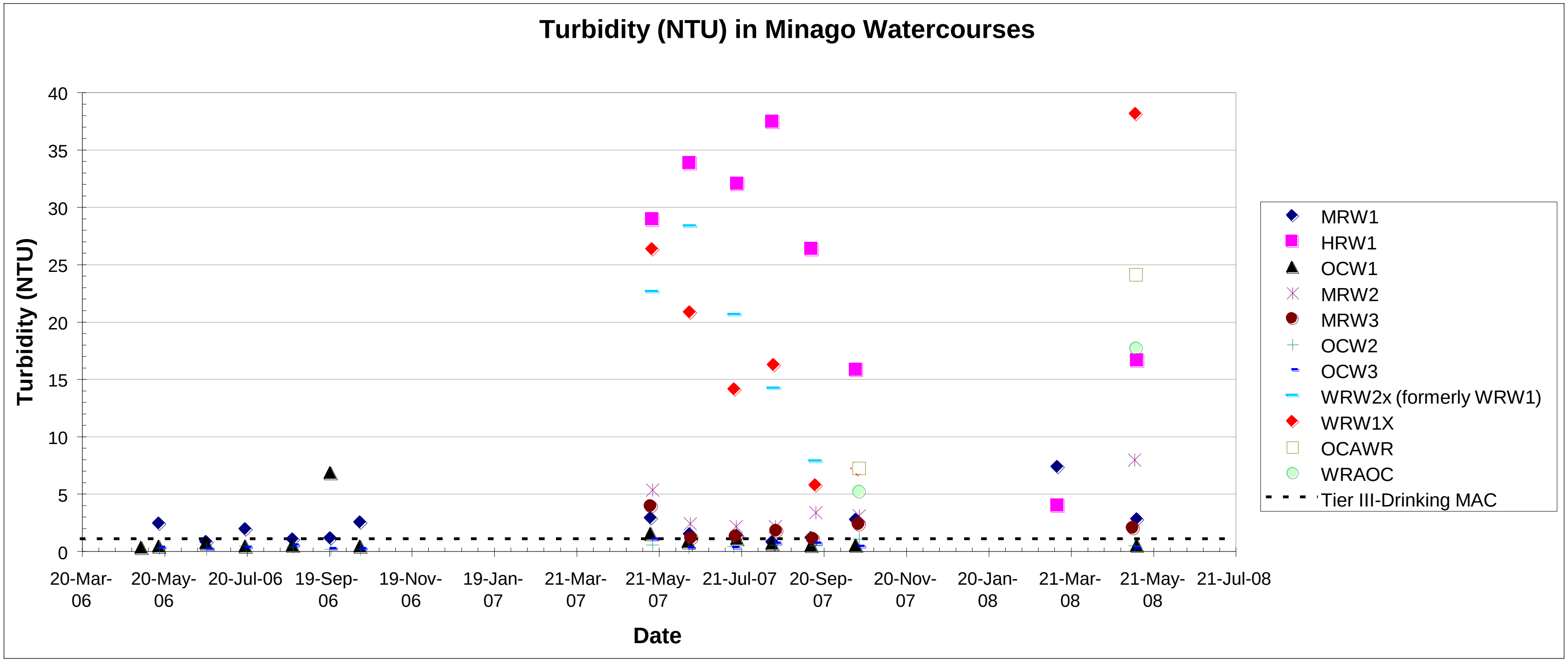


Figure 7.5-7 Turbidity (NTU) in Minago Surface Watercourses

Nitrite-N

The nitrite-N concentration in watercourses surrounding the Minago site ranged from <0.001 to 0.29 mg/L with average and median concentrations of 0.04 mg/L and 0.0005 mg/L, respectively (Table 7.5-4, Figure 7.5-8). In comparison, the maximum guideline level for nitrite-N, defined in the CCME (2007) guidelines for the protection of Aquatic Life, is 0.06 mg/L. To date, this guideline value was exceeded on 13 occasions in watercourses surrounding the Minago Project.

Copper

The total copper (Cu) concentration in watercourses surrounding the Minago site ranged from <0.0001 to 0.0064 mg/L with average and median concentrations of 0.0007 mg/L and 0.00037 mg/L, respectively (Table 7.5-4, Figure 7.5-9). In comparison, the maximum guideline level for total copper in the CCME (2007) guidelines for the protection of Aquatic Life, ranges from 0.002 to 0.004 mg/L depending on hardness. Based on the recorded total copper and hardness levels at Minago, the CCME guideline limit was exceeded twice (in Sept. 2007 and Mar. 2008) at sampling station HRW1 and once (in May 2006) at sampling station MRW1.

Total Dissolved Solids (TDS)

TDS in watercourses surrounding the Minago site ranged from 60 to 739 mg/L with average and median concentrations of 189.2 mg/L and 186.0 mg/L, respectively (Table 7.5-4, Figure 7.5-10). In comparison, the maximum TDS level, set in the *Manitoba Tier II Water Quality Objectives*, is 700 mg/L. Based on the recorded TDS levels at Minago, the Tier II guideline limit was exceeded once in March 2008 at sampling station HRW1.

Selenium and Silver

The total selenium (Se) concentration in watercourses surrounding the Minago site ranged from 0.0001 to 0.00135 mg/L with average and median concentrations of 0.00045 mg/L and 0.00025 mg/L, respectively (Table 7.5-4, Figure 7.5-11). In comparison, the maximum guideline level for total selenium, set in the Manitoba Tier III and the CCME (2007) guidelines for the protection of Aquatic Life, is 0.001 mg/L. Based on the recorded total selenium levels at Minago, the selenium guideline limit was only exceeded once in May 2007 at sampling station WRW1x.

The total silver (Ag) concentration in watercourses surrounding the Minago site ranged from 0.00001 to 0.00083 mg/L with average and median concentrations of 0.0002 mg/L and 0.00001 mg/L, respectively (Table 7.5-4, Figure 7.5-11). In comparison, the maximum guideline level for total silver, defined in the Manitoba Tier III and the CCME (2007) guidelines for the protection of Aquatic Life, is 0.0001 mg/L. Based on the recorded total silver levels at Minago, the silver guideline limit was only exceeded once in July 2007 at sampling station MRW2.

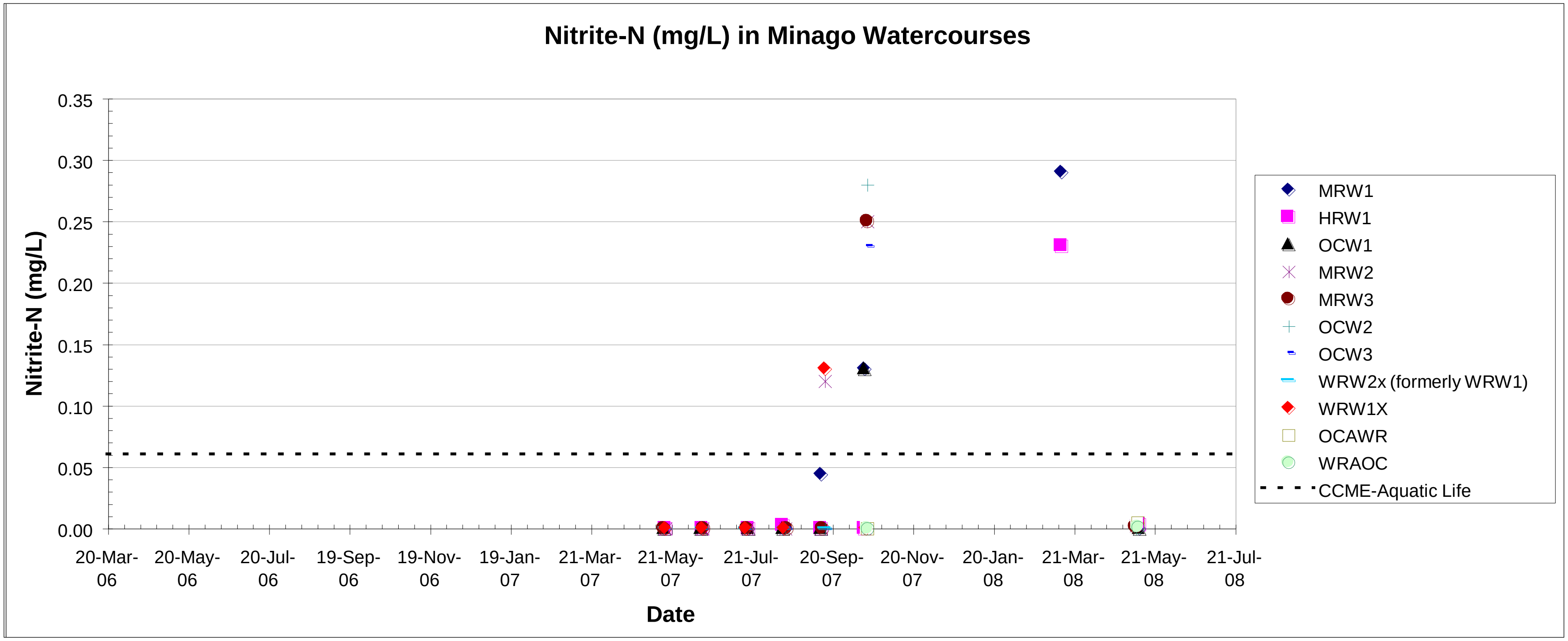


Figure 7.5-8 Nitrite-N (mg/L) in Minago Surface Watercourses

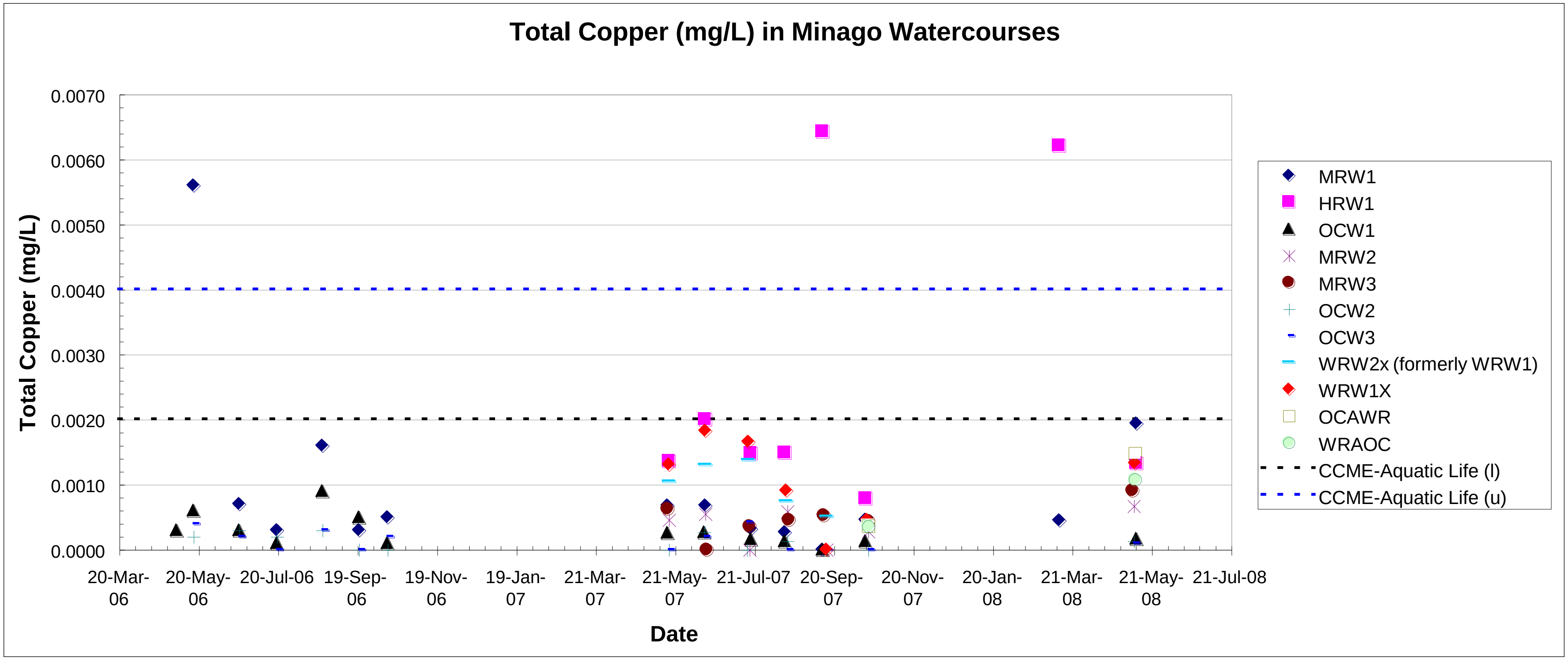


Figure 7.5-9 Total Copper (mg/L) in Minago Surface Watercourses

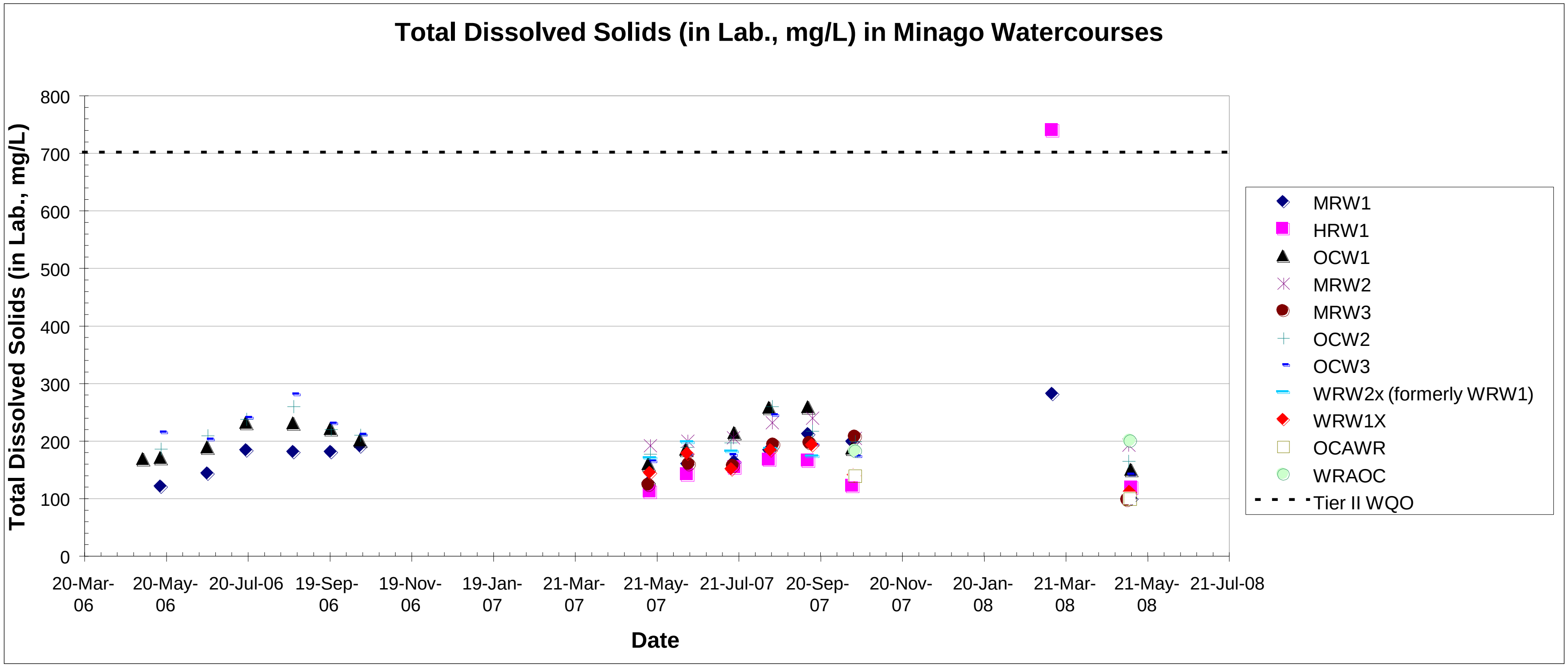


Figure 7.5-10 Total Dissolved Solids (mg/L) in Minago Surface Watercourses

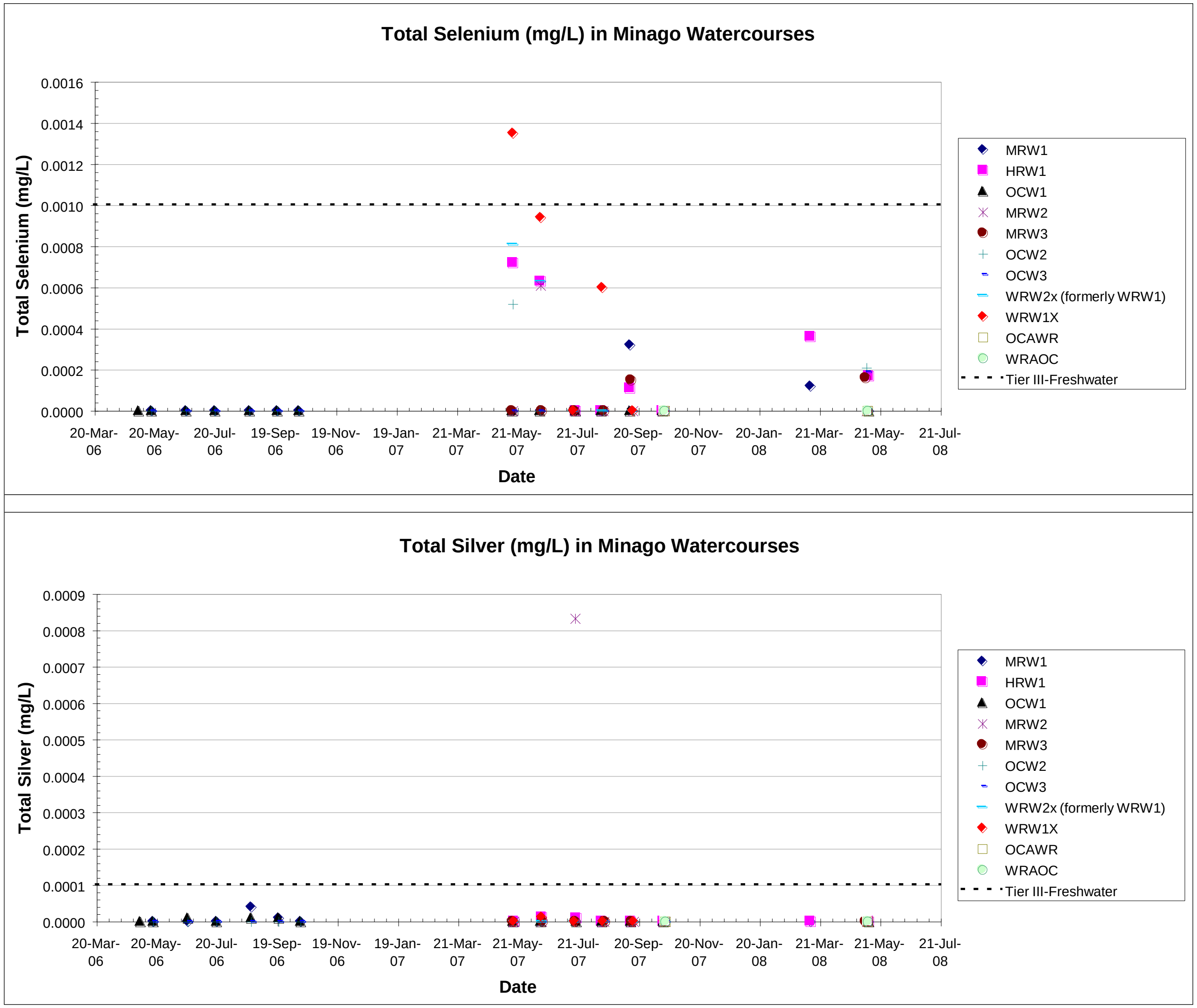


Figure 7.5-11 Total Selenium (mg/L) and Total Silver (mg/L) in Minago Surface Watercourses

7.5.3.2.6 Water Quality Results compared to Metal Mining Effluent Regulations

Table 7.5-7 presents average and median water quality results for all stations and all sampling events against limits of the Metal Mining Effluent Regulations (Environment Canada, 2002a). The only water quality parameter that exceeded MMER was Total Suspended Solids (TSS) (Figure 7.5-12). The MMER guideline value for TSS is 15 mg/L for a monthly mean and 30 mg/L for grab samples. At Minago, the total suspended solids measurements ranged from 0.5 to 65 mg/L with average and median concentrations of 11.5 mg/L and 5.0 mg/L, respectively. TSS exceeded the 2002 MMER guideline value of 30 mg/L for grab samples on 4 occasions at HRW1, on two occasions at WRW1x and WRW2x, and once each at OCAWR and WRAOC.

Table 7.5-7 Comparison of Water Quality Results to Metal Mining Effluent Regulations

		AVERAGE[1] May - Oct. All stations	**MEDIAN[1] May - Oct. All stations**	**MINIMUM May - Oct. All stations**	**MAXIMUM May - Oct. All stations**	**Metal Effluent**	**Mining Regulations**
Matrix	**Units**	Water	Water	Water	Water	(Monthly Mean)	Grab Sample
pH (Field)	pH Units	7.82	7.81	**7.01**	**8.84**	6.5-9.5	6-9.5
pH (Laboratory)	pH Units	8.07	8.07	**7.71**	**8.56**	6.0-9.5	6-9.5
Arsenic (As)-Total	mg/L	0.00066	0.00060	**0.00014**	**0.00452**	0.5	1.00
Copper (Cu)-Total	mg/L	0.00070	0.00037	**0.00010**	**0.00643**	0.3	0.60
Cyanide, Total	mg/L	0.0097	0.0095	**0.0056**	**0.0140**	1	2.00
Lead (Pb)-Total	mg/L	0.00017	0.00007	**0.00002**	**0.00221**	0.2	0.40
Nickel (Ni)-Total	mg/L	0.00076	0.00040	**0.00011**	**0.00641**	0.5	1
Zinc (Zn)-Total	mg/L	0.00152	0.00100	**0.0007**	**0.0060**	0.5	1
Tot. Suspended Solids	mg/L	11.5	5.0	**0.5**	**65.0**	15	30
Radium-226	Bq/L	0.00492	0.00250	**0.0050**	**0.050**	0.37	1.11

NOTE: 1 If the sample concentration was less than the detection limit, half the detection limit was used to compute the average and median.

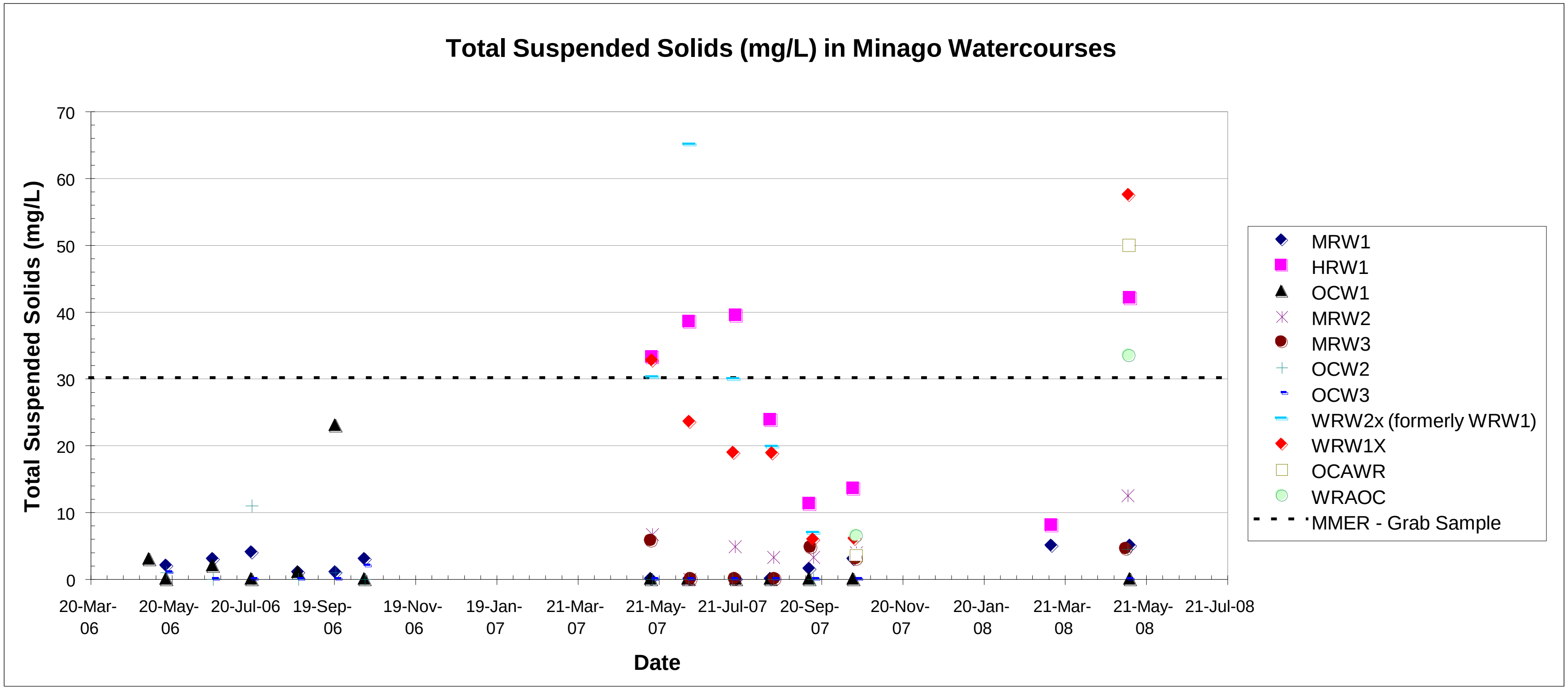


Figure 7.5-12 Total Suspended Solids (mg/L) in Minago Surface Watercourses

7.5.4 Effects Assessment

This section examines potential project effects on surface water and sediment quality. Existing conditions in the project area are characterized and effects of project activities are predicted. Effects predictions are based on Site Water Management Plans described in Section 2.14: Site Water Management. Projections of drainage and effluent quality from ongoing testing and assessment of ARD and metals leaching from the ultramafic waste rock and planned development rock are described in Section 2.8: Geochemical Rock Characterization, and planned infrastructure is detailed in Section 2.15: Site Facilities and Infrastructure. Information on predicted project effects on stream flows (Section 7.4: Surface Water Hydrology) and groundwater flows and quality (Section 7.6: Hydrogeology and Groundwater Quality) are integrated into the assessment of effects on surface water and sediment quality.

The findings of this section provide the basis for the assessment of potential project effects on aquatic biota discussed in Section 7.7: Benthos, Periphyton and Sediment Quality and in Section 7.8: Fish Resources. This section describes project effects under routine construction and operating conditions as well as during decommissioning and at closure. Potential effects of project-related accidents and malfunctions on surface water and sediment quality are discussed in Section 8: Accidents and Malfunctions.

7.5.4.1 Scope of Assessment

Surface water and sediment quality are identified as VECCs because they are sensitive to project effects and because they provide a vital link to sustaining healthy aquatic ecosystems. Assessment of project effects on water and sediment quality provides an indication of potential effects on aquatic organisms at the population and community levels. Many aquatic organisms have known tolerances and responses to metals, nutrients and sediment typically associated with mining operations. Potential project effects on water and sediment quality can result from the:

- introduction of sediments (total suspended solids (TSS)) to receiving waters due to runoff from disturbed areas during the construction and operational phases;
- changes to the Oakley Creek flow regime and water and sediment quality, related to clean water diversions and site water management (drainage collection and discharges from the Polishing Pond);
- discharge of effluent from the Polishing Pond to the Oakley Creek and the Minago River;
- seepage of contaminated groundwater from the Tailings and Ultramafic Waste Rock Management Facility (TWRMF) to Oakley Creek;
- discharge of TWRMF pond supernatant via the Polishing Pond to the Oakley Creek following mine closure.

Direct and indirect effects of water and sediment quality on aquatic life have been well recognized for over a century (Wetzel, 2001). Currently, the Canadian Council of Ministers of the

Environment (CCME) maintains and updates a list of scientifically derived water and sediment quality guidelines for the protection of various users, including aquatic life (CCME, 2007). Both periphyton and benthic invertebrates are used as indicators of water quality because of their recognized sensitivity to changes in nutrients, sediment (TSS) and metal levels. Water quality and biological community sampling are typically linked in government-developed biomonitoring programs in Canada (Environment Canada, 2002b) and the United States (Barbour et al., 1999).

Discharge of the Polishing Pond effluent to the receiving environment has potential for direct adverse effects on aquatic ecosystems, through toxicity of metals, nutrient enrichment (elevated nitrate/ammonia content from blasting residues), increased sulphate levels, changes in pH, and release of suspended sediments. Potential environmental effects of mine effluent discharge have been well documented, and may include excessive growth of periphyton resulting from nitrate or ammonia discharges, reduced abundance of periphyton and benthic invertebrates in areas close to discharge points, elimination of sensitive species, changes in community structure and deformities of periphyton induced by metals. Changes in periphyton and benthos productivity can have an effect on fish assemblages (abundance, size, bioaccumulation of metals in tissue), which can then affect birds and wildlife that consume fish. Project potential effects on periphyton and benthic invertebrate communities are detailed in Section 7.7: Benthos, Periphyton and Sediment Quality.

Metal Mining Effluent Regulations (MMER), under the *Fisheries Act*, and associated Environmental Effects Monitoring (EEM) programs, came into effect in 2002 and require three-year cycles of effluent and receiving environment monitoring. Environment Canada administers MMER. Mine permits and MMER describe effluent quality criteria. The regulation and the EEM guidance document (Environment Canada, 2002b) define statistically and ecologically supported procedures for assessing the effects of effluent discharge on the receiving environment. These include weekly, monthly or quarterly effluent monitoring, water monitoring in the receiving environment, acute and chronic effluent toxicity testing, benthic invertebrate and fish community studies, and assessment of supporting environmental parameters (e.g., habitat quality and nutrient levels).

Project components that have the potential to influence surface water and sediment quality are described briefly below. Further information on site water management facilities and design is provided in Section 2.14: Site Water Management.

Discharge of Site Drainage: Surface drainage will be collected in drainage ditches and directed to the Oakley Creek watershed. One of the main areas of surface disturbance in the Oakley Creek basin will be the Overburden Disposal Facility (ODF). Drainage from the ODF will be collected in ditches and pumped to the TWRMF. As noted above, TWRMF water will be incorporated in the process water balance circulation and any discharges will be directed to the Polishing Pond prior to discharge to the Oakley Creek and the Minago River.

Polishing Pond Discharge to Oakley Creek and Minago River: All open pit dewatering water and frac sand and ore processing water will be pumped to the Polishing Pond. Any excess water from this system will be discharged to the Oakley Creek and the Minago River. Effluent quality has been projected based on inputs to the Polishing Pond and discharges from the Polishing Pond to Oakley Creek and the Minago River. Receiving water quality in Oakley Creek and Minago River has been predicted based on the proposed rates of effluent discharge and receiving water flows and quality, which are outlined in Section 2.14.

The Polishing Pond effluent will meet or exceed MMER effluent quality criteria prior to discharge. Effluent will be discharged at approximately 70% and 30% to the Minago River and the Oakley Creek in the summer months (May to October), respectively; and at 65% and 0% to the Minago River and the Oakley Creek in the winter months (Nov.- Apr.), respectively. In the winter months (Nov. - Apr.), 35% of the Polishing Pond influent will be held back in the Polishing Pond for later discharge during the spring freshet (May).

Victory Nickel intends to develop Site-specific Water Quality Objectives (SS-WQO) for the project. The SS-WQO will be developed in conjunction with regulatory agencies, and will be based on CCME and Manitoba Tier II guidelines for the protection of aquatic life. The SS-WQO will take into consideration ambient water chemistry, e.g., the potential Contaminant(s) of Concern (COCs) level(s) in Minago River, William River and Oakley Creek.

All metal and ammonia levels in the Minago River and Oakley Creek will meet or exceed the SS-WQO, CCME and Tier II guidelines at the designated water quality compliance sites. There will be an increase in flows at and downstream of the discharge points on the Oakley Creek and Minago River, which provide dilution. Arsenic, copper, lead, nickel and zinc levels will meet CCME/Manitoba Tier II guideline limits immediately downstream of the effluent discharge point all year round.

Discharge of potentially contaminated groundwater seepage from the TWRMF to Oakley Creek: Seepage from the TWRMF during operations will be intercepted by seepage ditches surrounding the facility, and will be pumped back to the TWRMF.

Discharge from the TWRMF facility after mine closure: At the end of operations, the TWRMF will remain in place, with a water cover to prevent leaching of metals from the ultramafic waste rock and tailings. The supernatant water will be monitored for at least five years and potentially treated, if required.

A list of water and sediment quality VECCs has been defined for the project environmental assessment based on the EAP Report Guidelines (Fisheries and Oceans Canada) and COI. The selected VECCs and rationale for their selection are described in Table 7.5-8.

7.5.4.1.1 Temporal Boundaries

The temporal boundaries applicable to water and sediment quality include the period of record for the collection of baseline data and all phases of the project (construction, operation, decommissioning and closure). The potential for introduction of silt and sediment to area streams will be present in all phases, but greatest during construction. The potential for introduction of metals or nitrate/ammonia to streams will be present in all phases, but greatest during operation.

Table 7.5-8 Selected VECCs and Rationale for their Selection

VECC	Rationale for Selection	Linkage to EAP Report Guidelines or Other Regulatory Drivers	Baseline Data for EAP
Water Quality: total suspended solids (TSS)	• Potential for project effects due to ground disturbance, construction, and associated erosion and sedimentation, and dust and particulates in runoff from mine facilities (stockpiles, waste areas).	• Information requested in EAP Report Guidelines and EBS Work plan • CCME or other guidelines for protection of aquatic life • Will be required for MMER	2006 – 2008 Baseline Data
Water quality: pH, conductivity and alkalinity	• Potential for project effects due to ARD and ML affecting Polishing Pond effluent discharges to Oakley Creek and the Minago River and groundwater discharge to Oakley Creek. Characterizes sensitivity of receiving waters to project-related discharges. Changes in receiving water quality potentially affect aquatic resources, including fish.	• Information requested in EAP Report Guidelines and EBS Work Plan • CCME or other guidelines for protection of aquatic life • Will be required for MMER	2006 – 2008 Baseline Data
Water quality: sulphate concentrations	• Potential for project effects due to ARD affecting Polishing Pond effluent discharges to Oakley Creek and the Minago River and groundwater discharges to Oakley Creek. • Indicator of mine related changes in water quality due to ARD and ML.	• Information requested in EAP Report Guidelines and EBS Work Plan • CCME or other guidelines for protection of aquatic life • Will be required for MMER.	2006 – 2008 Baseline Data
Water quality: metals concentrations (*e.g.* Ni, Cd, Zn)	• Potential for project effects due to ARD and metal leaching affecting Polishing Pond effluent discharges to Oakley Creek and the Minago River groundwater discharges to Oakley Creek. • Potential for bioaccumulation and toxic effects on aquatic resources and fish.	• Information requested in EAP Report Guidelines and EBS Work plan • CCME or other guidelines for protection of aquatic life • Will be required for MMER	2006 – 2008 Baseline Data
Water quality: concentrations of nitrogen compounds (NO3 & NH4)	• Potential for project effects due to blasting residue and sewage effluent discharges in the Oakley Creek drainage. • Potential effects on primary productivity and associated effects on aquatic ecology. Potential toxicity to aquatic life in high concentrations.	• Information requested in EAP Report Guidelines and EBS Work Plan • Will be required for MMER	2006 – 2008 Baseline Data
Sediment quality: metals concentrations	• Potential for project effects due to Polishing Pond effluent discharges to Oakley Creek and the Minago River. • Effects on sediment quality provide an indicator of potential effects on benthic communities and related effects on fish. food.	• Information requested in EAP Report Guidelines and EBS Work Plan • Will be required for MMER	2006 – 2008 Baseline Data

decommissioning will include a period to stabilize the quality of TWRMF discharge to the Polishing Pond for ultimate closure.

Monitoring will be conducted following the reclamation of the TWRMF and its appurtenances to check the quality of TWRMF supernatant water and seepage, provide passive treatment at the Polishing Pond, if required, prior to discharge to Oakley Creek in order to ensure effective long-term management of ARD and metal leaching by submerging the tailings and ultramafic waste rock. The assessment of the closure phase assumes the stabilization of water quality conditions in the reclaimed TWRMF. It is anticipated that this will be possible, based on monitoring during the operations and decommissioning phases, and adaptive management to ensure effective long-term management of potential project effects originating from the tailings and groundwater.

7.5.4.1.2 Study Area

The local and regional study areas are shown in Figure 7.5-13. The local study area (LSA) includes all streams and associated waterbodies that may be influenced by mine site activities and transportation corridors (TCs). This includes the Oakley Creek watershed, William River, and the Minago River. Specifically, the LSA includes:

- the Oakley Creek watershed, which will be affected by diversions, the TWRMF, the industrial complex, the open pit operations, borrow areas, the campsite development, and permitted discharges from the Polishing Pond;
- Minago River, which will receive permitted effluent discharges from the Polishing Pond.

The regional study area (RSA) includes water bodies and watersheds beyond the LSA that reflect the general region to be considered for cumulative effects and that provide suitable reference areas for determining background conditions. It includes Hargrave River, Cross Lake, William Lake and Limestone Bay.

7.5.5 Baseline Conditions

7.5.5.1 Methods

Existing information from previous studies conducted for the project is summarized in this report. Water and sediment quality data have been compared to CCME and Manitoba (MB) Tier II guidelines for protection of aquatic life (CCME, 2007). Table 7.5-9 shows CCME guideline levels for water and sediment for the protection of aquatic life (CCME, 2002 and 2007).

7.5.5.2 Effects Assessment Methodology

Project effects on water and sediment quality were assessed in accordance with the EAP Report Guidelines using effects attributes defined in Table 7.5-10. The ecological and social contexts of effects are integrated in the magnitude attributes.

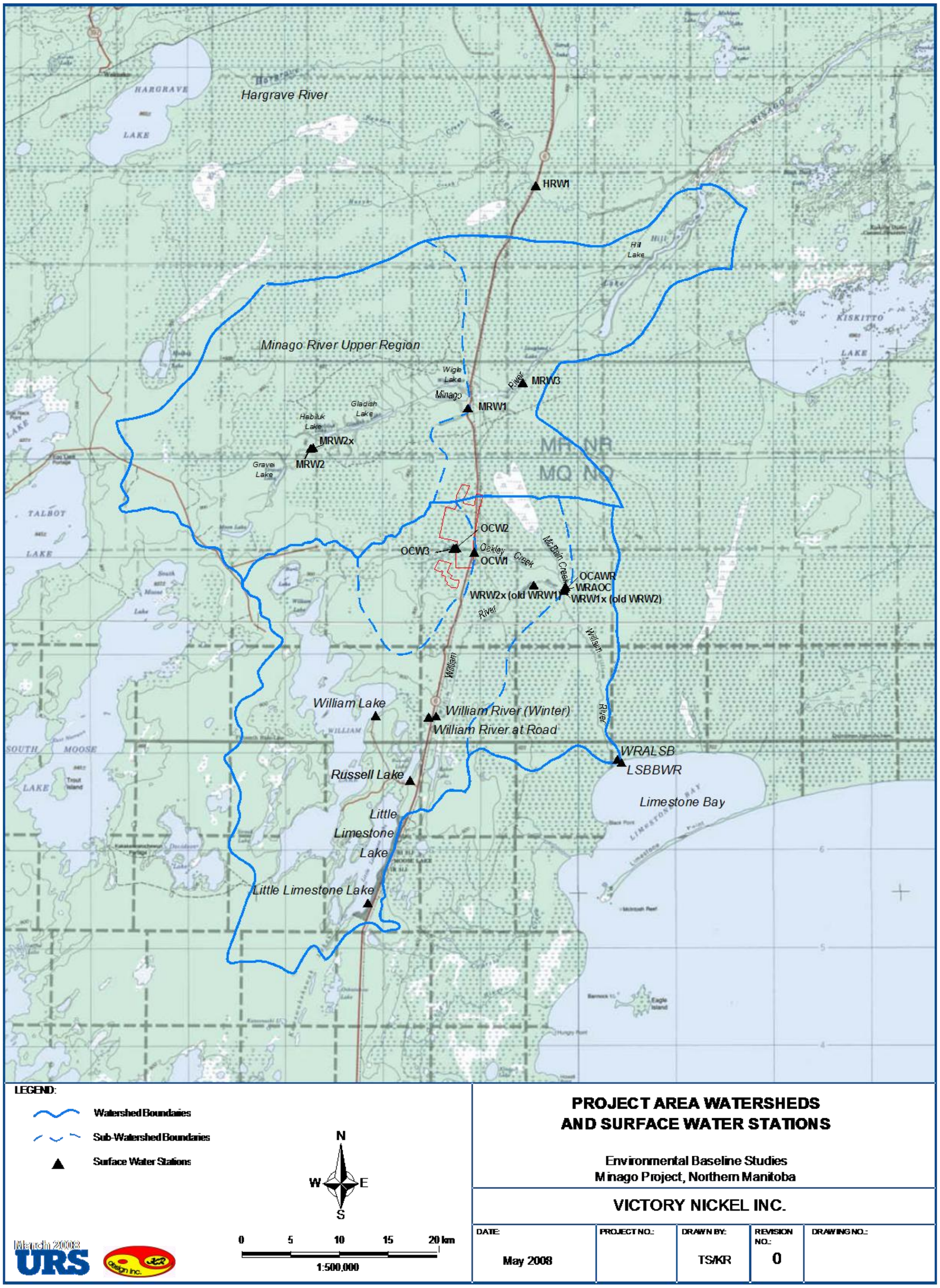


Figure 7.5-13 Watersheds in the LSA and RSA Study Areas

Table 7.5-9 CCME Guidelines for Protection of Freshwater Aquatic Life

Metal (total)	In Water (mg/L) (CCME, 2007)	In Sediment (µg/kg) (CCME, 2002)	
		ISQG[1]	PEL[2]
Aluminum	0.100	-	-
Arsenic	0.005	-	-
Cadmium	0.000017 or $10^{\{0.86[\log(hardness)]-3.2\}}$	600	3,500
Chromium	0.0089	-	-
Copper	0.002 (hardness = 0-120 mg/L $CaCO_3$) 0.003 (hardness = 120-180 mg/L $CaCO_3$)	35,700	197,000
Iron	0.30	-	-
Lead	0.001 (hardness = 1-60 mg/L $CaCO_3$) 0.002 (hardness = 60-120 mg/L $CaCO_3$) 0.004 (hardness = 120-180 mg/L $CaCO_3$)	35,000	91,300
Mercury		170	486
Molybdenum	0.073	-	-
Nickel	0.025 (hardness = 1-60 mg/L $CaCO_3$) 0.065 (hardness = 60-120 mg/L $CaCO_3$) 0.110 (hardness = 120-180 mg/L $CaCO_3$)	-	-
Selenium	0.001	-	-
Silver	0.0001	-	-
Zinc	0.030	123,000	315,000

Notes: [1] ISQG = interim sediment quality guideline
[2] PEL = probable effects level

Table 7.5-10 Effect Attributes for Surface Water and Sediment

Attribute	Definition
Direction	
Positive	Condition of VECC is improving.
Adverse	Condition of VECC is worsening or is not acceptable.
Neutral	Condition of VECC is not changing in comparison to baseline conditions and trends.
Magnitude	
Low	Effect on VECC can be quantified and there will be no change in a variable from ambient conditions.
Moderate	Effect on VECC can be quantified as a change in a variable from ambient conditions but change does not exceed threshold levels (in CCME and Manitoba Tier II Water or CCME Sediment Quality Guidelines).
High	Effect on VECC can be quantified as a change in a variable that exceeds threshold levels (in CCME Water or Interim Sediment Quality Guidelines).
Geographic Extent	
Site-Specific	Effect on VECC confined to a reach of a stream in the LSA (e.g. <500m).
Local	Effect on VECC extends throughout the LSA.
Regional	Effect on VECC extends into the RSA.
Duration	
Short-term	Effect on VECC is measurable for up to 1 year.
Medium term	Effect on VECC is measurable for 1 to 5 years.
Long-term	Effect on VECC measurable for longer than 5 years, but does not extend more than 10 years after decommissioning and final reclamation.
Far future	Effect on VECC measurable >10 years after decommissioning and abandonment.
Frequency (Short-term duration effects that occur more than once)	
Low	Effect on VECC occurs infrequently (<1 day per month).
Moderate	Effect on VECC occurs frequently (seasonal or several days per month).
High	Effect on VECC occurs continuously.
Reversibility	
Reversible	Effect on VECC will cease to exist during or after the project is complete.
Irreversible	Effect on VECC will persist during and/or after the project is complete.
Likelihood of Occurrence	
Unknown	Effect on VECC is not well understood and based on potential risk to the VECC, effects will be monitored and adaptive management measures taken, as appropriate.
High	Effect on VECC is well understood and there is a high likelihood of effect on the VECC as predicted.

Determination of Effects Significance

A residual effect on water and sediment quality will be considered significant for the project or cumulatively, based on the attributes defined in Table 7.5-10, if it is:

- a moderate magnitude adverse effect of high likelihood and long-term in duration or irreversible;
- a high magnitude adverse effect of high likelihood, except when it is only site-specific;
- a high magnitude adverse effect of high likelihood that is site-specific and far future in duration or irreversible.

Otherwise, effects are rated as not significant. In addition, the probability of occurrence of any significant adverse residual effects and the degree of confidence for each prediction are stated with a supporting rationale.

7.5.5.3 Project Effects

Potential project effects during construction, operations, decommissioning and closure are described by watershed in the following sections. Most project actions are expected to affect stream rather than lake water and sediments. Mitigation measures are also presented. Mitigation measures to protect water and sediment quality will also protect other aquatic VECCs (benthic invertebrates, periphyton, fish and fish habitat).

7.5.5.3.1 Construction

Oakley Creek

Facilities that will be constructed in the Oakley Creek basin include the open pit area and dewatering wells, the TWRMF, ore stockpiles, waste rock storage dumps and the industrial complex.

Oakley Creek is a short, low gradient stream, flowing on surface throughout, with limited fish resources. Baseline aluminum, iron, nitrate concentrations exceeded CCME 2007 guidelines for the protection of aquatic life. Moreover, chromium content in sediments was found to be naturally higher than criteria set by the CCME (2002). Thus, metal levels in surface waters and sediments are at times higher than CCME guidelines, reflecting the mineralized nature of the watershed. Data for the depositional river/lake sediments will provide a good basis for monitoring the effectiveness of the Water Management Plan over time.

The Oakley Creek basin has already been affected by access road construction and exploration programs. Potential project effects on Oakley Creek during construction include:

- **Increased suspended sediment solids in runoff from construction sites for various facilities in the basin:** VNI will implement its Erosion and Sediment Control Plan (Section 9: Environmental Management Plans) to minimize the risk of introducing suspended sediments to surface waters. Throughout the life of the project, project activities will involve ground disturbance with potential for erosion and stream sedimentation. In addition, all site drainage in the minesite construction zone will be collected in drainage ditches, directed towards surface sumps, and pumped to the Polishing Pond (Section 2.14: Site Water Management). Water will be contained in the Polishing Pond for use as process water and the balance will be discharged to the Oakley Creek and the Minago River watersheds. Prior to the construction of the Polishing Pond, existing and new ditches and sumps will be used and water will be settled, tested, treated with flocculants and coagulants as needed, before being discharged. Accordingly, no effects on water quality in Oakley Creek are anticipated.

- **Runoff from waste rock dumps, frac sand and ore stockpiles with potentially elevated nitrogen compounds, metals and suspended sediments**: The foundations of the waste rock dumps and ore stockpile areas are underlain by low permeability clays. Seepage from the dumps will be collected in ditches and directed towards local sumps, with ultimate discharge to the Oakley Creek.

- **Diversion of surface water drainage from disturbed areas in the Oakley Creek basin to the water management system**: Diversion of surface water flows may result in a small reduction of stream flows; those are however considered to be not significant since waters will ultimately flow back to the Oakley Creek, once they will have passed through the Polishing Pond.

Site management to collect mine water and potentially contaminated runoff in the construction zone is expected to minimize potential impacts on water quality in the Oakley Creek basin. No effect on water or sediment quality outside of natural variability is expected. Therefore, project effects on water and sediment quality in Oakley Creek during construction are predicted to be neutral or low magnitude and site-specific. Effects will continue through operations (see below) and so will be long-term. Effects of reduced surface water flows on water quality are expected to gradually decrease and return to pre-mining conditions during closure, and so will be reversible.

Minago River

There will be no effect during the early stages of construction as there will be no discharges to the Minago River. Discharge of water from the Polishing Pond will have minimum effects on the Minago River system. During construction, the main source of the water in Polishing Pond will be from the dewatering wells.

7.5.5.3.2 Operations

Oakley Creek and Minago River

Potential project effects on water and sediment quality in Oakley Creek that were identified for the construction phase will continue during operations. The Site Water Management Plan will continue to minimize potential impacts on the water quality in the Oakley Creek basin. Reclamation and stabilization of disturbed areas following construction will further reduce the risk of sedimentation from surface water runoff. Effluent discharge from the pit dewatering wells to the Polishing Pond will continue.

Potable water will be supplied from the dewatering wells. The majority of water for ore processing will come from mine dewatering, the remainder will be reclaim water from the Polishing Pond.

The main incremental effects on water and sediment quality in Oakley Creek during operations will be as follows:

- **TWRMF:** TWRMF seepage water with potentially elevated concentrations of metals and nutrients is expected to seep into seepage collection ditches. The seepage collection ditches will be located immediately downstream of the TWRMF to intercept the seepage. Seepage water will be recycled to the TWRMF.

- **Discharge of the Polishing Pond Effluent to Oakley Creek and Minago River:** The Polishing Pond will retain pit water, excess TWRMF supernatant (containing process effluents from the mill and Frac Sand Plant, sewage treatment plant effluent from the industrial complex, and site drainage). Discharge of effluent has the potential to result in elevated metals, sulphate, nitrate or ammonia (from blasting residues) and TSS levels in receiving waters. There may also be effects related to deposition and transport of particulate metals, resulting in increased metal levels in stream sediments. Further discussion of predicted receiving water quality in Oakley Creek is provided below.

The water balance for open pit dewatering and ore processing will result in a net increase on an annual basis, so discharges from the Polishing Pond to the Oakley Creek and the Minago River will be required. Effluent will be discharged under permit to the Minago River and the Oakley Creek. Stream flows will dilute the discharges. Section 2.14 provides a prediction of effluent quality and water quality in Oakley Creek and Minago River. Discharged effluent will meet MMER requirements at the discharge points downstream. Discharge of effluent to the Oakley Creek will occur mainly from May through October. Polishing Pond discharge to Minago River will occur all year round.

The following points are relevant to effluent discharge into Oakley Creek and the Minago River:

- all discharged effluent will meet MMER effluent criteria, including those for pH; and

- immediately downstream of the effluent discharge point, dilution alone will be sufficient to meet CCME guidelines and Manitoba Tier II water quality guidelines for the protection of aquatic life.

Nitrate levels may be elevated relative to baseline conditions throughout Oakley Creek and the Minago River downstream of the discharge. The CCME guideline (13 mg/L) is established in relation to nitrate toxicity, rather than eutrophication potential, and will not be exceeded in Oakley Creek. Nitrate/ammonia inputs from blasting will decrease over the operational phase and denitrification will reduce nitrate levels in effluent and stream water. Aquatic plants in the creek will also take up and store nitrate during the growing season, and release it later during decomposition, resulting in lower nitrate levels. Nitrate levels are likely to stimulate periphyton growth in the Oakley Creek and the Minago River.

From the baseline results, nitrate levels tend to be very low, rendering the stream sensitive to enrichment effects from nitrate. The magnitude and direction of the periphyton response to enrichment will depend on stream flows, light, temperature and available phosphorus, as well as inorganic nitrogen. In oligotrophic systems, some nutrient enrichment can be considered beneficial to benthic communities.

The effect of nutrient enrichment can be considered to continue over long distances, given the continual cycle of uptake in algae, decomposition and nutrient release, commonly described as "nutrient spiralling" (Wetzel, 2001). As a result, some effects on William River and Minago River may not be a problem due to the additional dilution provided by William River and Hargrave River, respectively.

Accumulation of selenium and other metals in depositional areas has become an issue of concern for mines (McDonald and Strosher, 2000; Chapman, 2004). However, research on the relationship between ambient levels and organism responses is in progress. Selenium has been noted to bio-accumulate in fish tissue, probably through consumption of benthic invertebrates that dwell in close contact with the metal-containing sediment. Current recommendations are for a maximum of 2 mg/kg in sediment (Engberg et al., 1998; Lemly, 2002). Selenium levels in Oakley Creek and Minago River sediment have been below that level, but will be monitored during mine operations. If levels show an increasing trend and are approaching guideline levels, additional sampling of benthic invertebrates and fish (sculpin) tissue metals analysis will be conducted in downstream fish-bearing areas. In the event of an increasing trend in sediment and tissue concentrations, adaptive management to reduce bio-available selenium levels will be implemented.

7.5.5.3.3 Decommissioning

Decommissioning will include:

- flooding of the pit;
- dismantling of the ore processing facilities and offices;

- modifications of the TWRMF embankment as required to ensure long-term saturation of the tailings and ultramafic waste rock and to provide a spillway for ultimate passive decanting of the TWRMF at closure;
- recontouring and revegetation of disturbed areas;
- decommissioning of clean water diversions; and
- reinstatement of natural drainage patterns.

The Polishing Pond will remain open.

In the initial phase, all extraneous project facilities will be removed and the disturbed areas left by their removal will be reclaimed. The sequence of decommissioning will allow flow stabilization and reclamation of large disturbed areas prior to the removal of redundant site water management facilities such as drainage collection ditches and settling ponds. An Erosion and Sediment Control Plan will be implemented (Section 9: Environmental Management Plans) in order to minimize effects of erosion and sedimentation on surface waters.

Minago River

At the end of the Nickel Processing Plant operations, pit dewatering will cease and at the end of Year 9 operations, discharges of the final effluent to the Minago River will cease. As the mine site is located within the Oakley Creek basin, decommissioning will have no effect on the Minago River other than a staged decrease in stream flows discussed in Section 7.4: Surface Water Hydrology.

Oakley Creek

The TWRMF closure design will ensure that the tailings and ultramafic waste rock will be saturated. The facility will be covered with a minimum of 1.5 m of water cover, so that minimal metals leaching will occur. Based on humidity cell tests, it is expected that the supernatant water quality of the TWRMF will reach an equilibrium with the aging tailings such that most, if not all, water quality parameters will meet the discharge criteria at closure. ARD/ML is not predicted to occur. The TWRMF supernatant will be monitored following the first phase of decommissioning before discharge to Oakley Creek via the Polishing Pond.

7.5.5.3.4 Closure

The Mine Closure Plan is described in Section 3.4 and in a separate report, entitled, “Minago Project - Closure Plan, 2010”. The Water Management Plan for closure is presented in Section 2.14.

Minago River

The potential impacts of ending the discharge of the final effluent from the Polishing Pond to the receiving environment will effect two main components, namely biological aspects (wetlands and stream habitats) and hydrological conditions (in Minago River and Oakley Creek).

These impacts will be low on wetlands since these vast ecosystems are quite resilient. Indeed, mosses, sedges and ericaceous shrubs are among the most widespread species in the region and can easily acclimate themselves to a wide variety of conditions (Campbell and Rochefort, 2001). Gradually, vegetation cover should switch back to what it was before, if no other change in climatic conditions will occur; otherwise, it would adapt itself to the prevailing climatic conditions. Bogs are not as sensitive as forest stands to climatic conditions, especially rainfall, since they are already wet ecosystems that have the capacity to store additional water. In fact, the development of bogs is mainly due to a combination of allogenic factors, such as temperature and precipitation, favouring a positive water balance (Payette, 1988; Foster and Wright, 1990).

The impacts of increasing water flow in the Minago River in terms of hydrology will likely be not significant since they are within the natural variation occurring in this region.

The impacts of a reduction in the water flow on stream habitats would be more significant, especially in winter low flow conditions. Lower water flow and thus water level would reduced stream habitat types and increase the risk of changes in water quality, therefore increasing seasonal stresses for fish and other biota.

Therefore, mitigation measures will have to be implemented in order to limit the potential impacts of such a change in water level conditions, meaning that water will have to be stored in the Polishing Pond in such a way that the final effluent flow after closure will be gradually reduced and not drastically. This would enable a comeback to pre-mining conditions. Staging flow to the Minago River will be developed.

The areas on which the discharge pipeline to the Minago River, the rock-filled channel and the diffuser will have been installed will be rehabilitated, meaning that they will be re-vegetated with green alders.

Oakley Creek

At closure, the quality of TWRMF supernatant will not cause a change in the quality of Oakley Creek water beyond the natural variability established over the period of baseline monitoring, as discussed above for the decommissioning phase. Accordingly, there will be no further effects of the project on Oakley Creek at closure. Legal discharge limits will be met.

7.5.5.4 Residual Project Effects and Significance

Residual adverse effects of the project on water and sediment quality are discussed below.

Polishing Pond Effluent - Oakley Creek

Residual effects during operations are expected to include some elevated levels of metals in Oakley Creek for a distance of up to 7 km downstream of the discharge point, with potential accumulation of metals in stream sediments in the same region. Downstream of the compliance point, levels of these substances will be below CCME / Manitoba guideline limits. No adverse effects are predicted downstream in fish-bearing waters of lower Oakley Creek (Section 2.14: Site Water Management).

There is potential for localized accumulation of metals in depositional sediment within the affected reach, with potential for uptake in periphyton and benthos, although this is considered unlikely due to the annual freshet that will mobilize and disperse stream sediments. From an ecological perspective, elevated metals in benthic invertebrates that drift downstream into fish-bearing reaches could contribute to bioaccumulation of metals in fish, although the likelihood of this is unknown, given the intervening areas of beaver pond and riffle habitat. Baseline fish tissue data has been collected for future reference. The EEM program will monitor water and sediment metals levels. If increasing trends are noted in sediment concentrations, follow-up monitoring of metals in fish tissue will be conducted to assess the possibility of bioaccumulation and improve mitigation, if necessary.

The project will be subject to the Metal Mining Effluent Regulations (MMER) (Environment Canada, 2002a) and will be required to monitor effluent discharges and the receiving environment using an EEM program, overseen by Environment Canada. Benthic invertebrate and fish communities will be monitored on a multi-year cycle to provide data about the effectiveness of the Water Management Plan and the environmental effects of discharges on the benthic community of Oakley Creek, and will guide decisions on mine practices and monitoring requirements.

In summary, the greatest effect of Polishing Pond effluent discharges on water quality in the Oakley Creek system will be between the effluent discharge point and the compliance point during operations. Effects in this reach are rated as adverse, moderate, local, long-term and reversible. All other effects on Oakley Creek are rated as low magnitude. The adverse effects of effluent discharge on water and sediment VECCs are expected to be not significant, throughout all phases of the project and at closure. The likelihood of effects occurring as predicted is high.

Flow Regime Changes - Oakley Creek

Some changes to flow regimes of Oakley Creek are anticipated (Section 7.4: Surface Water Hydrology) as a result of partial diversion of runoff to flood the pit for a period of approximately 10.6 years. Flows will remain higher than summer low flows. Using criteria in Section 7.5-12, the adverse effects of flow regime changes on water and sediment VECCs are expected to be not significant, throughout all phases of the project and at closure. The likelihood of effects occurring as predicted is high.

TWRMF Discharge – Oakley Creek at Closure

Tailings and ultramafic waste rock stored in the TWRMF will be covered with a minimum of 1.5 m of water following decommissioning of the operations, so that minimal metals leaching will occur. It is expected that the supernatant water quality of the TWRMF will reach an equilibrium with the aging of tailings such that most water quality parameters will meet the discharge criteria at closure. Tailings supernatant is not predicted to result in adverse effects on the Oakley Creek water quality (Section 2.14: Site Water Management).

7.5.5.5 Cumulative Effects and Significance

The only other development in the RSA that could affect water and sediment quality in stream basins affected by the project is the PTH6. The highway crosses Oakley Creek, Minago River and William River. Cumulative effects could potentially arise from introduction of pollutants to these streams from road accidents, spills and maintenance (sediment introductions from road drainage).

Localized residual effects of the project on water and sediment quality are expected to be not significant, and will not affect the overall ecological health of the streams. Contaminants from the PTH6 could potentially influence the Oakley Creek, Minago River, and William River. Effects on benthic communities could vary depending on the nature and volume of contaminants introduced, the season of occurrence and the associated ecological importance of these stream reaches to fish production at the time. Effects could vary from not significant to significant. Any contribution of project related effects to cumulative effects arising from the PTH6 are expected to be not significant.

7.5.5.6 Mitigation Measures

Mitigation measures are described in Table 7.5-11.

7.5.5.7 Monitoring and Follow-up

Follow-up Studies

At this point, it is felt that the 2006, 2007 and 2008 baseline studies will provide sufficient data for seasonal baseline water quality and sediment characterizations at the most relevant locations within the LSA and RSA. Additional monitoring programs will be established prior and during the construction and operational phases.

Monitoring Programs

Monitoring programs are recommended where the likelihood of project effects is unknown and there is concern that effects on the VECC might give rise to a management issue in a regulatory or social context. These programs are summarized in Table 7.5-12. Monitoring will be implemented by VNI.

The main monitoring program identified to determine effects on water and sediment quality from residual and cumulative effects will be the EEM program required under MMER for mines operating with a permitted discharge point. Monitoring for metal levels, particularly selenium, in sediment (depositional areas) will also be conducted.

Construction monitoring for release of sediment (TSS) to streams will be conducted as part of the Erosion and Sediment Control Plan (Section 9: Environmental Management Plans) during facility and transportation corridors construction, to monitor the effectiveness of mitigation measures.

Minago River and Oakley Creek flows will be monitored to assess predicted effects of hydrologic changes.

7.5.5.8 Summary of Effects

Project and cumulative effects are summarized in Table 7.5-13. Adverse effects that are rated moderate in magnitude and far future in duration are considered significant, as are those rated high in magnitude, that are local or regional in extent and of high likelihood or site specific, far future in duration or irreversible and of high likelihood.

Table 7.5-11 Mitigation Measures for Effects on Water and Sediment Quality

Potential Project Effect	Mitigation Measures
Construction	
Changes in water and sediment quality in Oakley Creek from contaminated construction site runoff, waste rock storage, and ore stockpiles	• Implement the Erosion and Sediment Control Plan (Section 9.2: Environmental Protection Plan) and Site Water Management Plan (Section 2.14) to ensure no contaminated drainage water enters Oakley Creek.
Minesite clearing of vegetation and increased sediment input to Oakley Creek	• Minimize vegetation removal and soil disturbance within the RSA. • Implement the Erosion and Sediment Control Plan and the Site Water Management Plan (Section 2.14) to ensure no sediment laden water enters Oakley Creek. • Revegetate disturbed areas as soon as possible.
Sediment inputs during the construction of transportation corridors in the Oakley Creek watershed basin	• Implement the Erosion and Sediment Control Plan (Section 9.2: Environmental Protection Plan). • Adhere to appropriate guidance documents for work around watercourses. • Revegetate cleared areas with native flora.
Operations	
Changes in water and sediment quality from TWRMF seepage to Oakley Creek and Minago River (metals, TSS, nutrients)	• Intercept seepage in collection ditches and recycle back to the TWRMF. Ultimate discharge to the receiving environment will be via the Polishing Pond. • Monitor effluent and receiving water quality and initiate adaptive management as required.
Changes in water and sediment quality in Oakley Creek and Minago River from the Polishing Pond discharges (metals, TSS, nutrients)	• Ensure effluent quality meets CCME / Manitoba Tier II guidelines at Station OCAWR. • Discharge wastewater in accordance with Manitoba and federal regulations. • Monitor effluent and receiving water quality and initiate adaptive management as needed.
Accumulation of metals in sediment of Oakley Creek and Minago River that have a potential for bioaccumulation	• Monitor water and sediment concentrations in Oakley Creek and Minago River. If results indicate an increasing trend, collect benthic invertebrates and sculpin for tissue metals analysis. • Apply adaptive management measures, if necessary.
Introduction of sediment and other road runoff contaminants into Oakley Creek and Minago River	• Reclaim/revegetate disturbed areas that are no longer in use. • Implement the Erosion and Sediment Control Plan (Section 9: Environmental Protection Plan).
Decommissioning	
Changes in water and sediment quality in Oakley Creek from site runoff where facilities have been removed and/or the ground has been recontoured	• Implement the Erosion and Sediment Control Plan (Section 9: Environmental Protection Plan) and the Site Water Management Plan (Section 2.14) to ensure no contaminated drainage water enters Oakley Creek. • Reseed recontoured areas as soon as possible.
Changes in water and sediment quality in Oakley Creek from the Polishing Pond effluent discharges (metals, TSS, nutrients)	• Discharge wastewater in accordance with Manitoba and federal regulations. • Ensure all discharges meet or exceed permit requirements. • Monitor effluent and receiving water quality and initiate adaptive management as required.
Closure	
Changes in water and sediment quality of Oakley Creek from ongoing tailings and waste rock storage	• Adhere to the Mine Closure Plan • Monitor water and sediment quality during decommissioning to confirm the effectiveness of management. • Maintain a water cover on top of the TWRMF as designed to minimize ARD/ML concerns.

Table 7.5-12 Monitoring and Follow-up Programs for Water and Sediment Quality

Potential Project Effect	Program Objectives	General Methods	Reporting	Implementation
Follow-up Programs				
None				
Monitoring Programs				
Monitoring for suspended sediments	• To confirm effectiveness of mitigation and immediately address compliance issues	• Monitor TSS at settling basins and in receiving waters according to permit schedule	• Manitoba Gov.'t and DFO as required	Proponent
Accumulation of selenium and other metals in depositional habitat	• To check potential for bioaccumulation. As needed, initiate contingency plans to address unexpected effects	• Concurrent with EEM program on three-year cycle. • Initiate benthic invertebrate of fish tissue sampling based on results of sediment analysis.	• Report to Manitoba Gov.'t and DFO	Proponent

Table 7.5-13 Summary of Effects on Water and Sediment Quality

Potential Effect	Level of Effect[1]						Effect Rating[2]	
	Direction	Magnitude	Extent	Duration/Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Construction								
Changes in water sediment quality in Oakley Creek from contaminated construction site runoff, waste rock storage, ore and frac sand stockpile	Adverse	Low	Site-specific	Short-term, Moderate frequency	Reversible	Low	Not significant	N/A
Operations								
Changes in Oakley Creek flow regime related to Open pit dewatering and diversion, affecting dilution capacity	Neutral	Low	Site-specific	Long-term	Reversible	Low	Not significant	N/A
Changes in water and sediment quality from TWRMF seepage to the Oakley Creek and the Minago River (metals, TSS, nutrients)	Adverse	Low	Site-specific	Long-term	Reversible	Unknown	Not significant	N/A
Changes in water and sediment quality in Oakley Creek from various discharges (metals, TSS, nutrients)	Adverse	Moderate	Local	Long-term	Reversible	High	Not significant	N/A
Changes in nitrate levels in Oakley Creek and Minago River from effluent discharges	Potentially positive	Moderate	Local to Regional	Long-term	Reversible	Unknown	Not significant	N/A
Accumulation of metals in sediment of Oakley Creek and Minago River with a potential for bioaccumulation in benthic communities and higher trophic levels	Adverse	Low	Site-specific	Long-term	Reversible	Unknown	Not significant	N/A

Table 7.5-13 (Cont.'d) Summary of Effects on Water and Sediment Quality

Potential Effect	Level of Effect[1]						Effect Rating[2]	
	Direction	Magnitude	Extent	Duration/Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Operations								
Introduction of sediment and other road runoff contaminants into Oakley Creek and Minago River	Adverse	Low	Site-specific	Long-term	Reversible	High	Not significant	N/A
Decommissioning								
Changes in water and sediment quality in Oakley Creek from site runoff where facilities have been removed and/or the ground has been recontoured	Adverse	Low	Site-specific	Short-term	Reversible	High	Not significant	N/A
Closure								
Changes in water and sediment quality of Oakley Creek from ongoing TWRMF supernatant discharge	Adverse	Low	Site-specific	Far future	Reversible	Unknown	Not significant	N/A

Notes: 1 Based on criteria in Table 7.5-11.

2 As outlined in the Effects Assessment Methodology

N/A not applicable

7.6 Hydrogeology and Groundwater Quality

With the Minago deposit situated under muskeg and under the Ordovician dolomite and Winnipeg Formation sandstones, the open pit will require dewatering to enable mining. Wardrop (2007) conducted an initial hydrogeological assessment in early 2007 with a goal to determine the underground flow regime and hydraulic conductivity of the various geological units that will be affected by mining. Groundwater quality was also characterized through chemical and physical analyses including pH, conductivity, alkalinity, sulphate, metals, and nitrogen compounds.

Preliminary pumping tests indicated that the peat and clay were water bearing but at very low yields and low hydraulic conductivity and thus of limited groundwater producing potential. The Ordovician limestone and sandstone, however, were found to have significant groundwater producing potential. Wardrop (2007) found that the principle stratigraphic units were overburden (peat and clay; OB), shallow limestone (SLS), limestone (LS), sandstone (SS), and granite (GR). Limestone at Minago is 55 m (180 ft) thick and consists of shallow limestone that has an upper zone of water bearing fractures (up to 40 m depth) and deep limestone underlying this zone. Underlying the limestone is approximately 10 m (30 ft) of sandstone, followed by some shale and weathered granite of the Precambrian Shield (Wardrop, 2007; Golder Associates, 2008a, 2008b).

The preliminary hydrogeological program, conducted in 2007, was followed by a comprehensive hydrogeological characterization of the site in the summer of 2008. The comprehensive hyrdogeological program, undertaken by Golder Associates and Golder Associates Innovative Applications (GAIA), involved pumping of four high capacity dewatering wells located along the perimeter of the proposed open pit mine and monitoring the hydrogeologic response in these wells and in 24 observation wells. Long-term pumping tests were conducted to lower the hydraulic heads within the limestone (LS) unit significantly below the limestone-overburden contact (i.e. allow its conversion from a confined to an unconfined aquifer). Results of the long duration pumping test program were used to develop a conceptual hydrogeological model of the Site and a groundwater flow model of the proposed open pit area. The complete report of the comprehensive hydrogeological study (Golder Associates, 2008b) is given in Appendix 7.6.

7.6.1 Objectives of the Comprehensive Hydrogeological Program

Minago's comprehensive hydrogeological program was conducted to determine the following aspects:

1. Estimate the hydrogeologic parameters for the main hydrostratigraphic units identified at the Site (i.e., transmissivity, storativity, and specific yield); The transmissivity, T, of an aquifer is a measure of how much water can be transmitted horizontally, such as to a pumping well. Storativity, S, is the volume of water released from storage per unit decline in hydraulic head in the aquifer, per unit area of the aquifer;
2. Identify key hydrogeologic boundaries, if any, that may affect the dewatering system;

3. Measure potential changes in shallow groundwater conditions as a result of pumping from the bedrock aquifers;
4. Assess the potential hydraulic connection of the bedrock aquifers with nearby surface water bodies;
5. Provide data for establishing the maximum yields for the planned dewatering wells; and,
6. Collect groundwater quality data from the bedrock aquifers to assess the potential impact of discharging groundwater to surface water bodies during development of an open-pit mine.

The above information was used to develop and calibrate a numerical groundwater flow model for the Minago Project site. The model was used as a tool to estimate the pumping rates and configuration of the dewatering well system that is required to provide sufficient dewatering for the proposed open pit and to estimate the extent of the drawdown cone created during mining. The overall objectives for the groundwater modelling study were to determine the number, location and depth of the dewatering wells and the total quantity of groundwater discharge that will likely be generated by the proposed open-pit mine.

7.6.2 Methodology - Pumping Test Program

The comprehensive hyrdogeological program involved pumping four high capacity dewatering wells (Figure 7.6-1) and monitoring hydrogeologic response in these pumping wells and in 24 observation wells. Golder Associates Innovative Applications (GAIA) carried out the installation of pumps, construction of well-head assemblies, and the connection of generators for this program, which was conducted over the period between July 30 and August 19, 2008.

Figure 7.6-2 shows the two locations (HG-3 and HG-7) of the dewatering wells, installed by Friesen Drilling in February 2008, together with the locations of the 24 observation wells that were installed as nine nested wells (MW-X-1 through MW-X-9).

At each dewatering well location, two pumping wells were completed, one in the limestone unit (HG-X-LS) and one in the sandstone unit (HG-X-SS). Each limestone dewatering well consists of 0.28 m (11-inch) diameter open hole wells, completed to a depth of 58 m (190 ft) in the fractured limestone unit, and cased through the overburden. Each sandstone dewatering well consists of a 0.25 m (10-inch) diameter steel-screened well completed to a depth of 72 m (237 ft) in the sandstone unit and sealed from the water-producing zone of the limestone unit above 57 m (188 ft) depth (Golder Associates, 2008a).

The monitoring wells were installed in each of the four primary stratigraphic units (9 OB wells, 6 SLS wells, 5 LS wells, 2 SS wells, and 2 GR wells). Figure 7.6-3 provides a schematic diagram of the pumping and monitoring well installations into the OB, SLS, LS, SS, and GR stratigraphic units. The distance of the monitoring wells to the pumping wells was approximately 40 m, 80 m, 300 m, and 2,000 m (Golder Associates, 2008b). Table 7.6-1 presents surveyed positions of each pumping and observation well. Detailed well log information is provided in Appendix 7.6.

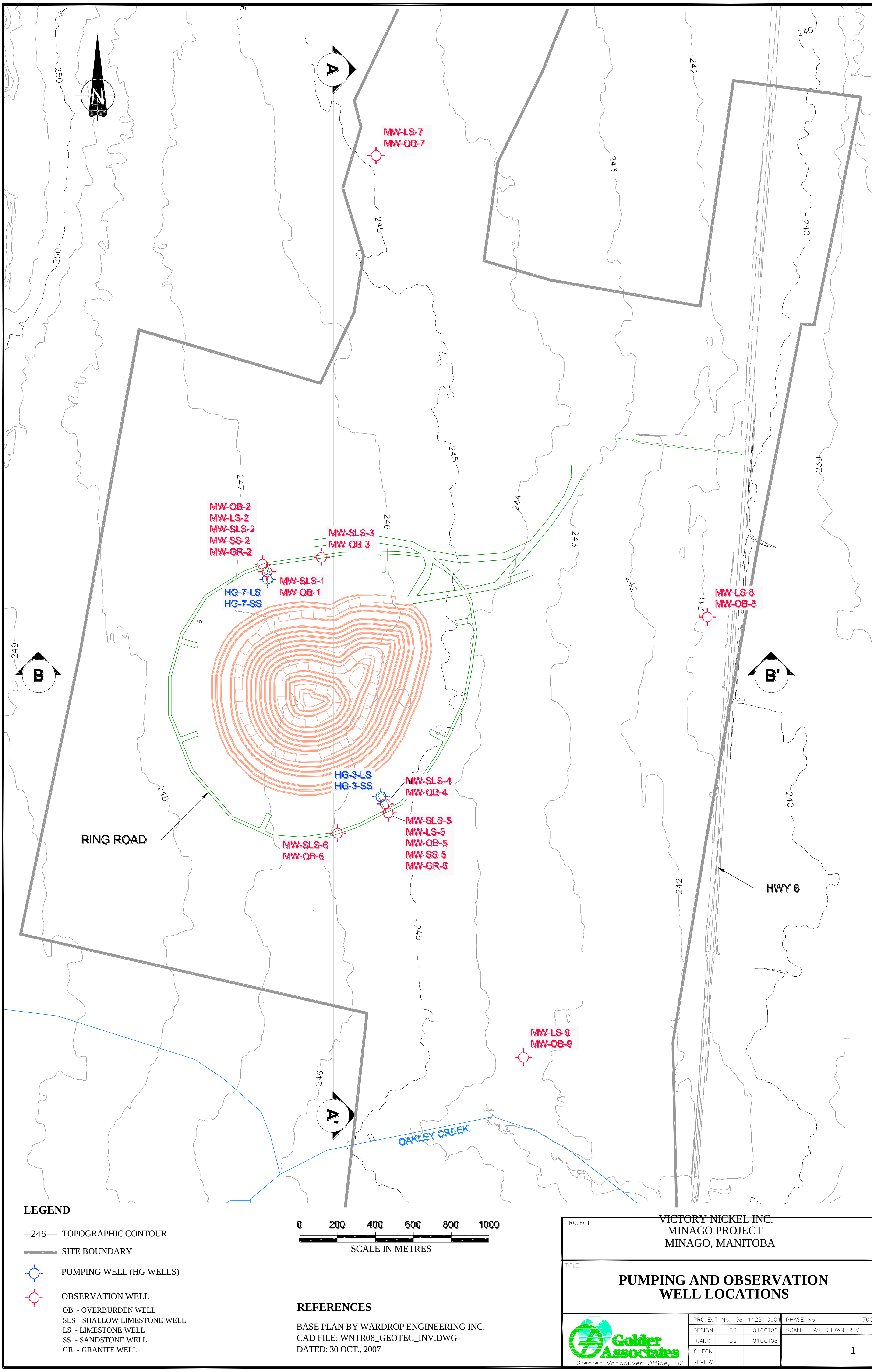
Source: VNI and Golder Associates (2008b)

Figure 7.6-1 Setup for the Groundwater Pump Test

Throughout the pumping program, the groundwater level was recorded at each well location using both manually operated water level metres and pressure transducers equipped with data loggers (Solinst Gold Leveloggers) and direct-read cables. A barologger was also deployed at the Site (i.e., it was placed within the above-ground protective steel casing of observation well MW-SS-5) to collect barometric pressure data throughout the program. This data was used to provide barometric correction to all the data generated by the pressure transducers.

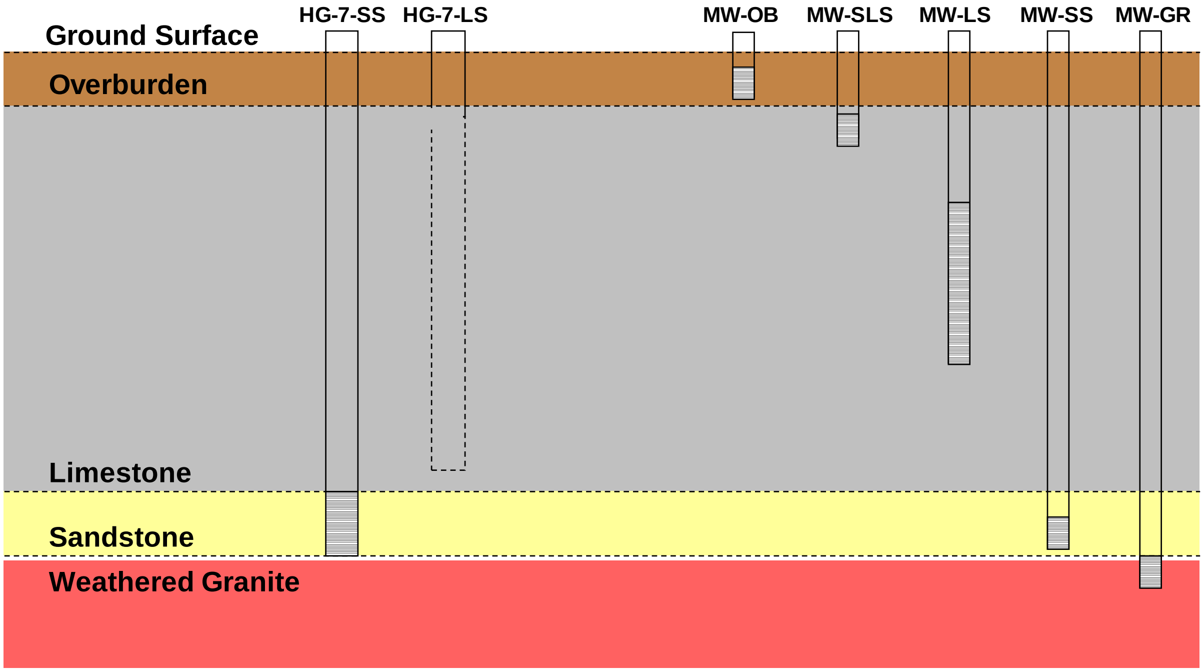
Prior to pumping, water level loggers were installed at all 28 well locations (4 dewatering and 24 monitoring wells) and water levels were recorded for 3 days to establish baseline water levels. This period was followed by a 4-day, individual step-drawdown tests at each pumping well to determine pumping rates for the long-term test of (Golder Associates, 2008b):

- 900 US gpm (204.3 m^3/h) at HG-7-LS;
- 100 US gpm (22.7 m^3/h) at HG-7-SS;
- 300 US gpm (68.1 m^3/h) at HG-3-LS; and,
- 100 US gpm (22.7 m^3/h) at HG-3-SS.



Source: Golder Associates (2008b)

Figure 7.6-2 Pumping and Observation Well Locations



Source: Golder Associates (2008b)

Notes:

HG-7-SS	Pumping Well 7, installed in sandstone (SS)
HG-7-LS	Pumping Well 7, installed in limestone (LS)
MW-OB	Monitoring well, installed in overburden
MW-SLS	Monitoring well, installed in shallow limestone
MW-LS	Monitoring well, installed in limestone
MW-SS	Monitoring well, installed in sandstone
MW-GR	Monitoring well, installed in granite

Figure 7.6-3 Schematic Well Installation Diagram

Table 7.6-1 Groundwater Pumping Test Well Locations

Well Name	NAD'83 UTM NORTH m	ZONE 14 UTM EAST m	Ground ELEV. m.a.s.l.	Top of Well m.a.s.l.	Stickup m
Pumping Wells:					
HG-3 LS	5992847.45	487656.77	245.89	246.89	1.00
HG-3 SS	5992857.95	487658.47	245.98	246.98	1.00
HG-7 LS	5993994.85	487056.57	247.21	248.26	1.05
HG-7 SS	5993984.75	487059.04	247.17	248.22	1.05
Observation Wells:					
MW-OB-1	5994026.08	487057.86	247.35	248.29	0.94
MW-OB-2	5994071.56	487050.07	247.16	248.20	1.04
MW-OB-3	5994103.21	487343.64	246.72	247.60	0.88
MW-OB-4	5992813.12	487681.64	245.71	246.84	1.13
MW-OB-5	5992782.12	487706.24	245.61	247.02	1.41
MW-OB-6	5992660.75	487430.95	246.13	247.33	1.21
MW-OB-7	5996197.10	487635.76	244.89	246.02	1.13
MW-OB-8	5993790.96	489383.37	240.82	241.95	1.13
MW-OB-9	5991490.11	488407.52	243.58	244.56	0.98
MW-SLS-1	5994027.41	487057.94	247.21	248.21	0.99
MW-SLS-2	5994066.57	487051.00	247.17	248.20	1.03
MW-SLS-3	5994103.97	487341.27	246.65	247.55	0.90
MW-SLS-4	5992815.51	487681.22	245.60	246.58	0.98
MW-SLS-5	5992779.40	487703.58	245.53	246.68	1.15
MW-SLS-6	5992663.53	487430.71	246.13	247.23	1.10
MW-LS-2	5994067.23	487038.93	247.22	248.27	1.04
MW-LS-5	5992774.04	487706.88	245.60	246.61	1.01
MW-LS-7	5996198.77	487632.33	244.99	246.64 *	1.64
MW-LS-8	5993791.16	489380.18	240.87	242.90 *	2.04
MW-LS-9	5991493.31	488409.36	243.54	244.91 *	1.38
MW-SS-2	5994070.24	487040.64	247.16	248.33	1.17
MW-SS-5	5992781.61	487699.45	245.67	246.56	0.88
MW-GR-2	5994070.48	487047.49	247.05	248.08	1.03
MW-GR-5	5992770.51	487697.33	245.67	246.64	0.96

Notes:
* Value includes pipe added to the well before the pumping test, due to artesian conditions.
m.a.s.l. - meters above sea level

Source: Golder Associates (2008b)

After the step drawdown test, a 5-day long-term pumping test was conducted in all pumping wells followed by two days of recovery. Thereafter, eight single well response tests were conducted to assess hydraulic parameters of the overburden (6 wells) and granite (2 wells) stratigraphic units.

7.6.2.1 Long-term Pump Test

The pumping test was carried out over the period between August 11 to 18, 2008, and consisted of five days of pumping and two days of recovery. Pumping of the dewatering wells was initiated sequentially, on separate days, such that pumping at HG-7-LS began at the start of Day 1, at HG-3 LS at the start of Day 2, at HG-7-SS on Day 3, and at HG-3-SS on Day 4. On Days 4 and 5, all the wells were pumping simultaneously, at a combined rate of approximately 1,400 USgpm (7,630 m^3/d). At the start of Day-6, all the pumps were turned off and well recovery monitoring occurred over Days 6 and 7.

During the long-term pumping test, the following was monitored:

- water levels every 10 to 30 seconds depending on the monitoring well location;
- pumping rates three times per day using an inline paddlewheel flow gauge (model F-1000 Rate-Totalizer from Blue White Industries). In addition, pumping rates were measured manually on approximately a daily basis using a 205 litre barrel and a stopwatch in order to calibrate the flow gauges and to verify the discharge measurements;
- general groundwater quality (pH, electrical conductivity, and temperature) twice daily for pH, temperature, specific conductance, and oxidation-reduction potential, using a WTW pH/Cond 3400i multi-meter;
- a groundwater sample was collected from each of the four dewatering wells on the fifth day of the long-term pumping test (August 15, 2008). Duplicate samples were taken from HG-7-LS and HG-3-SS for quality assurance/quality control (QA/QC) purposes;
- surface water flowrates at the Oakley Creek station OCW1 (daily) and at four roadside ditch locations several times during the pump test.

The potential for ground subsidence in response to decreased pore pressure in the overburden, was also monitored during the pumping test by assessing the change in vertical distance between two arbitrary reference points on the well heads of the granite observation wells, located approximately 80 m from the nearest dewatering wells. The results of the above monitoring programs are detailed elsewhere (Golder Associates, 2008b).

7.6.2.2 Single-Well Response Tests

Single-well response tests on observation wells were carried out after completion of the long-term pumping test in the form of slug tests. These tests were conducted to estimate the hydraulic properties of the lower permeability units, namely the overburden and the weathered granite. Six overburden observation wells (MW-OB-1, MW-OB-2, MW-OB-4, MW-OB-5, MW-OB-6, and

MW-OB-7) and both granite observation wells (MW-GR-2, and MW-GR-5) were tested (Figure 7.6-2). The test was initiated by rapidly submerging a solid slug of a known volume in the well. The initial water level displacement and the rate in fall of the water level in each well was recorded using both a pressure transducer and a manually-operated water level tape. Following completion of a falling head test, the slug was rapidly removed and the rise in water level in each well was recorded as part of the rising head test. The single-well response tests were conducted on August 18 and 19, 2008.

7.6.3 Pumping Test Program Results

7.6.3.1 Limestone Outcrops and Areas of Groundwater Recharge/Discharge Potential

Limestone outcrops were observed on Site, approximately 2 km northwest of the proposed pit area at a topographic knob, and off-site, approximately 9 km south of the Site at a Highway 6 road cut, and approximately 10 km northeast of the Site in the vicinity of the Minago River (Figure 7.6-4). The upper several metres of the limestone outcrops are weathered and contain planar apertures along horizontal bedding planes at intervals of about 10 cm, as well as numerous vertical joints and fractures. These types of features exist in the aquifer on a regional scale to a depth of about 30 m below ground surface, and provide pathways for much of the flow in the aquifer (Betcher et al., 1995). The limestone outcrop areas are likely recharge areas where precipitation may directly infiltrate the limestone aquifer.

Although the surficial geology map of Matile and Keller (2006) suggests that the streambeds of both the Minago River and Oakley Creek are largely contained within the overburden unit, the Minago riverbed was observed to cut into the limestone aquifer near Highway 6, approximately 10 km north of the Site, as shown on Figure 7.6-4. It is uncertain whether this area is a discharge or recharge area for the limestone aquifer.

Pre-pumping water levels in the limestone unit were above those in the overburden unit at all the well locations except those in the vicinity of HG-7 (including MW-1, MW-2, and MW-3). These conditions, which include flowing artesian wells, indicate that the overburden is an effective aquitard. These conditions create an upward hydraulic gradient across the overburden unit, such that surface water observed on the surficial peat that covers much of the Site likely does not contribute to groundwater recharge under non-pumping conditions.

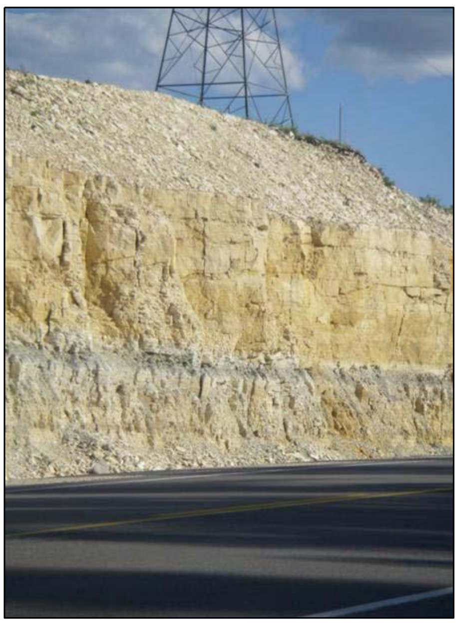
7.6.3.2 Pre-pumping Hydraulic Heads and Groundwater Flow Directions

The pre-pumping hydraulic head distribution in the overburden, limestone, sandstone, and granite units are presented in Appendix 7.6.

Figures 7.6-5 and 7.6-6 present pre-pumping hydrogeologic cross sections oriented north-south (Section A-A') and west-east (Section B-B') through the Site. Section B-B' (Figure 7.6-6) is aligned along the inferred direction of groundwater flow in the limestone and sandstone units. Based on the measurements of the hydraulic head in each well, as shown in Section B-B' (Figure 7.6-6), the inferred direction of groundwater flow in the limestone and sandstone units at the Site

A. Limestone outcrop at a quarry located approximately 12 km north-northeast of the Site.

C. Minago River at the Highway 6 bridge, approximately 12 km north of the Site.



B. Limestone outcrop along Highway 6 road cut, approximately 9 km south of the Site.

D. Flowing artesian conditions at MW-7-LS.

PROJECT: VICTORY NICKEL / MINAGO
MULTI-WELL PUMPING TEST PROGRAM
GRAND RAPIDS, M.B.

TITLE: **LIMESTONE OBSERVATIONS**

Golder Associates

PROJECT No.	08-1428-0001	FILE No.	----
DESIGN	MN	16OCT08	SCALE NTS
CADD			REV.
CHECK	CR		
REVIEW			

REVISION DATE: 16 OCT 08 BY: MN FILE: O:\Active_2008\1428\08-1428-0001 Victory Nickel Inc-Minago Site\Pumping Test Program\Report\Figures\Figures 5+6+11+12+14 Portrait.ppt

Source: Golder Associates (2008b)

Figure 7.6-4 Observation of Limestone and Artesian Conditions

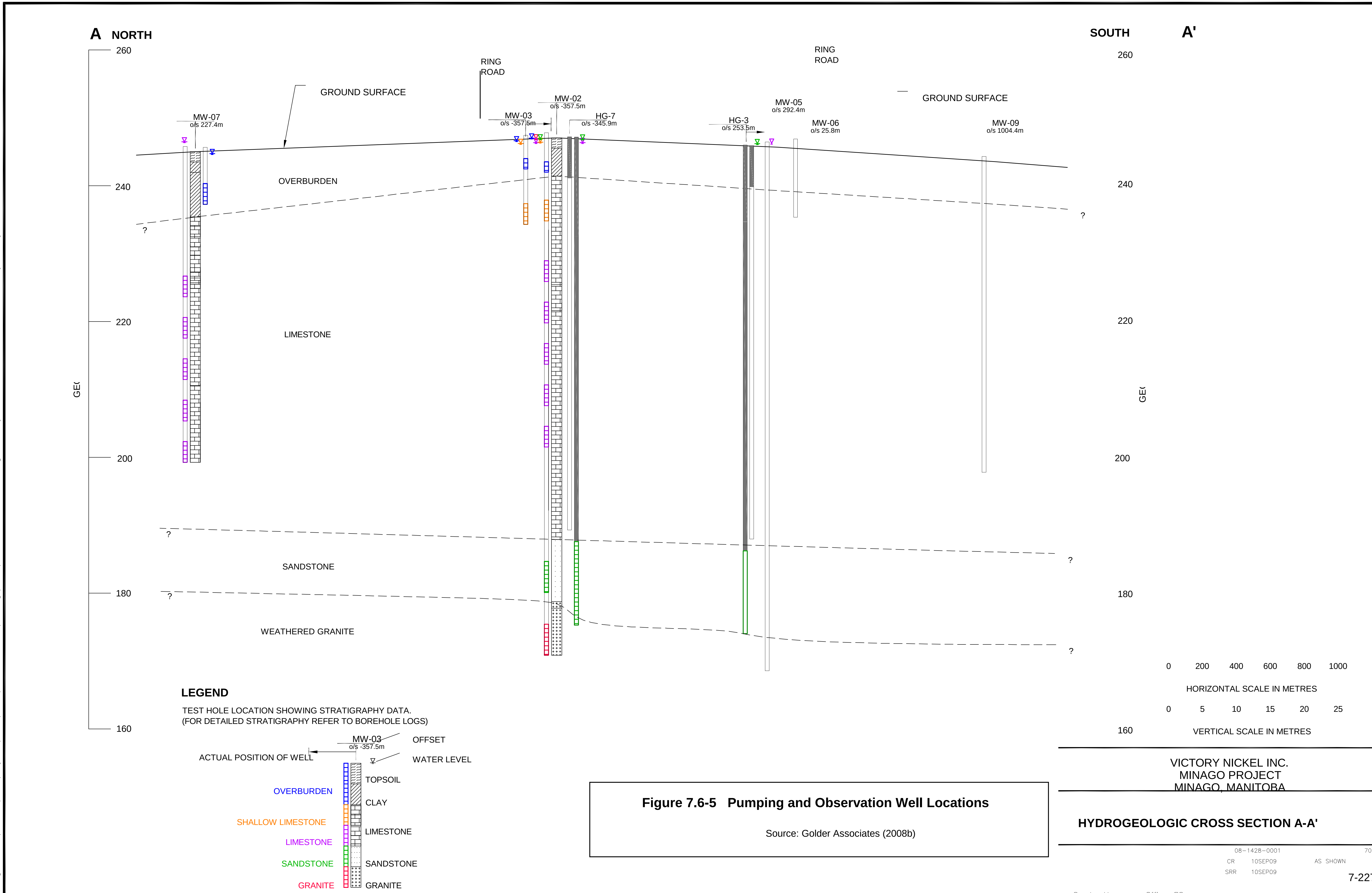


Figure 7.6-5 Pumping and Observation Well Locations

Source: Golder Associates (2008b)

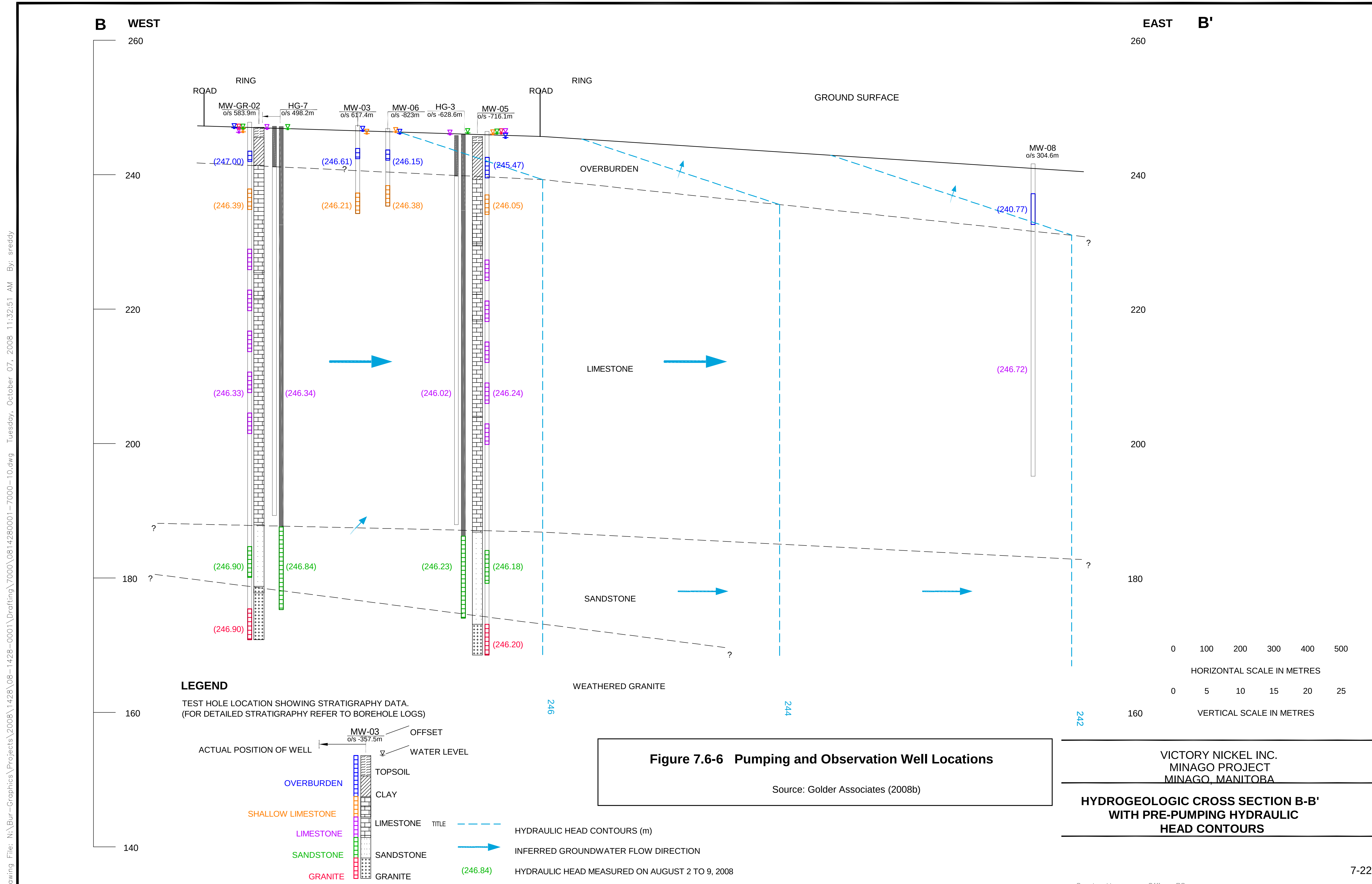


Figure 7.6-6 Pumping and Observation Well Locations

Source: Golder Associates (2008b)

is primarily horizontal (from west to east). A minor component of groundwater flow in the shallow limestone, except in the vicinity of HG-7, is inferred to be directed upward through the overburden, indicating that the ground surface is an area of groundwater discharge over much of the Site. Flowing artesian conditions prevailed at all well locations except those in the vicinity of HG-7 (including MW-1, MW-2, and MW-3). The vertical hydraulic gradient through the overburden prior to pumping was estimated to be between 0.1 and 0.6 over much of the Site, such that flow is predominantly upward through the overburden. In the vicinity of HG-7, however, the vertical gradient was estimated to be between -0.2 and -0.4, such that flow is predominantly downward. The hydraulic head in the limestone is also comparatively lower in the vicinity of HG-7, relative to those directly south, in the vicinity of HG-3. This difference in hydraulic conditions in the limestone in the vicinity of HG-7 suggests the presence of a higher hydraulic conductivity zone within the limestone in this area (Golder Associates, 2008b).

The inferred groundwater flow direction in the limestone unit is from west to east, with a horizontal hydraulic gradient of approximately 0.0018. Although there is an insufficient spacing of sandstone wells to determine the position of hydraulic head contours in the sandstone unit, the inferred direction of groundwater flow in this unit is also from west to east (Golder Associates, 2008b).

Based on the hydraulic head contours in Section B-B' (Figure 7.6-6), the horizontal hydraulic gradient in the sandstone unit is approximately 0.003. A component of groundwater flow in the sandstone unit, in the vicinity of the proposed mine pit area, is directed upward across the sandstone-limestone contact, with an upward hydraulic gradient ranging from 0 to 0.02 (Golder Associates, 2008b).

7.6.3.3 Maximum Drawdown Observed during the Pumping Test

The maximum drawdown was 17.3 m at HG-3-LS, 18.4 m at HG-7-LS, 31.1 m at HG-7-SS and 41.9 m at HG-3-SS (Golder Associates, 2008b). The maximum drawdown observed in each of the four hydrostratigraphic units, as recorded on the fifth day of the pumping test, is listed in Table 7.6-2 and illustrated in Figures 7.6-7 and 7.6-8. The maximum drawdown in the overburden ranged from 0.01 to 0.06 m at the Site, except at MW-OB-1 (located approximately 30 m from HG-7), where the drawdown was 2.4 m. During the pumping test, the ground surface remained saturated, even in the vicinity of MW-OB-1 possibly due to horizontal surface or subsurface flow in the peat (Golder Associates, 2008b).

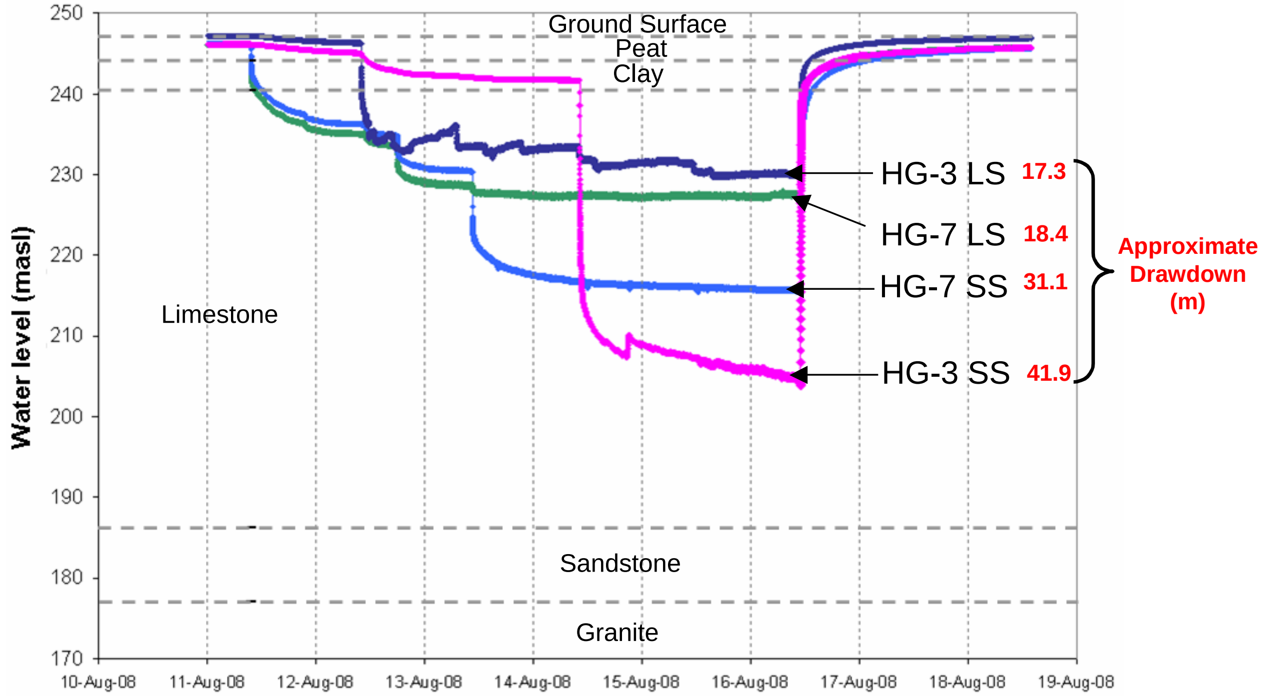
The maximum drawdowns in cross-section are shown in Figures 7.6-9 and 7.6-10. The cross sections indicate that a cone of depression was generated within each of the hydrostratigraphic units. As a result, groundwater flow at the Site was directed towards the dewatering wells, and generally toward the pit area, in all hydrogeological units, during the pumping test. The radius of influence of the pumping test is estimated to have been up to approximately 3 km around the proposed pit area based on these drawdown contours (Golder Associates, 2008b).

Table 7.6-2 Pre-Pumping Water Levels and Maximum Drawdown Levels

Well Name	Pre-pumping Water Level August 2 to 9, 2008			Water Level at Maximum Drawdown August 16, 2008 11:00AM			Drawdown
	m.a.s.l.	mbgs	mbtp	m.a.s.l.	mbgs	mbtp	m
Pumping Wells:							
HG-3-LS	246.02	-0.13	0.87	228.74	17.14	18.14	17.27
HG-3-SS	246.23	-0.25	0.75	204.37	41.60	42.60	41.86
HG-7-LS	246.34	0.87	1.92	227.92	19.29	20.34	18.42
HG-7-SS	246.84	0.33	1.38	215.80	31.38	32.43	31.05
Observation Wells:							
MW-OB-1	246.58	0.77	1.72	244.17	3.18	4.12	2.41
MW-OB-2	247.00	0.16	1.20	246.94	0.22	1.26	0.06
MW-OB-3	246.61	0.11	0.99	246.59	0.13	1.02	0.02
MW-OB-4	245.57	0.14	1.27	245.53	0.18	1.31	0.04
MW-OB-5	245.47	0.14	1.55	245.41	0.20	1.61	0.06
MW-OB-6	246.15	-0.03	1.18	246.14	-0.01	1.19	0.01
MW-OB-7	244.72	0.17	1.30	244.71	0.18	1.31	0.01
MW-OB-8	240.77	0.05	1.18	240.71	0.11	1.24	0.06
MW-OB-9	243.53	0.04	1.03	243.50	0.07	1.06	0.03
MW-SLS-1	246.30	0.91	1.91	237.26	9.95	10.95	9.04
MW-SLS-2	246.39	0.78	1.81	237.10	10.07	11.10	9.29
MW-SLS-3	246.21	0.44	1.34	239.96	6.69	7.59	6.25
MW-SLS-4	245.76	-0.16	0.81	240.98	4.62	5.60	4.78
MW-SLS-5	246.05	-0.52	0.63	242.11	3.41	4.56	3.94
MW-SLS-6	246.38	-0.25	0.85	245.37	0.76	1.86	1.01
MW-LS-2	246.33	0.90	1.94	233.59	13.63	14.68	12.74
MW-LS-5	246.24	-0.65	0.36	232.93	12.67	13.68	13.31
MW-LS-7	246.45	-1.46	0.19	244.90	0.10	1.74	1.55
MW-LS-8	242.72	-1.85	0.18	242.15	-1.28	0.75	0.57
MW-LS-9	244.67	-1.13	0.24	243.39	0.15	1.52	1.28
MW-SS-2	246.90	0.26	1.43	233.81	13.36	14.52	13.09
MW-SS-5	246.18	-0.51	0.38	236.60	9.07	9.95	9.58
MW-GR-2	246.90	0.15	1.18	233.39	13.66	14.69	13.51
MW-GR-5	246.20	-0.52	0.44	236.92	8.75	9.72	9.28

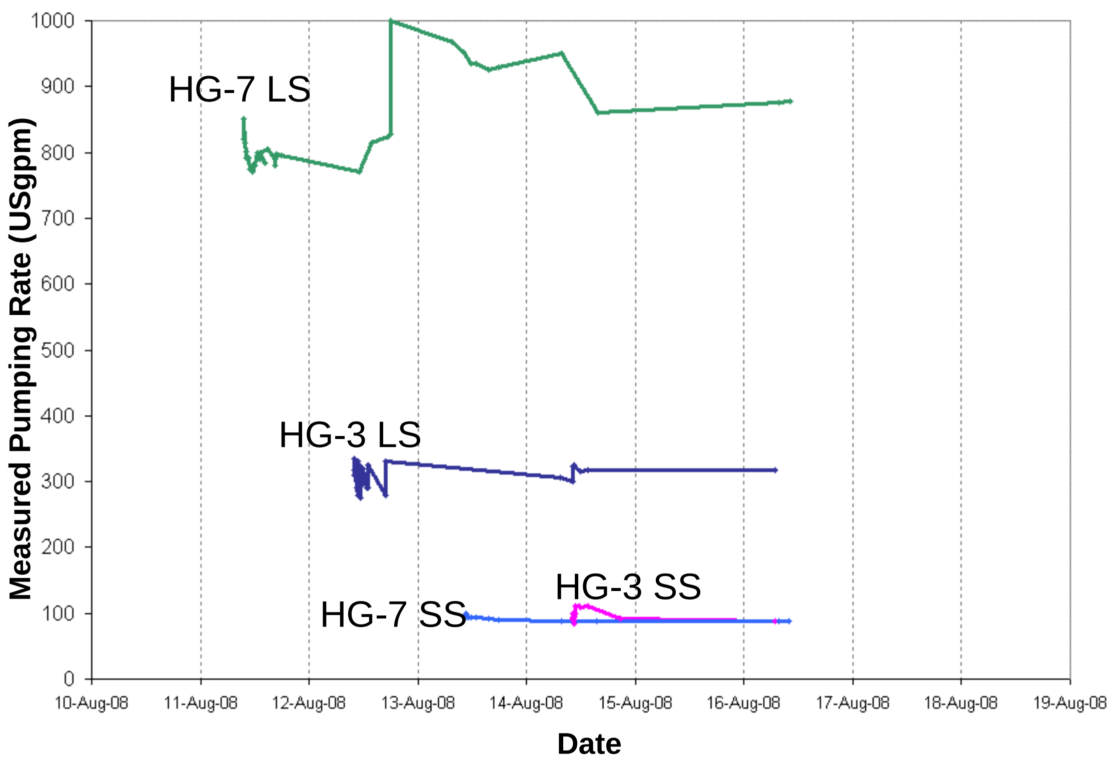
Notes:
m.a.s.l. - meters above sea level
mbgs - meters below ground surface
mbtp - meters below top of pipe

Source: Golder Associates (2008b)



Source: Golder Associates (2008b)

Figure 7.6-7 Water Levels during the August 2008 Pump Test



Source: adapted from (VNI and Golder Associates, 2008b)

Figure 7.6-8 Pumping Rates during the August 2008 Pump Test

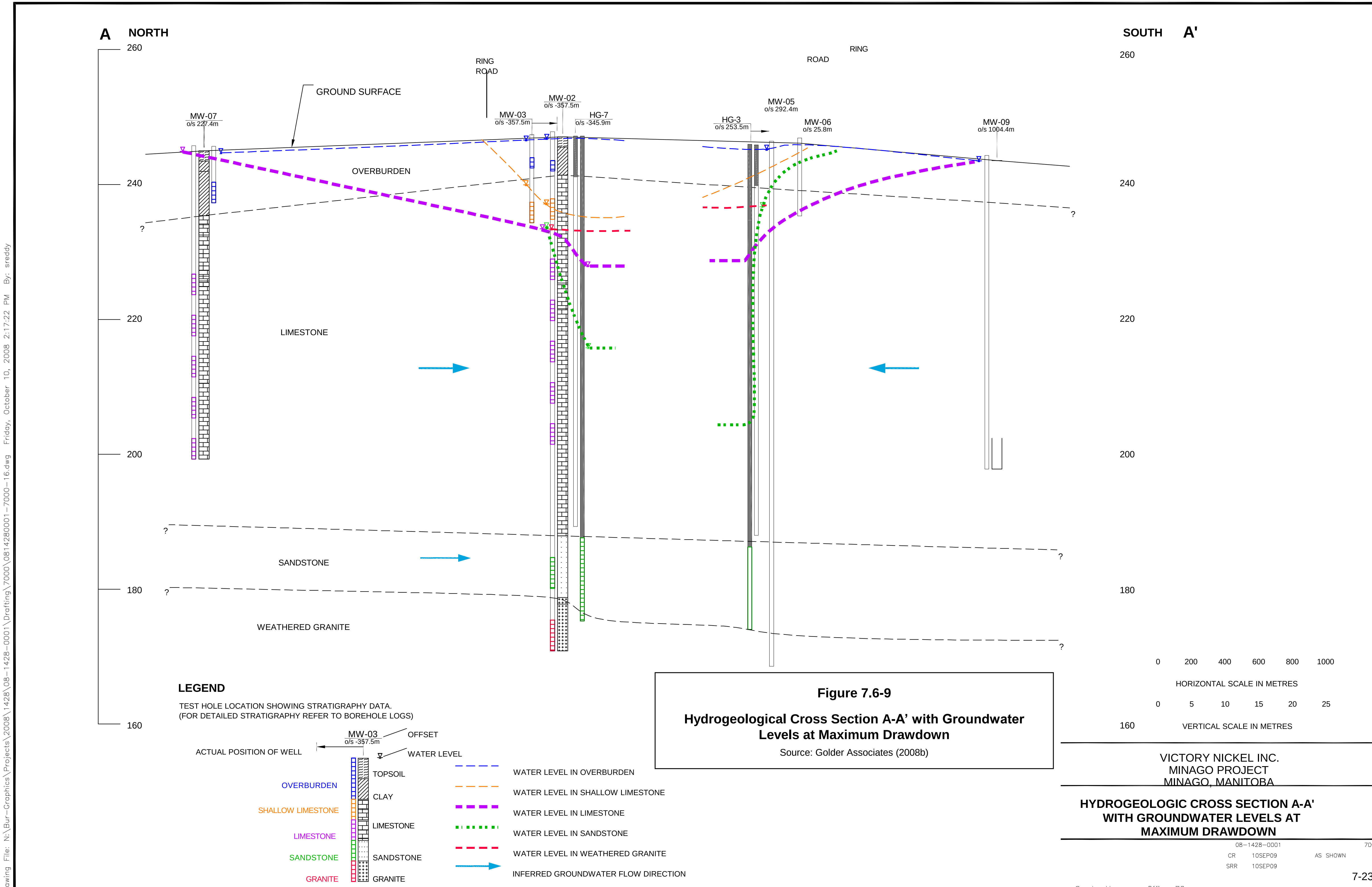
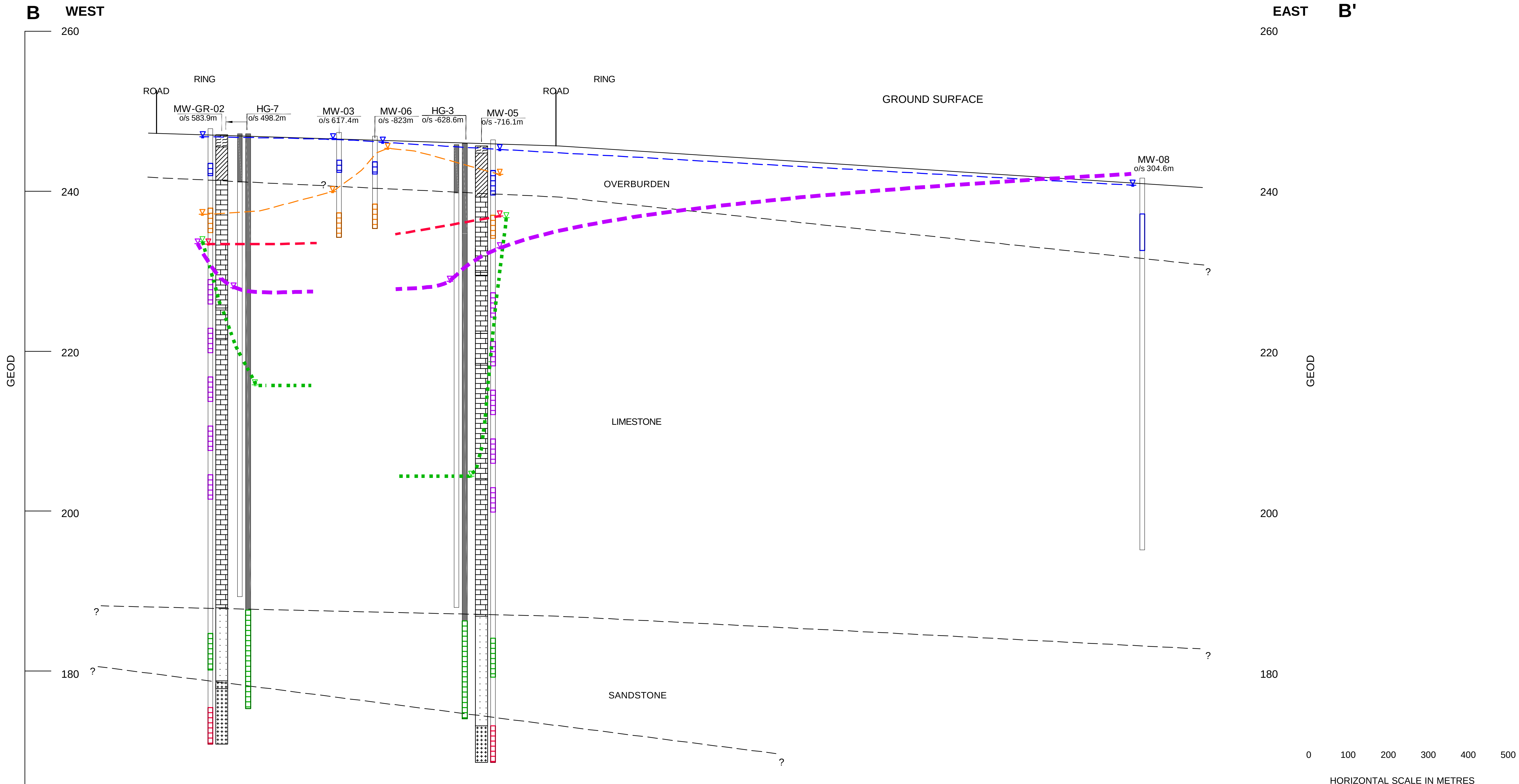


Figure 7.6-9

Hydrogeological Cross Section A-A' with Groundwater Levels at Maximum Drawdown

Source: Golder Associates (2008b)



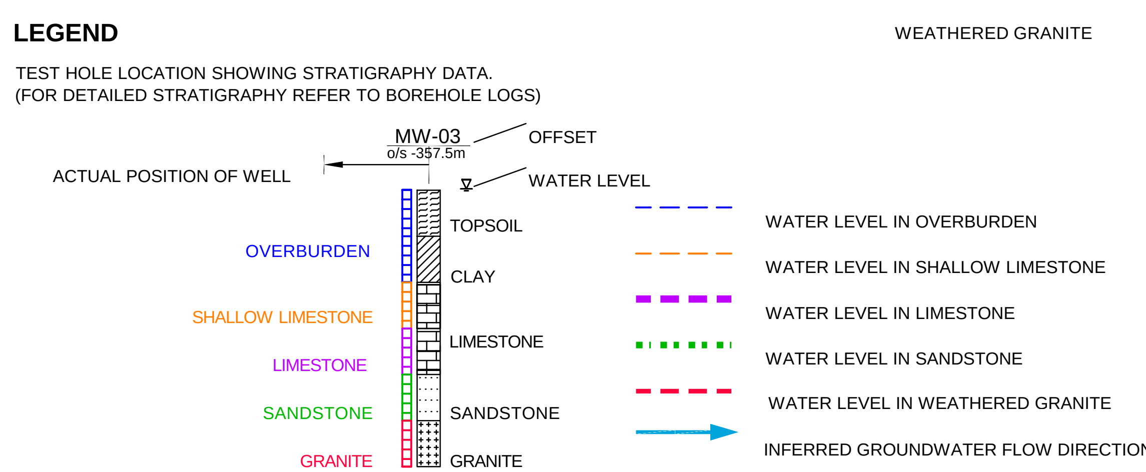


Figure 7.6-10

Hydrogeological Cross Section B-B' with Groundwater Levels at Maximum Drawdown

Source: Golder Associates (2008b)

VICTORY NICKEL INC.
MINAGO PROJECT
MINAGO, MANITOBA

HYDROGEOLOGIC CROSS SECTION B-B' WITH GROUNDWATER LEVELS AT MAXIMUM DRAWDOWN

Greater Vancouver Office, BC

Drawing File: N:\Bur-Graphics\Projects\2008\1428\08-1428-0001\Drafting\7000\0814280001-7000-17.dwg Friday, October 10, 2008 2:19:49 PM By: sreddy

7.6.3.4 Wide Area Analysis (Analysis of Steady-State Conditions)

The Copper and Jacob (1946) distance-drawdown method was selected as the primary method to analyze the pumping test data for the limestone aquifer because it provided wide-area estimates of the aquifer parameters useful for application to the groundwater flow model. Figures 7.6-11 and 7.6-12 present the results of the distance-drawdown analysis, which was carried out separately for each limestone dewatering well (HG-7-LS and HG-3-LS) and was based on the drawdown observed in the limestone wells at a time of 4.6 days after the start of the pumping test (i.e., at approximately the end of pumping). The drawdown observed at this time was considered representative of "late-time" data that is generally applicable to steady-state solutions such as the distance-drawdown method. As the drawdown in the shallow limestone (SLS) wells was generally less than the drawdown in the deeper limestone (LS) wells, separate straight-line analyses were conducted for the shallow and the deeper limestone units.

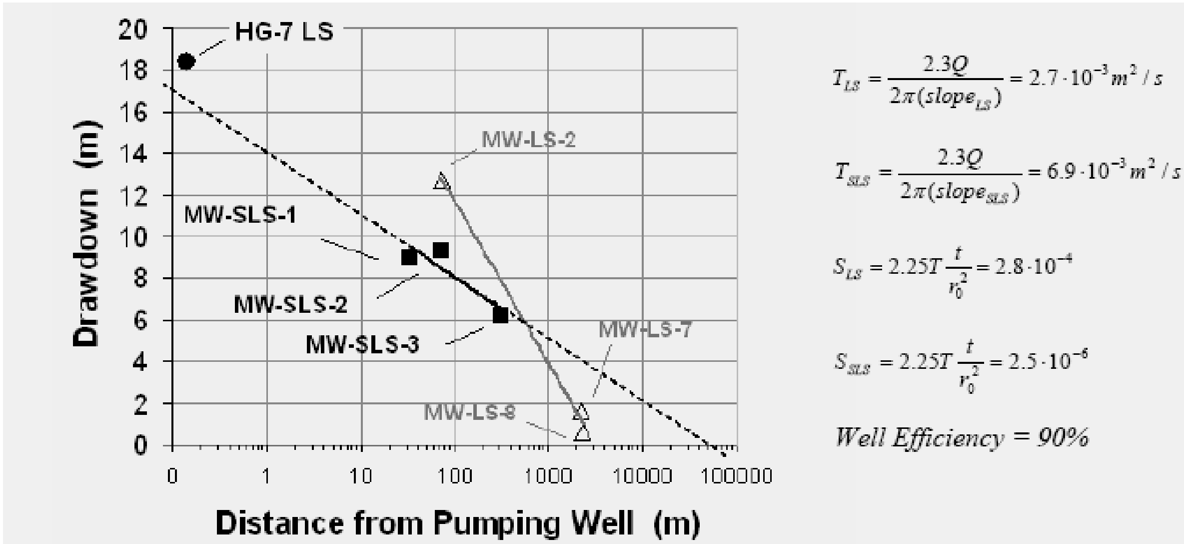
Table 7.6-3 summarizes the results of the distance-drawdown analysis for transmissivity and storativity of the limestone. The region around HG-7 is referred to as the North Pit Wall (NPW) zone and the region around HG-3 is referred to as the South Pit Wall (SPW) zone. Transmissivity at the North Pit Wall is estimated to be 6.9×10^{-3} m^2/s in the shallow limestone unit (T_{SLS}) and 2.7×10^{-3} m^2/s in the limestone unit (T_{LS}). Transmissivity at the South Pit Wall is estimated to be 1.8×10^{-3} m^2/s in the shallow limestone unit (T_{SLS}) and 8.7×10^{-4} m^2/s in the limestone unit (T_{LS}). Storativity estimates range from 2.5×10^{-6} to 4.5×10^{-3} (Golder Associates, 2008b).

Well efficiency, which quantifies the variation between the water level in the well and the water level in the formation adjacent to the well, is estimated to be 90% at HG-7-LS and 93% at HG-3-LS. A well efficiency greater than 90% is considered to be an indication of a good well construction. As the limestone dewatering wells are open hole wells, these high efficiencies were generally expected.

7.6.3.5 Detailed Analyses (Analyses of Transient Conditions)

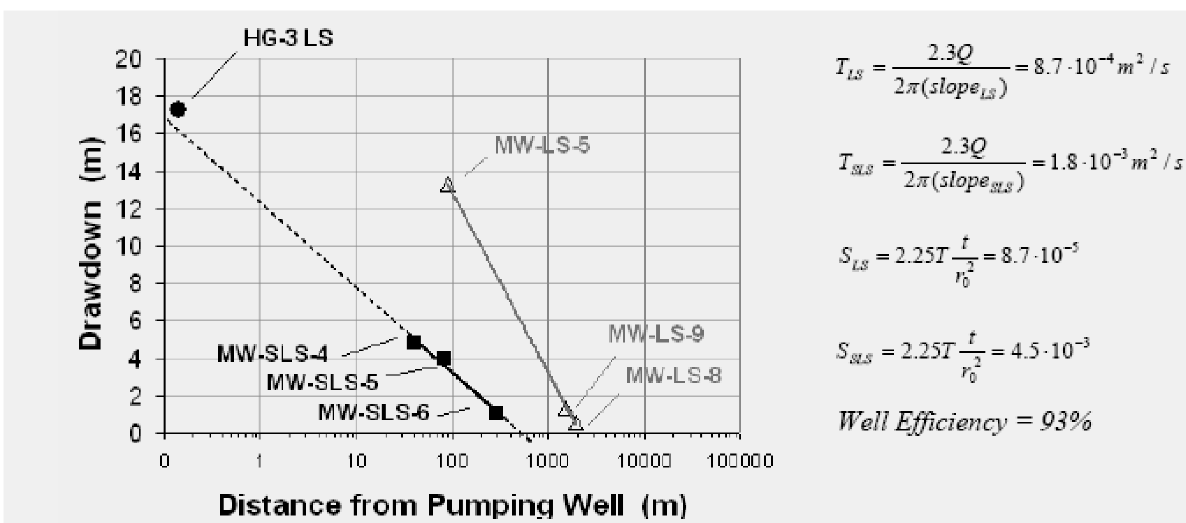
Groundwater flow to the dewatering wells at the Site during the pumping test caused water levels in the limestone aquifer to decline in a nonlinear fashion over time. As such, the time-varying drawdown data generated by the pumping test were also used to estimate the hydraulic properties of the limestone aquifer based on analytical solutions for non-steady flow to the pumping wells. The results of these analyses, presented in Table 7.3.6.5, generally support the distance-drawdown results presented above and also provide additional information regarding conditions in the aquifer and additional aquifer parameters of interest, such as specific yield (Golder Associates, 2008b).

The results listed in Table 7.3.6.5 from Butler's (1988) solution indicate that a region of high transmissivity (T) exists within approximately 350 m of HG-7 (i.e., North Pit Wall zone). This analysis accounted for pumping at all four dewatering wells by solving the groundwater flow equation at several time intervals during the pumping test and applying the principle of superposition. The associated transmissivity estimates from the Butler solution for the North Pit Wall zone (T_{SLS}: 1.4×10^{-2} m^2/s and T_{LS}: 7.5×10^{-3} m^2/s) are 2 to 3 times greater than those



Source: Golder Associates (2008b)

Figure 7.6-11 Distance-Drawdown Analysis for HG-7 LS



Source: Golder Associates (2008b)

Figure 7.6-12 Distance-Drawdown Analysis for HG-3 LS

Table 7.6-3 Distance-Drawdown Analysis

Zone	Hydrogeologic Unit	COOPER-JACOB DISTANCE DRAWDOWN METHOD Radius of Influence (r_0) km	Pumping Rate (Q) m^3/s	Slope (s/log cycle) m/m	Elapsed Time (t) s	Transmiss-ivity (T) m^2/s	Storativity (S)	Actual Drawdown m	Theoretical Drawdown m	Approximate Well Efficiency
North Pit Wall (HG-7 LS)	LS	3	0.06	8.0	4.0E+05	**2.7E-03**	2.8E-04	18.42	24.0	*
	SLS	50	0.06	3.2	4.0E+05	**6.9E-03**	2.5E-06	18.42	16.6	90%
South Pit Wall (HG-3 LS)	LS	2.4	0.022	9.3	4.0E+05	**8.7E-04**	8.7E-05	17.27	18.0	*
	SLS	0.5	0.022	4.5	4.0E+05	**1.8E-03**	4.5E-03	17.27	16.0	93%

Notes:

* Measurements not used in the calculation of well efficiency.

Source: Golder Associates (2008b)

Table 7.6-4 Summary of Other Pumping Test Analyses

Zone	Hydrogeologic Unit	BUTLER (1988) SOLUTION Transmiss-ivity (T) m²/s	Storativity (S) -	Radial Limits from HG-7 (R) m	THEIS (1935) SOLUTION Transmiss-ivity (T) m²/s	Storativity (S) -	MOENCH AND PRICKETT (1972) Specific Yield (Sy) -
North Pit Wall (HG-7 LS)	LS	7.5E-03	9.0E-05				0.02
	SLS	1.4E-02	1.8E-04	<350			0.01
South Pit Wall (HG-3 LS)	LS				1.3E-03	1.5E-04	
	SLS	(2.0E-3) [a]	(2.0E-4) [a]	>350	2.5E-03	3.6E-03	0.02
> 2km North and South of Pit Area (LS-7 and LS-9)	LS	4.0E-03	2.7E-04	>350			
> 2 km East of Pit Area (LS-8)	LS	5.6E-03	1.0E-03	>350			

Notes:

a. These results are inferred to be applicable to the South Pit Wall zone but are based on analysis of data from the North Pit Wall zone which include an evaluation of limestone heterogeneity at a radial distance of 350 m from the North Pit Wall area.

References:

Butler, J.J., Jr., 1988. Pumping tests in nonuniform aquifers—the radially symmetric case, Journal of Hydrology, vol. 101, pp. 15-30.

Moench, A.F. and T.A. Prickett, 1972. Radial flow in an infinite aquifer undergoing conversion from artesian to water-table conditions, Water Resources Research, vol. 8, no. 2,

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans. Vol. 16, pp. 519-524.

Source: Golder Associates (2008b)

estimated using the distance-drawdown method presented previously. However, the storativity of the shallow limestone for the North Pit Wall zone is almost an order of magnitude greater than that estimated using the distance-drawdown method. In the region extending beyond 350 m from HG-7 (i.e. including the South Pit Wall zone), the estimated transmissivity of the limestone based on the Butler solution (2.0×10^{-3} m^2/s) is similar to the range estimated using the distance-drawdown method. In the regions extending more than 2 km from HG-7 to the north and west, and more than 3 km from HG-7 to the south, the estimated transmissivity of the deeper limestone (4.0×10^{-3} m^2/s to 5.6×10^{-3} m^2/s) is within the range estimated for the near-pit zone (2.0×10^{-3} m^2/s near South Pit Wall to 7.5×10^{-3} m^2/s at the North Pit Wall) based on the Butler solution (Golder Associates, 2008b).

To check the quality of the distance-drawdown results for the South Pit Wall zone presented previously, the Theis (1935) solution was used to estimate the hydraulic properties of the South Pit Wall zone. To enable this analysis, the drawdown data for the South Pit Wall zone was corrected for well interference from HG-7-LS (North Pit Wall Area) and the 1-day delay in the start of pumping at HG-3-LS during the pumping test. The Theis analysis accounted for pumping from both the limestone and sandstone dewatering wells by applying the principal of superposition. The associated transmissivity estimates based on the Theis solution (T_{SLS}: 2.5×10^{-3} m^2/s and T_{LS}: 1.3×10^{-3} m^2/s) are approximately 1.5 times greater than those estimated using the distance-drawdown method presented previously (Golder Associates, 2008b).

7.6.3.6 Heterogeneity of the Limestone

Golder Associates (2008b) approximated the heterogeneity of the limestone aquifer by the following ratios in transmissivity (T) based on the analyses of both steady-state and the transient responses to the pumping test:

North Pit Wall versus South Pit Wall:

- T_{SLS} at North Pit Wall > T_{SLS} at South Pit Wall by a factor of: 4
- T_{LS} at North Pit Wall > T_{LS} at South Pit Wall by a factor of: 3

Shallow Limestone versus Deep Limestone:

- T_{SLS} at North Pit Wall > T_{LS} at North Pit Wall by a factor of: 2
- T_{SLS} at South Pit Wall > T_{LS} at South Pit Wall by a factor of: 2

Neat Pit versus Far Pit (Deep Limestone):

- T_{LS} approx. 2 km from pit > T_{LS} at South Pit Wall by a factor of: 3
- T_{LS} at North Pit Wall > T_{LS} approx. 2 km from pit by a factor of: 2

7.6.3.7 Area Impacted by Pumping During the Pumping Test

Based on the distance-drawdown analysis, the radius of influence of the pumping test in the deeper limestone is estimated to have been 3 km around HG-7-LS and 2.4 km around HG-3-LS (Golder Associates, 2008b).

7.6.3.8 Conversion to Unsaturated Conditions in the Shallow Limestone

During the pumping test, the water level dropped below the top of the limestone in the region within 75 to 300 m of HG-7 and the region within 40 m of HG-3. The Moench and Prickett (1972) method was used to assess the unconfined storage properties of the limestone aquifer for wells completed within these regions. The Moench and Prickett (1972) method solves the groundwater flow equation analytically, for flow to a pumping well in a confined aquifer that undergoes a conversion to unconfined conditions. The specific yield (S_y) of the shallow limestone unit was estimated to be between 0.01 and 0.02, as shown on Table 7.6-4. This estimate lies within the typical range of S_y for limestone, which has been reported to range from 0.005 to 0.05 (ASCE, 1996). It should be noted that this analysis yielded results for T and S for the limestone that are considered less accurate than the values reported above. This caveat is based on the assessment that the response of the aquifer to pumping was dominated by the zone of high transmissivity near HG-7, rather than the conversion to unsaturated conditions in the shallow limestone unit (Golder Associates, 2008b).

7.6.3.9 Assessment of Vertical Hydraulic Conductivity for the Overburden

The Hantush-Jacob (1995) steady state solution for leaky aquifers was used to estimate the vertical hydraulic conductivity of the overburden clay (i.e. the overlying aquitard), from the measurements of drawdown made during the pumping test. Based on the results from the overburden wells situated at least two kilometres from the pumping wells (MW7-OB, MW8-OB and MW9-OB), the vertical hydraulic conductivity (K_V) of the overburden was estimated to range from 4×10^{-9} m/s to 6×10^{-9} m/s (Golder Associates, 2008b).

7.6.3.10 Analysis of Single-Well Response Tests

Based on the single-well response tests, the horizontal hydraulic conductivity estimates for the overburden aquitard ranged from 6×10^{-6} m/s to 6×10^{-9} m/s, with a geometric mean of 4×10^{-8} m/s. This mean is one order of magnitude greater than the mean vertical hydraulic conductivity estimate for the overburden based on the pumping test analyses ($K_V = 5\times10^{-9}$ m/s), indicating an anisotropy ratio (K_H/K_V) of 10 for the overburden aquitard (Golder Associates, 2008b).

The horizontal conductivity for weathered granite was estimated to be 4×10^{-7} m/s on the north side of the proposed pit area (MW-2-GR) and 4×10^{-9} m/s on the south side of the proposed pit area. The geometric mean of these results is 4×10^{-8} m/s (Golder Associates, 2008b).

7.6.3.11 Assessment of Pre-Pumping Vertical Flow through the Overburden

Using Darcy's Law for flow through porous media (groundwater flux (q) = hydraulic conductivity (K) × hydraulic gradient ($\partial h/\partial z$)) and the estimates of hydraulic gradient and K_V presented above, the vertical flux through the overburden prior to pumping was estimated to have been (Golder Associates, 2008b):

- North Pit Wall Area: q = downward 1×10^{-9} m/s (40 mm/yr);
- South Pit Wall Area: q = upward 8×10^{-10} m/s (10 mm/yr); and,
- About 2 km from Pit: q = upward 2×10^{-9} m/s (60 mm/yr).

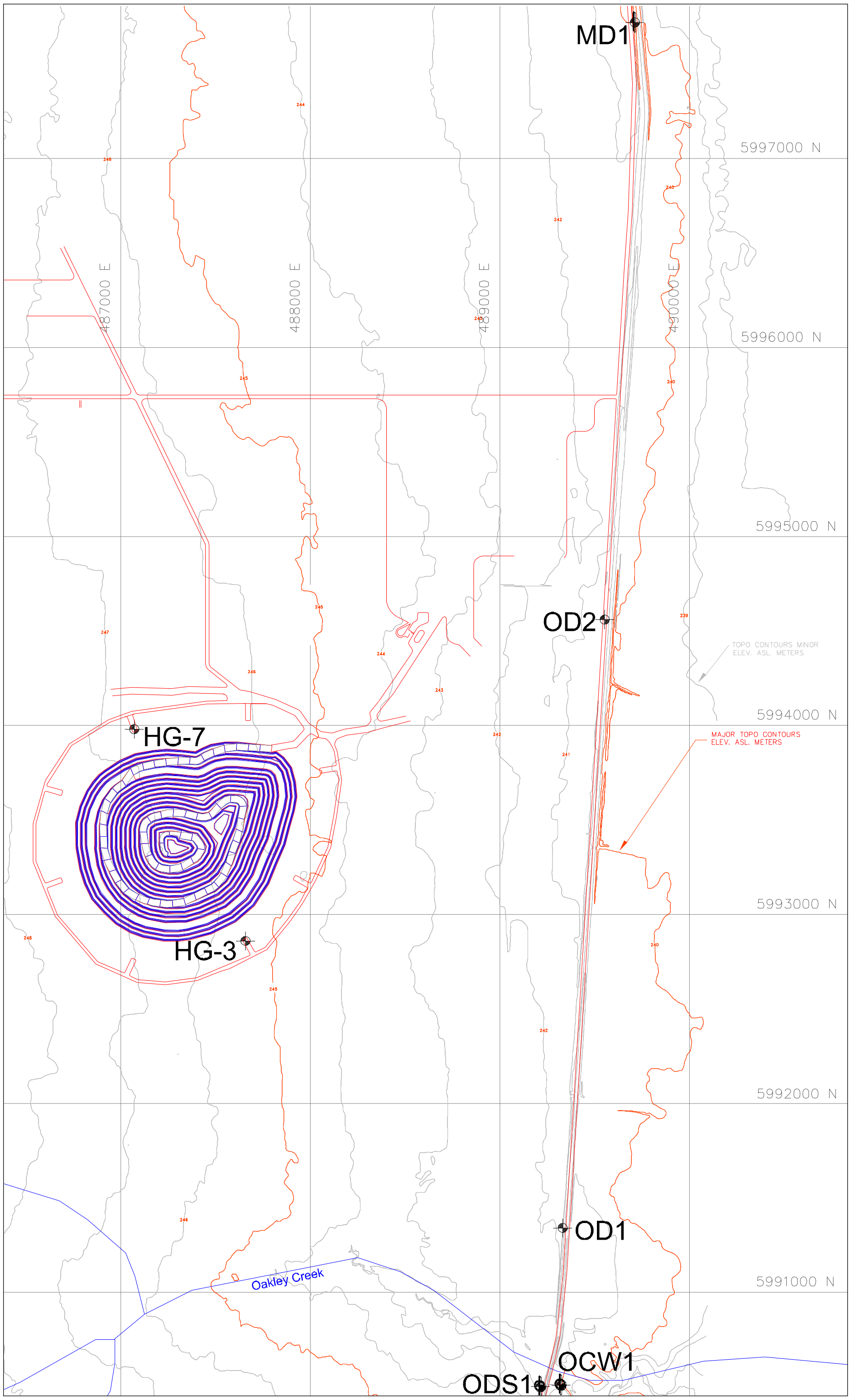
7.6.3.12 Effects of the Groundwater Pump Test on Surface Water

To determine whether the groundwater pumping test program had an efffect on the surface water, streamflow and water quality measurements were conducted at three locations (OD1, OD2, and MD1) in the roadside ditch closest to the dewatering wells, at Oakley Creek station OCW1, and at one location south and upstream of Oakley Creek (ODS1) (Table 7.6-5 and Figure 7.6-13). The groundwater pump test was conducted at HG-3 (wells HG-3 LS and HG-3 SS) and at HG-7 (wells HG-7 LS and HG-7 SS) in a sub-watershed north of Oakley Creek (Figure 7.6-13). Water quality was also assessed in William River at WRW1x, just downstream of the confluence of Oakley Creek with William River.

Station ODS1 served as a reference station, as it receives drainage from a southern sub-watershed of Oakley Creek, which was completely unaffected by the groundwater pump test, but subject to the same local precipitation. Surface water from OD1, OD2, and ODS1 drains into Oakley Creek whereas surface water from MD1 drains into Minago River.

Table 7.6-5 Coordinates of the Surface Water Monitoring Locations during the August 2008 Groundwater Pump Test

Sampling Location	GPS Coordinates (14 U NAD 83)		Location Description
	Northing (m)	Easting (m)	
OCW1	N 5990510	E 489322	Oakley Creek just east of Highway 6
ODS1	N 5990502	E 489214	Southwestern roadside ditch draining into Oakley Creek on western side of Highway 6
OD2	N 5994560	E 489553	Western roadside ditch near the Minago entrance
OD1	N 5991341	E 489332	Northwestern roadside ditch draining into Oakley Creek
MD1	N 5997719	E 489712	Roadside ditch draining into Minago River near the northern property boundary on western side of Highway 6



Source: Golder Assoicates, 2008b

Figure 7.6-13 Surface Water Monitoring Locations during the August 2008 Groundwater Pump Test Program

Discharge measurement stations were established at each monitoring site. Anchors were established on the right and left banks at each discharge measurement station, such that a tag line could be stretched between the anchors that was perpendicular to the current. Discharge was measured according to U.S. Geological Survey (USGS) standard procedures (Buchanan and Somers, 1969) with a SonTek Flow Tracker® current meter. The SonTek Flow Tracker® current meter measures velocities ranging from 0.001 m/s (0.003 ft/s) to 4.5 m/s (15 ft/s). The current meter was suspended from a wadding rod. The discharge (instantaneous streamflow) was calculated from the velocity, depth, and width measurements in the same manner as detailed in the Hydrology Section (Section 7.4).

Staff gages, installed on either the right or the left edge of the channel, were used to monitor water surface elevations and Hobo Water Level Loggers (U20-001-04; 0-4 m) were installed at every station.

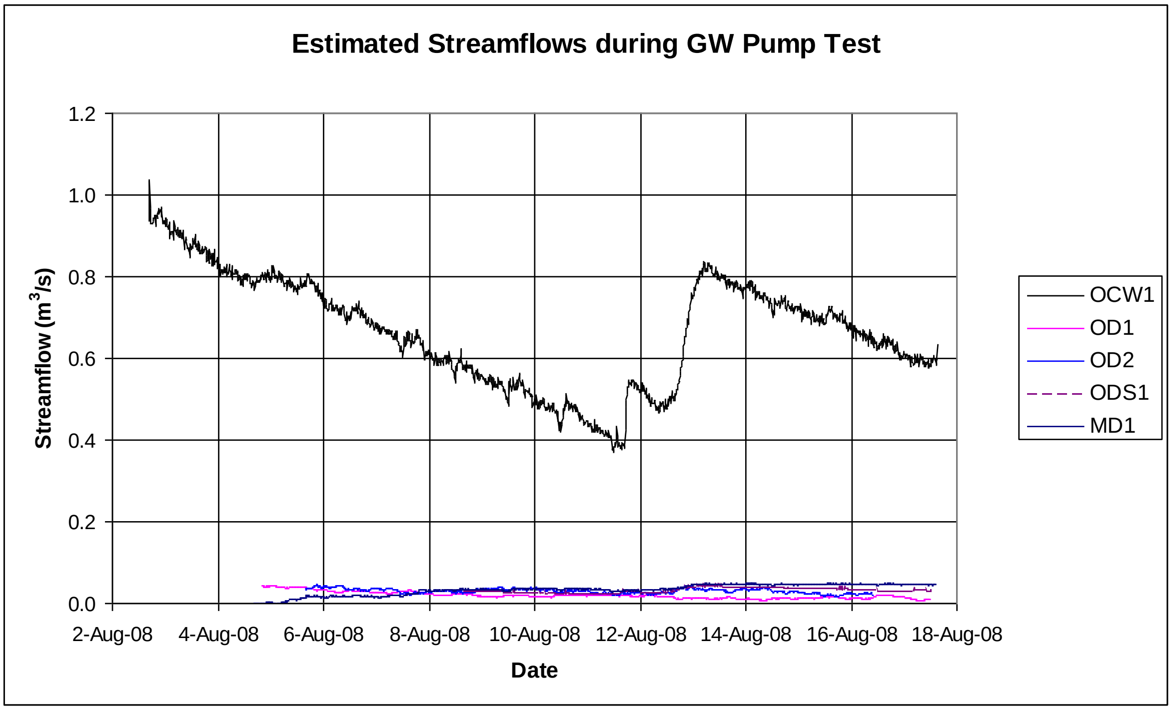
Results of the streamflow measurements are illustrated in Figure 7.6-14a for OCW1, OD1, OD2, ODS1, and MD1 and in Figure 7.6-14b for ODS1. These flow measurements are based on the water level logger measurements that were calibrated with manual flow and water elevation measurements. Details of manual flow and water elevation measurements for these streamflow measurements are provided in Appendix 7.6.

Streamflows at OCW1 were dominant. The minimum streamflow at OCW1 was 0.37 m^3/s compared to a maximum streamflow of 0.05 m^3/s recorded at any of the other surface water monitoring stations. Streamflow increases at OCW1 were likely primarily due to precipitation rather than the groundwater pump test, as the shape of the streamflow-time curve at OCW1 and ODS1 were very similar in terms of periodicity of streamflow peaks and valleys. The difference between the two streamflow-time profiles was that the streamflow at OCW1 was approximately 10 times the streamflow at ODS1 and that the streamflow peaks and valleys occurred approximately 45 minutes to 1.5 hours earlier at the upstream station ODS1 compared to the downstream station OCW1.

Figure 7.6-15 illustrates streamflows recorded at the roadside ditch surface water monitoring locations OD1, OD2 and MD1 and Figure 7.6-16 illustrates the groundwater pumping rates used during the August 2008 pump test. By comparison of those two Figures, it may be inferred that the only station that might have been slightly affected by the groundwater pump test is MD1 as its streamflow rate remained relatively constant throughout the pump test whereas the streamflows at the other stations tended to drop off after the precipitation event on August 12-13, 2008 had passed.

Surface water quality was assessed with a multiparameter YSI 600 QS Instrument. Surface water quality results are summarized in Table 7.6-6 for the stations OCW1, OD1, OD2, ODS1, and MD1. The vast majority of the water quality parameters was relatively constant. The coefficient of variation (mean divided by standard deviation) was only greater than 15% for dissolved oxygen (DO), the Oxidation-Reduction Potential (ORP), and depth. The measurement depth varied likely to different operators taking measurements. Although the measurement depth varied for the recorded water quality measurements, no correlation was found between depth and the other parameters for the data recorded.

(a)



(b)

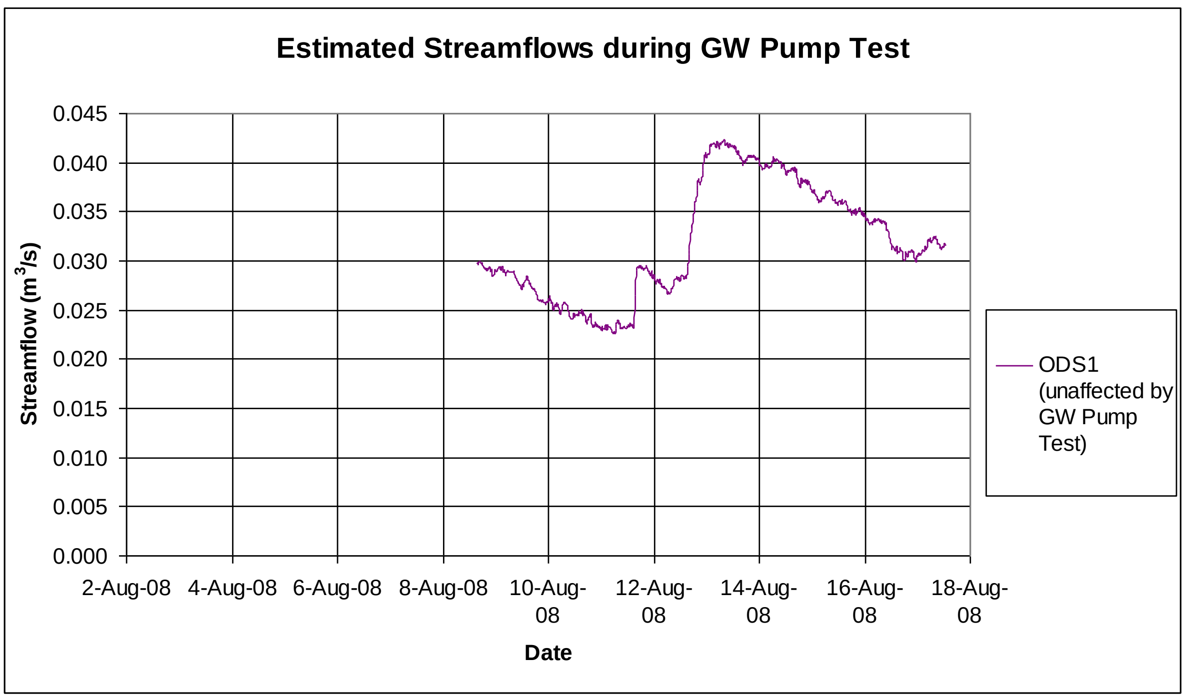


Figure 7.6-14 August 2008 Streamflows recorded at OCW1, OD1, OD2, ODS1, and MD1

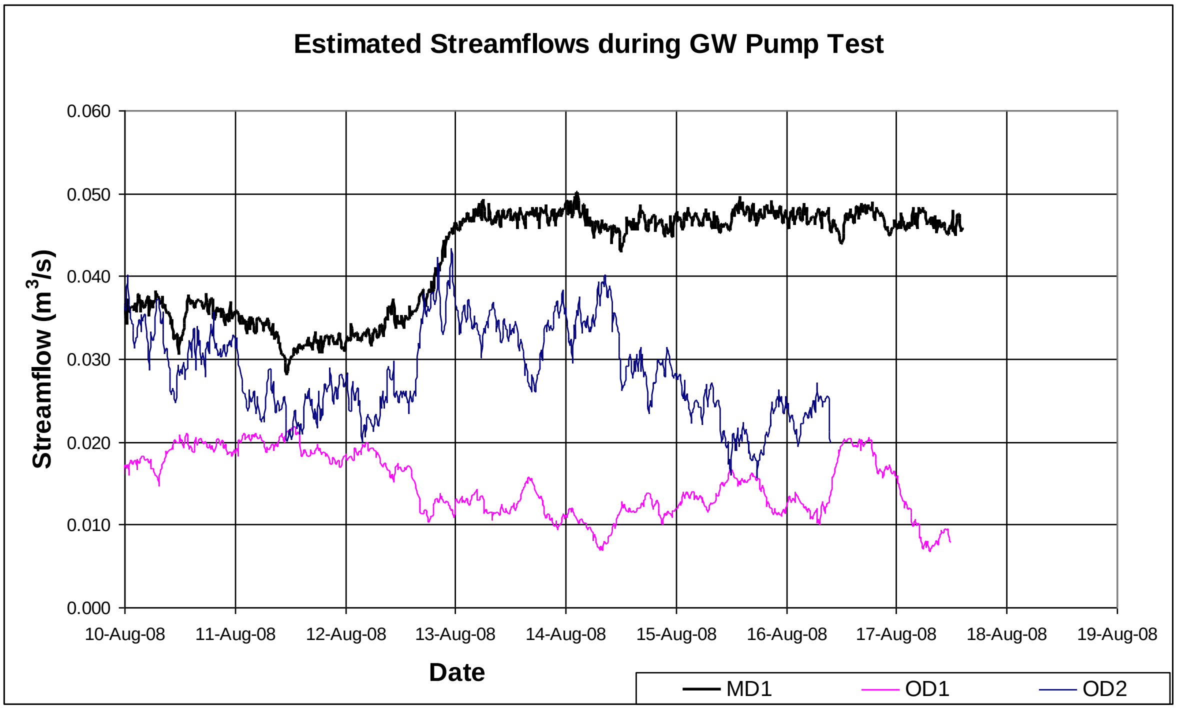
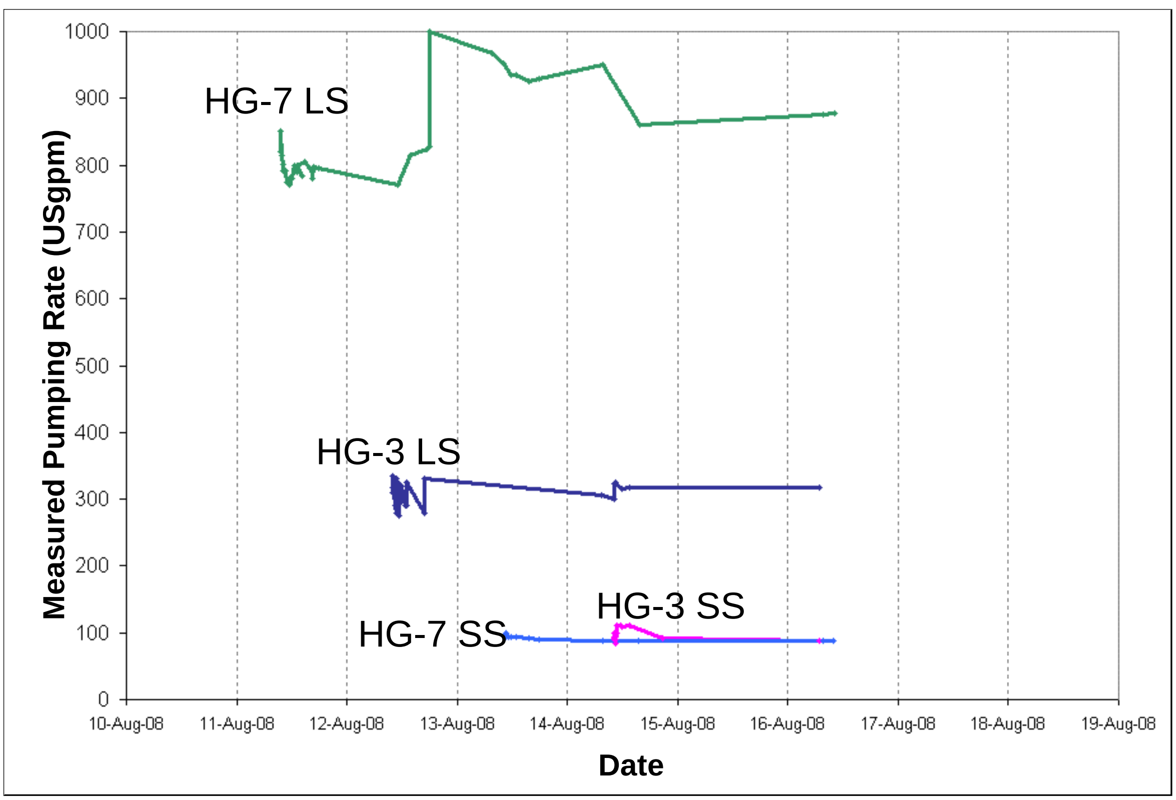


Figure 7.6-15 August 2008 Streamflows recorded at MD1, OD1, and OD2



Source: adapted from VNI and Golder Associates, 2008

Figure 7.6-16 August 2008 Groundwater Pumping Rates

Table 7.6-6 Surface Water Quality measured during the Aug-2008 Pump Test

Sampling Location	Sampling Station	Date	Temperature (°C)	Specific Conductivity (EC1) (uS/cm)	Conductivity (EC2) (uS/cm)	Total Dissolved Solids (g/L)	DO% (%)	DO Concentration (mg/L)	Depth (m)	pH	ORP (mV)	Barometric Pressure (psi)
Oakley Creek immediately east of Highway 6	**OCW1**	04-Aug-08	17.92	308	266	0.200	99.5	9.43	0.046	7.93	222	14.21
	OCW1	09-Aug-08	17.64	329	283	0.214	86.7	8.27	0.023	7.92	194	14.35
	OCW1	10-Aug-08	18.82	335	295	0.218	77.3	7.19	0.053	6.94	254	14.33
	OCW1	11-Aug-08	18.48	340	297	0.221	78.2	7.33	0.027	7.25	192	14.24
	OCW1	12-Aug-08	17.68	330	284	0.215	72.0	6.86	0.106	7.39	290	14.18
	OCW1	13-Aug-08	16.64	322	270	0.209	75.6	7.35	0.035	7.31	288	14.23
	OCW1	14-Aug-08	19.30	329	304	0.214	84.6	7.80	0.044	7.24	195	
	OCW1	15-Aug-08	20.73	341	313	0.222	85.4	7.65	0.053	7.40	219	14.34
	OCW1	16-Aug-08	18.66	347	305	0.226	71.5	6.68	0.022	7.31	238	14.31
	OCW1	17-Aug-08	20.26	352	320	0.229	82.5	7.46	0.025	7.56	199	14.24
		Average	18.61	333	294	0.217	81.3	7.60	0.043	7.42	229	14.27
		Standard Dev.	1.24	13	18	0.008	8.4	0.79	0.025	0.31	38	0.06
		Coeff. Of Variation	7%	4%	6%	4%	10%	10%	**58%**	4%	**16%**	0.4%
Southwestern roadside ditch draining into Minago River	**MD1**	4-Aug-08	14.75	136	109	0.088	91.9	9.31	0.113	7.81	231	14.19
	MD1	6-Aug-08	17.74	142	123	0.092	83.2	7.92	0.212	6.78	213	14.38
	MD1	9-Aug-08	16.39	147	123	0.095	86.2	8.43	0.064	7.74	222	14.36
	MD1	11-Aug-08	16.31	155	129	0.101	43.6	4.25	0.076	7.07	154	14.24
	MD1	12-Aug-08	16.63	150	126	0.098	54.4	5.30	0.053	7.24	230	14.18
	MD1	13-Aug-08	15.42	148	121	0.096	54.4	5.43	0.083	7.23	242	14.23
	MD1	14-Aug-08	18.47	154	135	0.100	73.6	6.91	0.042	6.50	158	14.36
	MD1	15-Aug-08	20.49	158	145	0.103	78.3	7.05	0.009	7.12	255	14.34
	MD1	16-Aug-08	20.50	168	154	0.110	35.3	3.18	0.022	7.11	128	14.27
		Average	17.41	151	129	0.098	66.8	6.42	0.075	7.18	204	14.28
		Standard Dev.	2.07	9	13	0.006	20.3	2.02	0.060	0.41	45	0.08
		Coeff. Of Variation	12%	6%	10%	6%	**30%**	**32%**	**81%**	6%	**22%**	1%
Western roadside ditch near the Minago Entrance	**OD2**	5-Aug-08	16.63	185	155	0.120	64.3	6.26	0.106	7.09	178	14.27
	OD2	6-Aug-08	18.20	191	166	0.124	51.6	4.87	0.200	7.07	49	14.39
	OD2	9-Aug-08	19.72	202	182	0.132	82.4	7.51	0.110	7.42	77	14.37
	OD2	12-Aug-08	18.90	228	201	0.148	64.4	5.97	0.097	7.21	166	14.17
	OD2	13-Aug-08	16.96	233	197	0.151	38.9	3.75	0.098	7.10	256	14.23
	OD2	14-Aug-08	18.90	231	204	0.150	52.6	4.87	0.044	6.65	98	14.37
	OD2	15-Aug-08	19.83	224	202	0.146	46.8	4.27	0.046	6.86	110	14.34
		Average	18.45	213	187	0.139	57.3	5.36	0.100	7.06	133	14.31
		Standard Dev.	1.26	20	20	0.013	14.3	1.30	0.052	0.25	71	0.08
		Coeff. Of Variation	7%	10%	11%	10%	**25%**	**24%**	**52%**	3%	**53%**	1%
Western roadside ditch draining into Oakley Creek close to Oakley Creek	**OD1**	4-Aug-08	13.73	136	107	0.089	57.1	5.92	0.028	7.47	145	14.22
	OD1	9-Aug-08	17.25	149	127	0.097	45.4	4.33	0.069	7.36	128	14.37
	OD1	11-Aug-08	15.24	154	125	0.100	46.3	4.65	0.034	6.95	160	14.25
	OD1	13-Aug-08	16.13	152	126	0.099	45.4	4.44	0.014	6.90	303	14.26
	OD1	14-Aug-08	15.12	150	121	0.098	18.3	1.81	0.115	6.61	194	14.38
	OD1	15-Aug-08	17.83	156	135	0.102	32.2	3.05	0.076	6.72	231	14.34
	OD1	16-Aug-08	17.57	159	135	0.103	38.0	3.63	0.052	6.96	230	14.27
		Average	16.12	151	125	0.098	40.4	3.97	0.055	6.99	199	14.30
		Standard Dev.	1.52	7	10	0.005	12.4	1.30	0.034	0.31	61	0.06
		Coeff. Of Variation	9%	5%	8%	5%	**31%**	**33%**	**62%**	4%	**31%**	0%
Southwestern roadside ditch draining into Oakley Creek	**ODS1**	10-Aug-08	20.09	243	220	0.158	96.5	8.76	0.005	6.66	221	14.34
	ODS1	12-Aug-08	17.42	241	207	0.157	81.7	7.82	0.005	7.14	300	14.17
	ODS1	13-Aug-08	16.74	238	200	0.155	83.1	8.07	0.040	7.30	250	14.23
	ODS1	14-Aug-08	22.23	252	239	0.164	85.5	7.45	0.060	6.93	194	14.38
	ODS1	15-Aug-08	23.25	250	237	0.163	86.7	7.40	0.033	7.05	242	14.33
	ODS1	16-Aug-08	23.16	253	244	0.165	88.4	7.56	0.018	7.37	214	14.27
		Average	20.48	246	224	0.160	87.0	7.84	0.027	7.07	237	14.29
		Standard Dev.	2.88	6	18	0.004	5.3	0.52	0.022	0.26	37	0.08
		Coeff. Of Variation	14%	3%	8%	3%	6%	7%	**81%**	4%	**16%**	1%

Note: ***16%*** Coefficients of variation greater than 15% are highlighted in bold and red.

Figure 7.6-17 illustrates the measurements for ORP and DO for the surface water monitoring locations tested. Although a response to the groundwater pump test is not discernible in the water quality results, what is noticable is that the lowest dissolved oxygen and Oxidation-Reduction Potentials were measured at OD1, OD2, and MD1 in the 4.5-8.4 m wide roadside ditches that were dug as part of the Highway #6 maintenance program. At OD1, OD2 and MD1, the DO levels were below the Tier II Manitoba guideline value of 5.5 mg/L on several occasions. In comparison, much higher dissolved oxygen concentrations and ORP values were measured at the natural Oakley Creek station OCW1 and the much narrower, incised roadside ditch location ODS1. The DO concentration ranged from 7.2 to 9.4 mg/L at OCW1 and from 7.4 to 8.8 mg/L at ODS1.

In summary, the August 2008 groundwater pump test did not have a significant effect on surface waters in the vicinity of the Minago Project as shown in Figures 7.6-14 to 7.6-16.

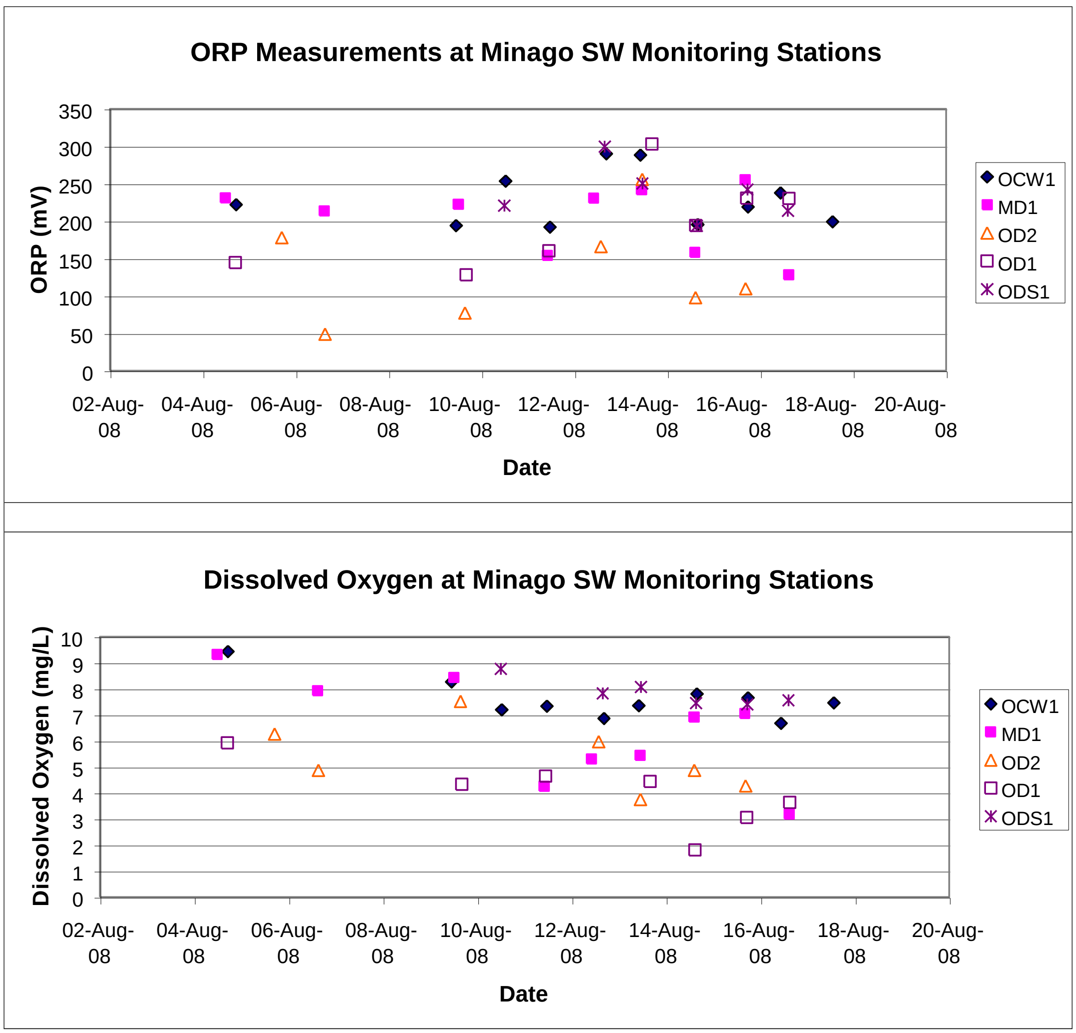


Figure 7.6-17 August 2008 Surface Water Quality Results

7.6.3.13 Summary of Pumping Test Results

A summary of the hydrogeological parameters considered representative for each of the four main hydrostratigraphic units at the Site is presented in Table 7.6-7. These values are based on the results of the pumping test and single-well response tests and also consider the conceptual hydrogeological model of the Site. In addition, the results of the pumping test program indicate the following (Golder Associates, 2008b):

1. The influence of significant hydrogeologic (recharge or zero-flux) boundaries were not identified in the hydraulic response to pumping during the pumping test program. This is likely because of the distance to the nearest surface water body in contact with the limestone aquifer (*i.e.,* the Minago River is approximately 10 km from the dewatering wells) and the limited duration of the pumping test. Oakley Creek, located approximately 1 km south of the dewatering wells is likely not in direct contact with the limestone aquifer (*i.e.,* its bed lies in the overburden); therefore, it was not observed to act as a significant hydrogeologic boundary.
2. Limestone outcrops 2 km northwest and 9 km south of the Site are likely areas where recharge to the limestone aquifer occurs through net infiltration of precipitation.
3. The overburden was not significantly affected by pumping during the pumping test, except in the near vicinity (approximately 30 m) of the North Pit Wall zone (HG-7).

7.6.4 Conceptual Model of the Groundwater Flow at Minago

Based on the regional hydrogeological setting, the well logs, and the hydraulic response to pumping, a conceptual model was developed for groundwater flow in the upper 75 m of the subsurface at the Site. The limestone aquifer forms the main aquifer at the Site. The limestone aquifer is confined by the overburden clay deposit: a 5 m-thick aquitard. The upper 20 to 30 m of the limestone unit is more permeable than the deeper limestone, particularly in the North Pit Wall region. The ambient groundwater flow direction in the limestone is from west to east. During pumping, the water level in the limestone was lowered below the top of the limestone (*i.e.,* below the bottom of the overburden unit) within about 100 m of the dewatering wells, under the pumping rates of the pumping test. In these regions, the limestone aquifer becomes unconfined, and groundwater is released through aquifer drainage. Some amount of leakage from the overburden aquitard into the limestone aquifer occurs, providing some additional flow to the dewatering wells. The sandstone aquifer is affected by pumping in the limestone, and experiences greater drawdown than in the limestone because of its comparatively lower hydraulic conductivity. The weathered granite that is in direct contact with the sandstone aquifer is likely more permeable than the underlying non-weathered granite. The non-weathered granite likely acts as a lower confining unit, or an aquitard, that provides minimal leakage to the sandstone unit, possibly through vertical fractures.

Table 7.6-7 Summary of Hydrogeologic Parameters

Hydrogeologic Unit	**Overburden (OB)**	**Shallow Limestone (SLS)**		**Deeper Limestone (LS)**			**Sandstone (SS)**	**Weathered Granite (GR)**
Zone	all	North Pit Wall	South Pit Wall	North Pit Wall	South Pit Wall	2 km from Pit	near Pit	near Pit
Depth to the Top of Unit (m)	0	5.9	5.7	5.9	5.7	8.4	59	70.4
Unit Thickness (m)	7	33	21	20	32	30	11.4	10
T (m^2/s)	n/a	1.E-02	2.E-03	5.E-03	1.E-03	4.5E-03		n/a
S (-)	n/a	2.E-05	3.E-03	2.E-04	1.E-04	1.0E-03		n/a
K (m/s) *	K_H = 4E-8 ; K_V = 5E-9	3.E-04	1.E-04	2.E-04	4.E-05	1.5E-04		1.E-08
S_s (m^{-1})		7.E-07	1.E-04	8.E-06	4.E-06	3.3E-05		7.E-06
S_y (-)		0.01		0.02				

Notes:

*Hydraulic conductivity (K) assumed to be isotropic unless horizontal (K_H) and vertical (K_V) hydraulic conductivity is presented.

Source: Golder Associates (2008b)

7.6.5 Numerical Groundwater Model

The conceptual hydrogeologic model presented in the previous section was used as a basis for the construction of a numerical hydrogeologic model for the site. Following calibration, this model was used to predict the dewatering requirements for limestone and sandstone units that will be intersected by the proposed open pit. Details of model construction (model code selection, model mesh, boundary conditions) and calibration are given in Golder Associates (2008b) (Appendix 7.6).

7.6.6 Dewatering System Design

The calibrated groundwater model was used to simulate the pumping wells that will be necessary for dewatering of the limestone and sandstone units. The results were used to estimate the number, location, and pumping rates for these wells, and the total pumping rate for the entire wellfield. Based on this analysis, typical well installation schematics were developed, and recommendations were provided with respect to the observation well network that will be required to monitoring dewatering progress during mine pit development.

7.6.7 Mine Dewatering Predictions and Uncertainty

Prior to the full-scale dewatering simulations, preliminary model simulations were conducted to assess the approximate amount of time required for the dewatering to occur once pumping is started. These preliminary simulations, together with the observations gathered during the 5-day pumping test, suggested that limestone dewatering is relatively rapid and that the cone of depression created by dewatering would reach a near-steady state configuration within several months after the full dewatering system is implemented. This relatively rapid response to pumping is primarily related to the low storage and high transmissive properties of the limestone unit. Consequently, it was decided that the model simulations representing the full-scale dewatering system could be conducted in steady-state without considering groundwater storage effects.

Several model runs were completed where the location and number of dewatering wells were varied in an attempt to essentially dewater the limestone unit within the pit area and depressurize the underlying sandstone unit. It is not practical to attempt full dewatering of the sandstone unit as it is of a lower permeability when compared to limestone; therefore it would receive steady recharge from above. Nevertheless, depressurization of the sandstone unit is considered to be sufficient because, due to its relatively low hydraulic conductivity it is not considered to be able to provide significant inflows to the pit. Instead, any localized and minor inflows from sandstone could be mitigated using sub-horizontal drainholes installed from the pit benches.

The dewatering wells considered in the analysis were simulated using specified head boundaries, constrained to allow outflow of groundwater only, that were assigned in model layers representing the limestone and sandstone. It was assumed that pumping from these wells would lower the water level in each well below the limestone/sandstone contact. With drawdown at each pumping well fixed, the model calculated the pumping rate at each well thus allowing rapid evaluation of various dewatering options without constant rate adjustments.

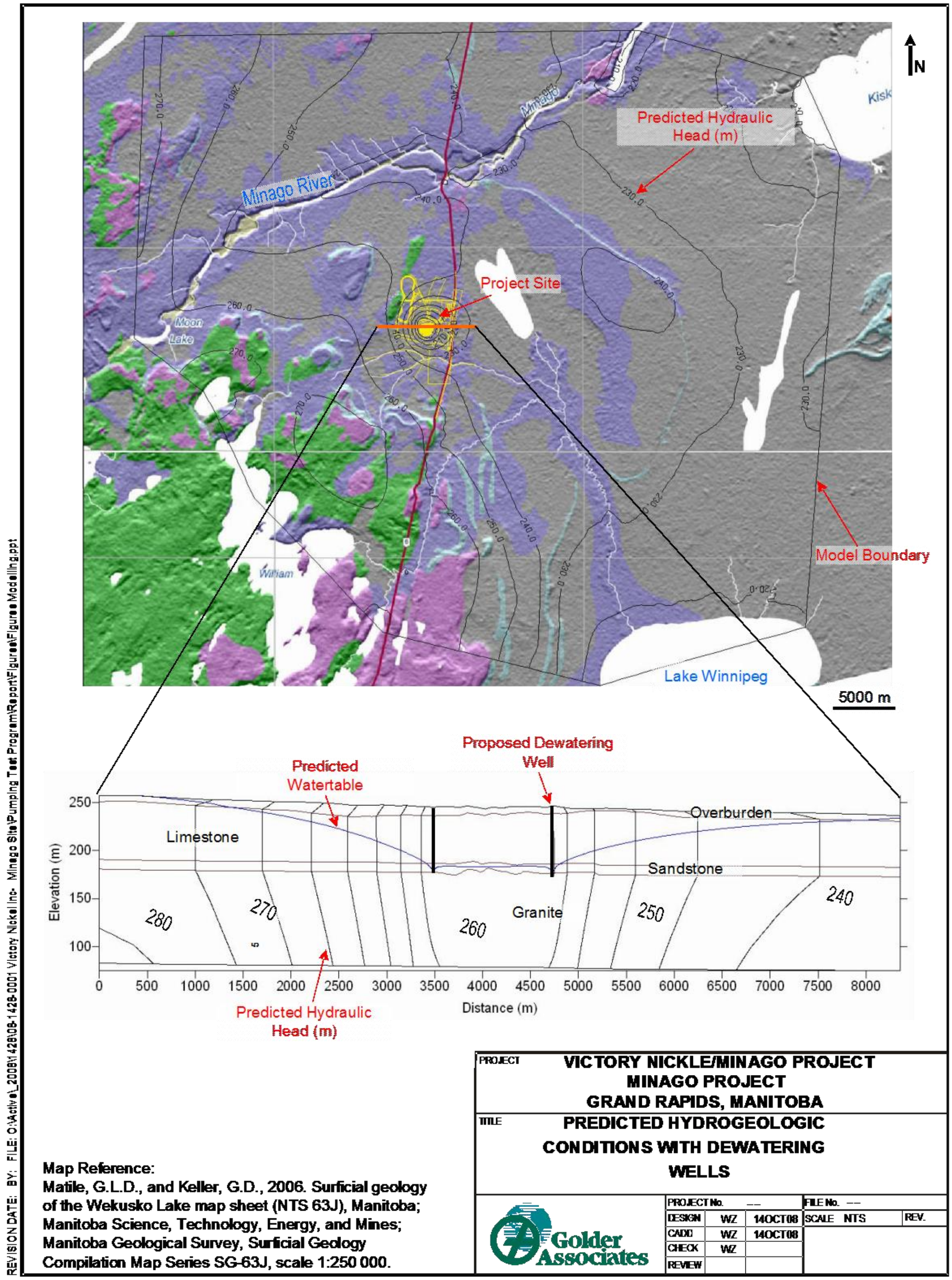
Figure 7.6-18 and Figure 7.6-19 present the hydrogeologic conditions predicted for a wellfield that provided the required dewatering of the limestone unit without excessive pumping and/or number of pumping wells. The design consists of 12 dewatering wells located at a distance of approximately 300 m to 400 m along the crest of the ultimate pit, and pumping simultaneously from the limestone and sandstone units. The total pumping rate for the wellfield is predicted to be approximately 40,000 m^3/day (7,300 IN summary, the August 2008), and the average pumping rate for an individual well is estimated at about 3,300 m^3/day (600 USgpm). As presented on Figure 7.6-18, pumping at these rates is sufficient to lower the water table to near the limestone and sandstone contact. The associated drawdown cone (Figure 7.6-19), defined using a 1 m drawdown contour, is predicted to extend laterally in the limestone to a distance of approximately 5,000 m to 6,000 m from the proposed open pit.

Although the groundwater model was developed using a comprehensive hydrogeologic dataset, and was successfully calibrated to the pre-pumping conditions and pumping test, uncertainty exists with respect to the predicted dewatering rates. This uncertainty is inherent in any hydrogeologic assessment, as it is simply not practical to drill boreholes at dense enough spacing that would allow identification and testing of all heterogeneities, discontinuities, etc. To address this uncertainty, a series of sensitivity analyses were conducted such that selected model parameters were varied over their uncertainty ranges, and their influence on the predicted dewatering rates was assessed. These parameters included the hydraulic conductivity of the limestone unit, the hydraulic conductivity of the overburden, and the recharge rate. During calibration, other model parameters were found to have a relatively small influence on model predictions. The results of this analysis suggest that the actual dewatering rate for the entire wellfield could vary from 25,000 m^3/day (4,600 USgpm) to 90,000 m^3/day (16,500 USgpm).

7.6.8 Dewatering Wells Construction

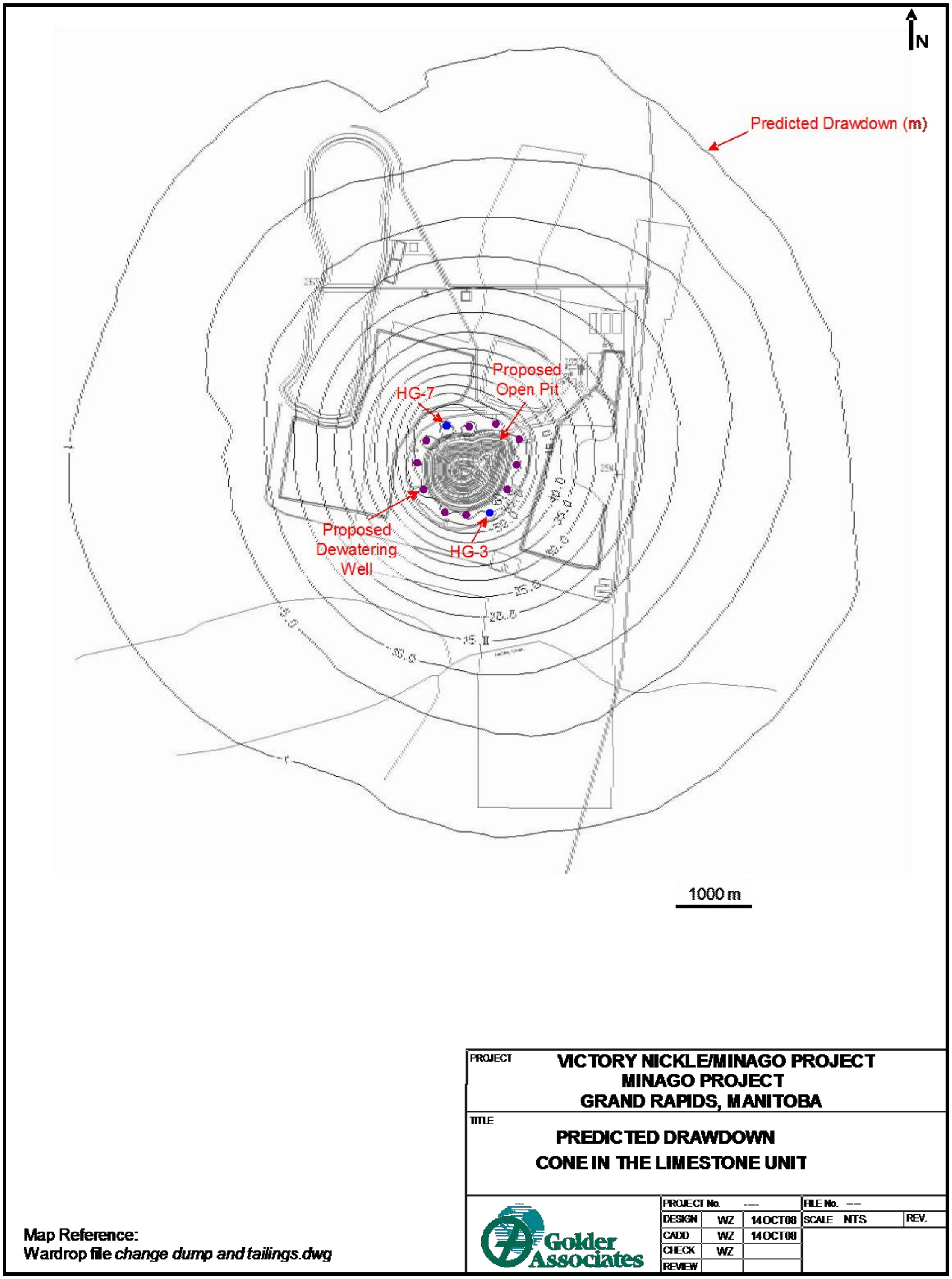
The recommended dewatering well design includes the following (Figure 7.6-20):

- Each well will be drilled 10 m into the weathered granite unit;
- A sump will be placed in the bottom 5 m of the well;
- A well screen will be placed above the sump such that it is completed in at least 5 m of limestone;
- The well casing in the limestone will be slotted throughout most of its length;
- The well annulus in the limestone will be filled with gravel to allow free downward drainage; and,
- The pump will be installed in the sump in the bottom 5 m of each well.



Source: Golder Associates, 2008b

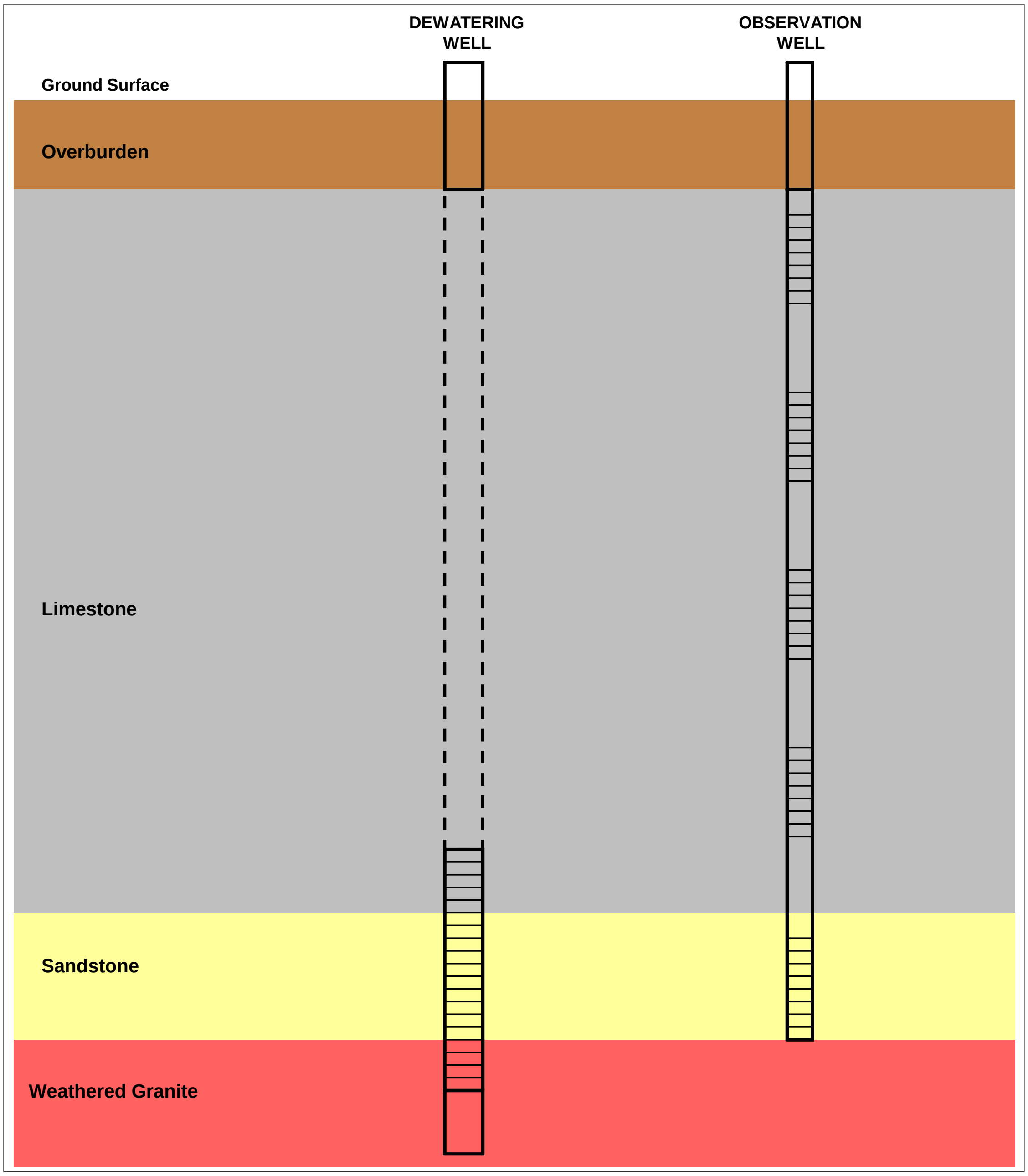
Figure 7.6-18 Predicted Hydrogeological Conditions with Dewatering Wells



Source: Golder Associates, 2008b

Figure 7.6-19 Predicted Drawdown Cone in the Limestone Unit

Note: Drawdown cone is predicted to extend laterally in the limestone to a distance of approximately 5,000 m to 6,000 m from the proposed open pit.



Source: Golder Associates (2008b)

Figure 7.6-20 Schematic for Proposed Dewatering Wells and Observation Wells

The above design will allow well pumping to the extent that drawdown in the well will be near the bottom of the screen. This would effectively create a seepage face in the well screen/slotted casing that intersects the sandstone–limestone contact. A schematic of the recommended well design is presented in Figure 7.6-20.

7.6.8.1 Monitoring Network

A minimum of one standpipe piezometer will be required for up to two pumping wells, for a total of six standpipe piezometers. These piezometers would be screened throughout the entire thickness of limestone and sandstone for the purpose of monitoring the water table position during dewatering. A schematic of the recommended observation well design is presented in Figure 7.6-20.

7.6.9 Summary and Conclusions

The primary focus of the hydrogeological study was to estimate the configuration of the dewatering well system required for the operation of the proposed mine pit; to estimate the total required pumping rate for dewatering; and to estimate the extent of the drawdown cone created during open pit mining. The hydrogeological study concluded that a total of 12 dewatering wells completed in both the limestone and sandstone aquifers, at distances of approximately 300 m to 400 m along the crest of the ultimate pit, will be required to operate simultaneously (Golder Associates, 2008b). The total quantity of groundwater likely to be generated by these wells is 40,000 m^3/day (7,300 USgpm). The average pumping rate for an individual well is estimated to be 3,300 m^3/day (600 USgpm) (Golder Associates, 2008b).

7.6.10 Groundwater Quality

To date, several groundwater samples have been collected from the Minago Property. Groundwater samples were collected as part of the initial hydrogeological program in 2007, after the installation of pumping wells in March 2008, and at the end of the long-term pump test in August 2008. All groundwater samples were collected in a representative manner and according to standard groundwater sampling protocols to minimize sample contamination. For example, a groundwater sample was collected from each of the four dewatering wells on August 15, 2008, the fifth day of the pumping test. Duplicate samples were taken from HG-7-LS and HG-3-SS for quality assurance/quality control (QA/QC) purposes. The samples were collected using an in-line sampling port constructed in the well head assembly. Samples were preserved as necessary and stored at approximately 4ºC until delivered to the laboratory (ALS Laboratory Group) in Vancouver, British Columbia (Golder Associates, 2008b). The samples were analyzed for major anions, nutrients, cyanide, total organic carbon and total metals.

7.6.10.1 Water Quality Guidelines

Relevant water quality guidelines for the environmental assessment for the Minago Project are covered in a separate section on Surface Water Quality (Section 7.5). In this document, water quality results were compared to the Final Draft Manitoba Water Quality Standards, Objectives and Guidelines (Williamson, 2002) and the Canadian Council of Ministers of the Environment (CCME) Guidelines for the Protection of Aquatic Life (CCME, 2007). The Tier III Water Quality Guidelines contain guidelines developed by the federal Canadian Council of Ministers of the Environment (CCME). These guidelines were developed to ensure that the most sensitive species in the aquatic receiving environment are protected at all times along with an adequate margin of safety. Summaries of Minago groundwater water quality results also list guideline limits for the 2002 *Metal Mining Effluent Regulations* (MMER).

7.6.10.2 Summary of Groundwater Results

Table 7.6-8 summarizes the groundwater quality in the limestone and sandstone formations below the Minago Property. Table 7.6-8 lists the average, maximum and minimum concentrations measured in the limestone and sandstone. A complete summary of groundwater water quality results is presented in Appendix 7.6 and laboratory certified reports are given in Appendix L7.6.

Table 7.6-8 Summary of Groundwater Quality in Limestone and Sandstone (This page: Total Concentrations)

PARAMETER	Units	LIMESTONE AVERAGE [1] Mar-2007 & Aug-2008	LIMESTONE MAXIMUM [1] Mar-2007 & Aug-2008	LIMESTONE MINIMUM [1] Mar-2007 & Aug-2008	SANDSTONE AVERAGE [1] Mar-2007 & Aug-2008	SANDSTONE MAXIMUM [1] Mar-2007 & Aug-2008	SANDSTONE MINIIMUM [1] Mar-2007 & Aug-2008	REGULATIONS: Manitoba Water Quality Standards, Objectives, and Guidelines (Williamson, 2002) – TIER II Water Quality Objectives	Manitoba – TIER III - Water Quality Guidelines – Drinking – MAC	Manitoba – TIER III – Drinking – IMAC	Manitoba – TIER III – Freshwater	Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 2007)	Metal Mining Liquid Effluents (2002) – Monthly Mean	Metal Mining Liquid Effluents (2002) – Grab Sample
Physical Tests														
Dissolved Hardness (CaCO3)	mg/L	291	297	285	286	287	285							
Hardness (as CaCO3)	mg/L	283	307	242	235	294	165							
Conductivity	µS/cm	643	682	606	673	688	633	1000						
pH	pH Units	8.12	8.2	8.04	8.12	8.18	8.05					6.5-9	6-9.5	6-9.5
Total Metals														
Aluminum (Al)-Total	mg/L	0.060	**0.108**	0.035	0.0231	0.0261	0.0215				0.005 - 0.1	0.005 - 0.1		
Antimony (Sb)-Total	mg/L	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025			0.006				
Arsenic (As)-Total	mg/L	0.00247	0.00294	0.00218	0.00025	0.00028	0.00021			0.025	0.15 mg/L (4-Day, 3-Year) [A]	0.005[k]	0.5	1
Barium (Ba)-Total	mg/L	0.0733	0.076	0.0694	0.050	0.061	0.0445		1					
Beryllium (Be)-Total	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001							
Bismuth (Bi)-Total	mg/L	0.00025	0.00025	0.00025	0.00025	0.00025	0.00025							
Boron (B)-Total	mg/L	0.128	0.177	0.096	0.330	0.401	0.197			5				
Cadmium (Cd)-Total	mg/L	0.0000057	0.0000057	0.0000057	0.0000057	0.0000057	0.0000057		0.005			0.000017[c,l]		
Calcium (Ca)-Total	mg/L	55.0	59.7	45.7	45.7	56.8	31.6							
Chromium (Cr)-Total	mg/L	0.001	0.001	0.001	0.001	0.001	0.001		0.05					
Trivalent Chromium (Cr-III)	mg/L											0.0089[c,k]		
Hexavalent Chromium (Cr-VI)	mg/L											0.001[k]		
Cobalt (Co)-Total	mg/L	0.00028	0.00029	0.00027	0.00010	0.00019	0.00005							
Copper (Cu)-Total	mg/L	0.00077	0.00078	0.00077	0.00025	0.00029	0.00022					0.002-0.004[m]	0.3	0.6
Iron (Fe)-Total	mg/L	**0.48**	**0.73**	**0.34**	0.16	0.17	0.13				0.3	0.3[d]		
Lead (Pb)-Total	mg/L	0.00044	0.000493	0.000389	0.00046	0.00073	0.00030		0.01			0.001-0.007[o]	0.2	0.4
Lithium (Li)-Total	mg/L	0.0204	0.0279	0.0156	0.0396	0.0455	0.0286							
Magnesium (Mg)- Total	mg/L	35.4	38.4	31.1	29.4	37.1	21							
Manganese (Mn)-Total	mg/L	0.00930	0.00997	0.00882	0.00957	0.01200	0.00833							
Mercury (Hg)-Total	mg/L	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005		0.001		0.0001			
Inorganic Mercury	mg/L											0.000026		
Methylmercury	mg/L											0.000004[c,w]		
Molybdenum (Mo)-Total	mg/L	0.0005	0.0005	0.000393	0.0011	0.0011	0.00112				0.073			
Nickel (Ni)-Total	mg/L	0.0011	0.0012	0.00094	0.0004	0.0010	0.00013					0.025-0.15[p]	0.5	1
Phosphorus (P)-Total	mg/L	0.15	0.15	0.15	0.15	0.15	0.15					narrative [x]		
Potassium (K)-Total	mg/L	5.54	7.9	4.27	8.12	9.39	5.74							
Selenium (Se)-Total	mg/L	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005		0.01		0.001	0.001[d]		
Silicon (Si)-Total	mg/L	4.87	5.06	4.76	4.03	4.06	4.01							
Silver (Ag)-Total	mg/L	0.000005	0.000005	0.000005	0.000005	0.000005	0.000005				0.0001	0.0001[d]		
Sodium (Na)-Total	mg/L	24.3	32.2	20.2	66.9	83.4	34							
Strontium (Sr)-Total	mg/L	0.233	0.262	0.218	0.353	0.372	0.314		5 Bq/L					
Thallium (Tl)-Total	mg/L	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025				0.0008	0.0008[j]		
Tin (Sn)-Total	mg/L	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005							
Titanium (Ti)-Total	mg/L	0.007	0.011	0.005	0.005	0.005	0.005							
Uranium (U)-Total	mg/L	0.00049	0.000624	0.000276	0.00047	0.00105	0.000183			0.02				
Vanadium (V)-Total	mg/L	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005							
Zinc (Zn)-Total	mg/L	0.002	0.002	0.002	**0.042**	**0.073**	0.004					0.03[d]	0.5	1

Notes:

1 If a reported concentration was below the detection limit, half the detection limit was used for the calculations.

MAC - Maximum Acceptable Concentration

0.073 BOLD AND UNDERLINED VALUE EXCEEDS GUIDELINE LIMIT.

IMAC - Interim Maximum Acceptable Concentration

References:

Williamson, D. 2002. Manitoba Water Quality Standards, Objectives, and Guidelines. Manitoba Conservation Report 2002-11, Water Quality Management Section, Water Branch, Manitoba Conservation, Winnipeg, MB.

Table 7.6-8 (Cont.'d) Summary of Groundwater Quality in Limestone and Sandstone (This page: Dissolved Concentrations)

PARAMETER	Units	LIMESTONE AVERAGE [1] Mar-2007 & Aug-2008	LIMESTONE MAXIMUM [1] Mar-2007 & Aug-2008	LIMESTONE MINIMUM [1] Mar-2007 & Aug-2008	SANDSTONE AVERAGE [1] Mar-2007 & Aug-2008	SANDSTONE MAXIMUM [1] Mar-2007 & Aug-2008	SANDSTONE MINIIMUM [1] Mar-2007 & Aug-2008	REGULATIONS – Manitoba Water Quality Standards, Objectives, and Guidelines (Williamson, 2002): TIER II Water Quality Objectives	TIER III - Water Quality Guidelines: Drinking MAC	TIER III - Water Quality Guidelines: Drinking IMAC	TIER III - Water Quality Guidelines: Freshwater
Physical Tests											
Dissolved Hardness (CaCO3)	mg/L	291	297	285	286	287	285				
Hardness (as CaCO3)	mg/L	283	307	242	235	294	165				
Dissolved Elements											
Aluminum (Al)-Dissolved	mg/L	0.00397	0.0215	0.0001	0.00722	0.0344	0.0005				0.005 - 0.1
Antimony (Sb)-Dissolved	mg/L	0.00020	0.00045	0.000025	0.000179	0.0006	0.000025			0.006	
Arsenic (As)-Dissolved	mg/L	0.00088	0.00122	0.0003	0.0006214	0.0021	0.000162	0.15 mg/L (4-Day, 3-Year) [A]		0.025	Tier II
Barium (Ba)-Dissolved	mg/L	0.0816	0.1110	0.0542	0.0634	0.0839	0.0473		1		
Beryllium (Be)-Dissolved	mg/L	0.00006	0.00010	0.00003	0.00007	0.0001	0.000025				
Bismuth (Bi)-Dissolved	mg/L	0.00014	0.00025	0.00003	0.00016	0.00025	0.000025				
Boron (B)-Dissolved	mg/L	0.1511	0.199	0.0986	0.2572	0.361	0.171			5	
Cadmium (Cd)-Dissolved	mg/L	0.00002	0.00003	0.0000057	0.00001	0.00002	0.000005	Hardness dependent [B] (e.g. 0.00163 mg/L chronic; 0.00267 mg/L acute at hardness 65 mg/L $CaCO_3$)	0.005		Tier II
Calcium (Ca)-Dissolved	mg/L	48.3	56.7	23.9	44.4	55.1	30.4				
Cesium (Cs) - Dissolved	mg/L	0.00002	0.00003	0.000015	0.000015	0.000015	0.000015				
Chromium (Cr)-Dissolved	mg/L	0.00046	0.001	0.0001	0.000638	0.00107	0.0001	Hardness dependent [C] (e.g.,0.052 mg/L Cr-III chronic at hardness 65 mg/L; 0.011 mg/L Cr-VI 4-Day, 3-Year)	0.05		Tier II
Cobalt (Co)-Dissolved	mg/L	0.00041	0.00078	0.00005	0.00019	0.00036	0.00005				
Copper (Cu)-Dissolved	mg/L	0.000315	0.00092	0.00005	0.00024	0.00055	0.00005	Hardness dependent [D] (e.g.,0.0062 mg/L chronic at hardness 65 mg/L $CaCO_3$)			Tier II
Iron (Fe)-Dissolved	mg/L	0.018	0.049	0.005	0.0386	0.093	0.005				0.3
Lead (Pb)-Dissolved	mg/L	0.00091	0.00378	0.00001	0.0000408	0.000074	0.000025	Hardness dependent [E] (e.g., 0.00157 mg/L chronic at hardness 65 mg/L $CaCO_3$)	0.01		Tier II
Lithium (Li)-Dissolved	mg/L	0.0232	0.0299	0.0157	0.03316	0.0413	0.0265				
Magnesium (Mg)-Dissolved	mg/L	34.7	37.6	31.7	28.4	36.3	19.9				
Manganese (Mn)-Dissolved	mg/L	0.0375	0.0824	0.000318	0.02879	0.09650	0.00734				
Mercury (Hg)-Dissolved	mg/L	0.000015	0.000025	0.000005	0.00001	0.00003	0.00001		0.001		0.0001
Molybdenum (Mo)-Dissolved	mg/L	0.001512	0.003200	0.000418	0.00142	0.00242	0.00108				0.073
Nickel (Ni)-Dissolved	mg/L	0.00145	0.00230	0.00075	0.00110	0.00200	0.00005	Hardness dependent [F] (e.g., 0.036 mg/L chronic at hardness 65 mg/L $CaCO_3$)			Tier II
Phosphorus (P)-Dissolved	mg/L	0.1	0.15	0.05	0.11	0.15	0.05				
Phosphorus (P) - Dissolved by SM 4500 PF Method	mg/L	0.009	0.018	0.005	0.007	0.01	0.004				
Potassium (K)-Dissolved	mg/L	5.90	8.03	4.18	7.138	9.17	5.48				
Rubidium (Rb) - Dissolved	mg/L	0.00267	0.00293	0.00252	0.00266	0.00285	0.00246				
Selenium (Se)-Dissolved	mg/L	0.0002	0.0005	0.0001	0.00016	0.00025	0.00005		0.01		0.001
Silicon (Si)-Dissolved	mg/L	5.09	5.24	4.97	4.71	5.73	4.24				
Silver (Ag)-Dissolved	mg/L	0.0000075	0.00002	0.000005	0.00001	0.00004	0.000005				0.0001
Sodium (Na)-Dissolved	mg/L	29.9	38.7	20.6	58.0	86.9	34.4				
Strontium (Sr)-Dissolved	mg/L	0.274	0.328	0.191	0.3478	0.386	0.316		5 Bq/L		
Sulphur (S) - Dissolved	mg/L	5.1	5.8	4.7	5.15	5.3	5				
Tellurium (Te) - Dissolved	mg/L	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005				
Thallium (Tl)-Dissolved	mg/L	0.000025	0.000025	0.000025	0.000025	0.000025	0.000025				0.0008
Tin (Sn)-Dissolved	mg/L	0.0000375	0.00005	0.000025	0.00005	0.00005	0.00005				
Titanium (Ti)-Dissolved	mg/L	0.002625	0.005	0.00025	0.0031	0.005	0.00025				
Tungsten (W) - Dissolved	mg/L	0.00159	0.00217	0.00122	0.00122	0.00129	0.00115				
Uranium (U)-Dissolved	mg/L	0.00048	0.000591	0.000279	0.000436	0.000996	0.000166			0.02	
Vanadium (V)-Dissolved	mg/L	0.000263	0.0005	0.000025	0.00013	0.00050	0.00003				
Zinc (Zn)-Dissolved	mg/L	**0.3092**	**0.6490**	0.0005	**0.52**	**2.54**	0.004	Hardness dependent [G] (e.g., 0.082 mg/L chronic at hardness 65 mg/L $CaCO_3$)			Tier II
Zirconium (Zr) - Dissolved	mg/L	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025				

Notes:

1 If a reported concentration was below the detection limit, half the detection limit was used for the calculations.

MAC - Maximum Acceptable Concentration

IMAC - Interim Maximum Acceptable Concentration

2.54 BOLD AND UNDERLINED VALUE EXCEEDS GUIDELINE LIMIT.

References:

Williamson, D. 2002. Manitoba Water Quality Standards, Objectives, and Guidelines. Manitoba Conservation Report 2002-11, Water Quality Management Sect., Water Br., Manitoba Conservation, Winnipeg, MB.

Table 7.6-8 (Cont.'d) Summary of Groundwater Quality in Limestone and Sandstone (This page: Other Parameters)

PARAMETER	Units	LIMESTONE AVERAGE [1] Mar-2007 & Aug-2008	LIMESTONE MAXIMUM [1] Mar-2007 & Aug-2008	LIMESTONE MINIMUM [1] Mar-2007 & Aug-2008	SANDSTONE AVERAGE [1] Mar-2007 & Aug-2008	SANDSTONE MAXIMUM [1] Mar-2007 & Aug-2008	SANDSTONE MINIIMUM [1] Mar-2007 & Aug-2008	REGULATIONS: Manitoba Water Quality Standards, Objectives, and Guidelines (Williamson, 2002) – TIER II Water Quality Objectives	Manitoba – TIER III - Water Quality Guidelines – Drinking – MAC	Manitoba – TIER III – Drinking – IMAC	Manitoba – TIER III – Freshwater	Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME, 2007)	Metal Mining Liquid Effluents (2002) Monthly Mean	Metal Mining Liquid Effluents (2002) Grab Sample
Field-Measured Parameters														
Conductivity	µS/cm	448	451	443	486	504	451.0	1000						
Dissolved Oxygen	mg/L	6.2	8.0	**2.5**	**2.3**	**3**	**2**	varies with life-stages & temperature; 6.5 mg/L (30-Day, 3-Year if temp. > 5°C); Instantaneous Minimum 5 mg/L (if T>5°C)						
Iron II	mg/L	**0.4**	**0.6**	0.3	0.27	0.3	0.2				0.3	0.3[d]		
pH	pH units	7.46	7.49	7.44	7.56	7.61	7.47					6.5-9		
Redox	mV	44.3	51	31	46.3	51.0	37.0							
Temperature	°C	5.9	6.1	5.5	6.5	7.0	6.2							
Physical Tests														
Dissolved Hardness (CaCO3)	mg/L	291	297	285	286	287	285							
Hardness (as CaCO3)	mg/L	283	307	242	235	294	165							
Conductivity	µS/cm	643	682	606	673	688	633	1000						
pH	pH Units	8.12	8.2	8.04	8.12	8.18	8.05					6.5-9	6-9.5	6-9.5
Total Dissolved Solids	mg/L	344	372	284	369.4	390	351	700						
Total Suspended Solids		4.7	7.9	1.5	1.5	1.5	1.5	Dependent on background TSS (5 mg/L (30-Day, 3 Year) or 25 mg/L (1-Day, 3-Year) or 10% (1-Day, 3-Year) of induced change from background)			Tier II	narrative	15	30
Turbidity (NTU)	NTU	**33.7**	**69.8**	**4.82**	**21.0**	**77.6**	**1.02**		1.0		Tier II	narrative		
Colour, True		6.4	7.9	5.6	5.1	5.1	5.1							
Anions and Nutrients														
Ammonia as N	mg/L	0.089	0.143	0.058	0.151	0.265	0.080	pH and temperature dependent (lowest concentration for all categories = 1.17 mg/L for pH 7.8)			Tier II	see factsheet		
Alkalinity, Total (as CaCO3)	mg/L	323	342	300	319	344	294							
Alkalinity (PP as CaCO3)	mg/L	0.25	0.25	0.25	0.25	0.25	0.25							
Bicarbonate (HCO3)	mg/L	415	418	410	417	420	414							
Alkalinity, Carbonate (as CaCO3)	mg/L	0.25	0.25	0.25	0.25	0.25	0.25							
Alkalinity, Hydroxide (as CaCO3)	mg/L	0.25	0.25	0.25	0.25	0.25	0.25							
Chloride (Cl)	mg/L	12.9	17.8	9.8	19.2	23.9	14.2							
Fluoride (F)	mg/L	**0.32**	**0.41**	**0.244**	**0.50**	**0.70**	**0.36**		1.5			0.12[c]		
Sulfate (SO4)	mg/L	13.7	16.4	11.7	21.2	27.7	14.3							
Nitrate (as N)	mg/L	0.0039	0.008	0.0025	0.0023	0.003	0.0025		10			2.93 [c,u]		
Nitrite (as N)	mg/L	0.0023	0.005	0.0005	0.0011	0.003	0.0005		0.97		CCME	0.06 [z]		
Nitrate plus Nitrite (as N)	mg/L	0.009	0.013	0.005	0.002	0.003	0.003	10						
Total Kjeldahl Nitrogen	mg/L	0.190	0.270	0.094	0.198	0.230	0.139							
Total Nitrogen	mg/L	0.273	0.280	0.270	0.220	0.230	0.230							
Calcium (Ca)-Total	mg/L	58.1	59.7	55.7	56.8	56.8	56.8							
Magnesium (Mg)-Total	mg/L	37.5	38.4	35.9	37.0	37.1	36.8							
Radiological Parameters														
Radium-226	Bq/L	0.07	0.11	0.04	0.015	0.02	0.01		0.6				0.37	1.11
XNo class														
Total Organic Carbon		2.50	3.11	2.19	0.93	1.17	0.81							
Cyanides														
Cyanide, Weak Acid Diss		0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0052 mg/L (4-Day, 3-Year)			Tier II	0.005 (as free CN)		

Notes:

1 If a reported concentration was below the detection limit, half the detection limit was used for the calculations

MAC - Maximum Acceptable Concentration

IMAC - Interim Maximum Acceptable Concentration

77.6 BOLD AND UNDERLINED VALUE EXCEEDS GUIDELINE LIMIT.

References:

Williamson, D. 2002. Manitoba Water Quality Standards, Objectives, and Guidelines. Manitoba Conservation Report 2002-11, Water Quality Management Section, Water Branch, Manitoba Conservation, Winnipeg, MB.

NOTES:

A Arsenic limits: 0.15 mg/L for averaging duration 4 days (4-Day, 3-Year or 7Q10 Design Flow); 0.34 mg/L for averaging duration 1 hr (1-Day, 3-Year or 1Q10 Design Flow)

B Cadmium limits: [e{0.7852[ln(Hardness)]-2.715}]×[1.101672-{ln(Hardness)(0.041838)}] for 4 days averaging duration.
[e{1.128[ln(Hardness)]-3.6867}]×[1.136672-{ln(Hardness)(0.041838)}] for 1 hour averaging duration.

C Chromium limits:Chromium III: [e{0.8190[ln(Hardness)]+0.6848}]×[0.860] for 4 days averaging duration.
Chromium III: [e{0.8190[ln(Hardness)]+3.7256}]×[0.316] for 1 hour averaging duration.
Chromium VI: 0.011 mg/L for averaging duration 4 days (4-Day, 3-Year or 7Q10 Design Flow); 0.016 mg/L for averaging duration 1 hr (1-Day, 3-Year or 1Q10 Design Flow)

D Copper limits: [e{0.8545[ln(Hardness)]-1.702}]×[0.960] for 4 Days hour averaging duration.
[e{0.9422[ln(Hardness)]-1.700}]×[0.960] for 1 hour averaging duration.

E Lead limits: [e{1.273[ln(Hardness)]-4,705}]×[1.46203 -{ln(Hardness)(0.145712)}] for 4 Days averaging duration.
[e{1.273[ln(Hardness)]-1.460}]×[1.46203 -{ln(Hardness)(0.145712)}] for 1 hour averaging duration.

F Nickel limits: [e{0.8460[ln(Hardness)]+0.0584}]×[0.997] for 4 Days averaging duration.
[e{0.8460[ln(Hardness)]+2.255}]×[0.998] for 1 hour averaging duration.

G Zinc limits: [e{0.8473[ln(Hardness)]+0.884}]×[0.976] for 4 Days averaging duration.
[e{0.8473[ln(Hardness)]+0.884}]×[0.978] for 1 hour averaging duration.

Footnotes for the CCME Aquatic Guidelines (Canadian Council of Ministers of the Environment. Dec. 2007. Canadian water quality guidelines for the protection of aquatic life).

c Interim guideline.
d No fact sheet created.
j The technical document for the guideline is available from the Ontario Ministry of the Environment.
k Substance has been re-evaluated since CCREM 1987 + Appendixes. Either a new guideline has been derived or insufficient data existed to derive a new guideline.
l Cadmium guideline = 10{0.86[log(hardness)] - 3.2}.
m Copper guideline = 2 $\mu g \cdot L^{-1}$ at [CaCO3] = 0–120 $mg \cdot L^{-1}$
= 3 $\mu g \cdot L^{-1}$ at [CaCO3] = 120–180 $mg \cdot L^{-1}$
= 4 $\mu g \cdot L^{-1}$ at [CaCO3] >180 $mg \cdot L^{-1}$
o Lead guideline = 1 $\mu g \cdot L^{-1}$ at [CaCO3] = 0–60 $mg \cdot L^{-1}$
= 2 $\mu g \cdot L^{-1}$ at [CaCO3] = 60–120 $mg \cdot^{L-1}$
= 4 $\mu g \cdot L^{-1}$ at [CaCO3] = 120–180 $mg \cdot L^{-1}$
= 7 $\mu g \cdot L^{-1}$ at [CaCO3] = >180 $mg \cdot L^{-1}$
p Nickel guideline = 25 $\mu g \cdot L^{-1}$ at [CaCO3] = 0–60 $mg \cdot L^{-1}$
= 65 $\mu g \cdot L^{-1}$ at [CaCO3] = 60–120 $mg \cdot L^{-1}$
= 110 $\mu g \cdot L^{-1}$ at [CaCO3] = 120–180 $mg \cdot L^{-1}$
= 150 $\mu g \cdot L^{-1}$ at [CaCO3] = >180 $mg \cdot L^{-1}$
u For protection from direct toxic effects; the guidelines do not consider indirect effects due to eutrophication.
w May not protect fully higher trophic level fish; see factsheet for details.
x Canadian Trigger Ranges (for further narrative see factsheet), Total Phosphorus ($ug \cdot .L^{-1}$):
ultra-oligotrophic <4
oligotrophic 4-10
mesotrophic 10-20
meso-eutrophic 20-35
eutrophic 35-100
hyper-eutrophic >100
z Guideline is expressed as µg nitrite-nitrogen$\cdot L^{-1}$. This value is equivalent to 197 µg nitrite$\cdot L^{-1}$.

7.6.11 Effects Assessment

Groundwater circulates as part of the hydrologic cycle and can contribute significantly to surface water flow. This section describes the interface of project components with groundwater circulation and quality and the resulting effects on surface water flows and quality and the project water balance. This section refers to climate information described in Section 7.1: Climate. The findings of this section have been integrated into the assessment of surface water flows presented in Section 7.4: Surface Water Hydrology, Section 7.5: Surface Water Quality, and Section 2.14: Site Water Management.

7.6.11.1 Scope of Assessment

Issues and Selection of Valued Ecosystem and Cultural Components (VECCs)

Potential effects of the project on groundwater include:

- interception of groundwater flows by pit development with corresponding reductions in groundwater discharge to surface water flows;
- effects on groundwater quality due to exposed ultramafic rock pit walls that are potentially acid generating (PAG);
- effects on quality of surface receiving waters;
- seepage of contaminated water from the Tailings and Ultramafic Waste Rock Management Facility (TWRMF), affecting the quality of shallow groundwater flows; and
- reduction in water table due to pit dewatering.

The main effect of the project on groundwater flows and quality is related to pit development in the Oakley Creek watershed. Accordingly, the focus of this section is to assess how mine dewatering will alter groundwater levels and quality in the vicinity of the mine, as a basis for determining potential effects on surface water flow and water quality in the Oakley Creek watershed. Other potential effects are small, localized and can be readily mitigated. For the Oakley Creek watershed, all potential effects are characterized and mitigation measures are described within this section. All issues pertaining to the effects of the TWRMF on groundwater seepage and quality in the Oakley Creek watershed are presented in Section 2.14: Site Water Management.

Groundwater VECCs were defined for the project environmental assessment based on EAP Report Guidelines and Environmental Baseline Study (EBS) work and initial findings of field investigations. VECCs for groundwater were selected based on potential project effects and linkages to surface water quality and flows as well as related effects on other VECCs (water and sediment quality, aquatic biota, fish, and wildlife habitat ecosystems). Table 7.6-9 presents a summary of the groundwater VECCs that may be affected by mine dewatering.

Table 7.6-9 Groundwater VECCs, Selection Rationale and Data Sources

VECC	Rationale for Selection	Linkage to EAP Report Guidelines or Other Regulatory Drivers	Baseline Data for EAP
Groundwater quality: pH, conductivity, alkalinity, sulphate, metals, and nitrogen compounds (nitrate & ammonia)	• Potential project effects due to open pit development and associated potential for ARD, metals leaching, and blasting residue affecting groundwater quality • Provides input to characterization of changes in chemical characteristics of surface waters	• Linked to CCME, Manitoba Tier II or other guidelines for the protection of aquatic life in surface waters • Monitoring will be required for permitting	2008 field data
Groundwater flows	• Potential project effects due to pit dewatering, effects on downstream groundwater and surface flows in the Oakley Creek basin and input of diverted groundwater flows to the project water balance • Provides input to characterization of effects on flows and chemical loadings to surface waters • Provides design parameters for mine water pumping	• Linked to CCME, Manitoba Tier II or other guidelines for the protection of aquatic life in surface waters • Linked to effects on aquatic habitat in surface waters • Monitoring will be required for permitting	2008 field data

Temporal Boundaries

The timeframe for assessing effects of groundwater encompasses the period of record for the baseline data collection conducted in 2008, full development of the pit during operations (i.e., period of maximum mine dewatering), and closure (i.e., after decommissioning and the restoration of the groundwater table in the mine area). Conditions during each phase are discussed relative to baseline conditions.

Study Area

The local study area (LSA) for assessment of effects of the pit dewatering on groundwater is delineated by the Oakley Creek watershed. Groundwater intercepted by pit development will be pumped to surface where it will be introduced to the ore processing water balance and surplus water will be discharged to the Oakley Creek and the Minago River watersheds (Section 2.14: Site Water Management).

The assessment of potential changes in surface water flows in Oakley Creek and Minago River are discussed in Section 7.4: Surface Water Hydrology and Section 2.14: Site Water Management.

As no other existing or reasonably foreseeable future developments are known, which would result in effects on groundwater in the Oakley Creek or the Minago River drainages, no regional study area for cumulative effects has been defined. A regional study area for effects of the project on surface water flows and quality is detailed in Section 7.4: Surface Water Hydrology.

7.6.11.2 Effects Assessment Methodology

Groundwater extraction to dewater the pit will result in a lowered groundwater table in the vicinity of the site and may result in reduced groundwater discharge to adjacent surface water systems. Baseline conditions representing pre-mining groundwater levels were quantified and groundwater levels during the 2008 pumping test program were recorded and operational dewatering wells yields were estimated based on typical groundwater response, bedrock hydraulic conductivity, site geology, topography and available groundwater monitoring data. The groundwater seepage into the pit was estimated and the number of wells required to attain the required levels during operation were determined.

Effects Attributes for Groundwater

Residual project and cumulative effects on water and sediment quality were characterized using effects attributes defined in Table 7.6-10. Groundwater levels may affect surface water flow and quality, which are discussed in Section 7.4: Surface Water Hydrology and Section 7.5: Surface Water Quality. The ecological, economic and social contexts of effects on groundwater are reflected in the attributes for magnitude of effects on surface water flows, water and sediment quality, and associated effects on aquatic biota, fish and wildlife.

Determination of Effects Significance for Groundwater

A residual project effect on groundwater will be considered significant, if there is an adverse effect of high likelihood, moderate to high magnitude, local to regional in geographic extent, and irreversible.

The significance of project effects on groundwater will also be reflected in the determination of effects significance for other VECCs including surface water quality, hydrology, aquatic resources and wildlife.

Table 7.6-10 Effects Attributes for Pit Dewatering

Attribute	Definition
Direction	
Positive	N/A
Adverse	Large flow of water into the mine and reduced groundwater discharge into surface streams. Change in groundwater quality causing deterioration of water quality in the Polishing Pond.
Neutral	No change in groundwater discharge rate to surface streamflow; no effects on surface water quality.
Magnitude	
Low	Flow: 1 L/s Quality: Change in groundwater quality does not have a measurable effect on surface water quality.
Moderate	Flow: 10 L/s Quality: Change in groundwater quality results is a measurable effect on surface water quality parameter(s), but change does not exceed threshold level (CCME water quality guidelines).
High	Flow: 50 L/s Quality: Change in groundwater quality results is a measurable effect on surface water quality parameter(s), which exceed(s) threshold level (CCME water quality guidelines).
Geographic Extent	
Site-specific	Effect confined to localized reach of affected stream.
Local	Effect extends the length of the affected stream.
Regional	Effect extends downstream of directly affected drainage.
Duration	
Short-term	Less than 1 year
Medium term	1 to 5 years
Long-term	Mine operating period and immediately after closure
Far future	Following closure and/or permanent
Frequency (Short Term duration effects that occur more than once)	
Low	Frequency within range of annual variability and does not pose a serious risk to the VECC or its economic or social/cultural values.
Moderate	Frequency exceeds range of annual variability, but is unlikely to pose a serious risk to the VECC or its economic or social/cultural values.
High	Frequency exceeds range of annual variability and is likely to pose a serious risk to the VECC or its economic or social/cultural values.
Reversibility	
Reversible	Effects on VECC will cease during or after the project is complete.
Irreversible	Effects on VECC will persist during and/or after the project is complete.
Likelihood of Occurrence [1]	
Unknown	Effect on VECC is not well understood and based on potential risk to the VECC or its economic or social/cultural values. Effects will be monitored and adaptive management measures taken, as appropriate.
High	Effect on VECC is well understood and there is a high likelihood of effect on the VECC as predicted.

Note: 1 This attribute characterizes the likelihood that the effect will occur as predicted and as characterized by the effect attributes based on the status of scientific or statistical information, experience and observations of similar cause/effect relationships, and/or professional judgement of the author.

7.6.11.3 Project Effects

7.6.11.3.1 Operations

Effect of Pit Dewatering on Oakley Creek Basin

Results from the pumping tests conducted by Golder Associates in 2008 indicate that there is no hydraulic connection between the limestone aquifer and the Oakley Creek (Golder Associates, 2008b). This is partly due to a thick layer of clay underlying the creek bed. The clay formation has low hydraulic conductivity. Therefore, water flows in the Oakley Creek will not be affected by the pit dewatering activities. In addition, some of the water from the Polishing Pond will be returned back to Oakley Creek during the summer months (Section 2.14: Site Water Management). It is important to note that Oakley Creek is frozen in the winter months.

Dewatering of the pit is not expected to create gradients that could result in drainage of the lakes, creeks and rivers into the pit. Dewatering of the mine is not expected to affect water levels in the adjacent Oakley Creek, Minago River and William River. The lowering of the groundwater table in the pit area during operations is an adverse effect of moderate magnitude, site-specific in extent, long-term in duration and reversible when the pit is closed and dewatering ceases. As noted above, groundwater inflow rates may be higher than the projected average immediately following excavation. Such an occurrence would be an adverse effect, of potentially high magnitude, local in extent, short-term in duration and reversible. The ecological, social and cultural contexts for effects on groundwater relate to associated effects on surface water quality and aquatic habitat. Potential reductions in groundwater discharge to surface streams during low flow periods and in the winter are considered moderate, site specific in extent, long-term in duration and reversible in nature.

Pit Water Quality

Groundwater may increase metal concentrations as a result of acid rock drainage and metal leaching from the pit walls (Section 2.8: Geochemical Rock Characterization). Elevated hydrocarbon concentrations may also be expected from the use and maintenance of mechanized mining equipment and fuel oil in explosives. In addition, pit water will likely be affected by residual nitrogen in the form of nitrates or nitrites from ammonium-nitrate-based explosives. The presence of limestone may also have an effect on pit water chemistry by increasing pH levels (i.e., increasing alkalinity).

Impacted pit water will be pumped to the Polishing Pond during the Nickel Processing Plant operation (Year 1 through 8). During closure, pumping will cease and the pit will flood. No impacts to mine area groundwater quality are expected during the operations phase (Section 2.14: Site Water Management and Section 7.5: Surface Water Quality).

7.6.11.3.2 Closure

Open Pit

The pit will be left in place to flood. During the closure phase, the groundwater table in the pit area is expected to slowly return to pre-mining levels. Based on a total pit volume of 156,700,000 m^3, it could take about 10.7 years to flood the pit after closure (based on 40,000 m^3/day).

Pit Groundwater Quality at Closure

The pit water quality is anticipated to be the same as the baseline conditions. Flooding of the pit will eliminate the potential for ARD and metal leaching.

Pit discharges to the Oakley watershed will be monitored and there are no plans to create a fish habitat using the pit lake, once it is flooded. A barrier will be created to prevent fish movement between the Oakley Creek and the Pit Lake.

Groundwater is not expected to discharge immediately from the pit following closure, as it will take approximately 10.7 years to flood the pit. Initially, there is potential for pit water to contain suspended solids and possibly some metals.

A potential residual project effect is the discharge of metal and TSS contaminated pit water in the Oakley Creek basin at closure. The long water flow path to the Oakley Creek may dilute the potential effects of contaminated waters from the pit.

It is important to mention the potential function of the wetlands in the LSA and the RSA. Other than being one of the most important components of the regional landscape, wetlands play a role that no other ecosystem can provide. Wetlands act as natural water treatment systems. Wetlands tend to slow down the force of water, encouraging the deposition of sediments carried in the water. This is beneficial further downstream where deposition of sediments may block waterways. Nutrients are often associated with sediments and can be deposited at the same time. These nutrients may accumulate in the sub-soil, be transformed by chemical and biological processes or be taken up by wetland vegetation which can then be harvested and effectively removed from the system. Wetland vegetation also plays a role in slowing down the flow of water.

Many wetland plants have the capacity to remove toxic substances that have come from industrial discharges and/or mining activities. Some wetland plants have been found to accumulate heavy metals in their tissues at 100,000 times the concentration in the surrounding water and can detoxify certain kinds of effluent (Ramsar, 2000). Some *Typha* and *Phragmites* species have been used to treat effluents from mining areas that contain high concentrations of heavy metals such as cadmium, zinc, mercury, nickel, copper and vanadium (Higgins and Mattes, 2003) and to treat waters running off roads and highways (Sérodes et al., 2003).

Indeed, wetlands have several functions that aid in the removal of metals in waters. These characteristics are required for certain processes to occur: adsorption and ion exchange, bioaccumulation, bacterial and abiotic oxidation, sedimentation, neutralization, reduction, and dissolution of carbonate minerals (Perry and Kleinmann, 1991; Kadlec and Wallace, 2008).

Wetlands have organic-rich substrates, which exchange dissolved metals. This exchange occurs between the dissolved metals and abundant humic and fulvic acids contained within the substrate (Wildeman et al., 1991). Moreover, especially in bogs, *Sphagnum*'s cation exchange capacity (CEC) is one of the most important mechanisms by which dissolved metals are adsorbed and represents the capacity of a soil to exchange and retain positively charged ions (cations). *Sphagnum* mosses, the main components of peat deposit, are essentially made of polysaccharides (many saccharide units linked by glycosidic bonds) which provide a high CEC and, by the way, a high acidifying capacity (van Breeman, 1995). The high CEC enables an efficient retention of nutrients from the surrounding environment (air and plant decomposition) coupled with the release of H^+ ions. CEC is also an indicator of a soil's capacity to prevent potential contamination of groundwater and surface water since cations such as arsenic, copper, iron, nickel, lead and zinc may also be retained within the peat deposit.

Wetland sediments are generally anoxic or anaerobic below a thin oxidized surface layer and contain organic carbon for microbial growth. The anoxic zone of the sediments provides conditions, which favour microbial and chemical reducing processes. Soluble metals are converted to insoluble forms by the anoxic conditions of wetland sediments. Settling of suspended solids occurs from water velocity control by the wetland's vegetation (Ramsar, 2000).

Processes within natural wetlands have been found to remediate contaminants contained in acid rock drainage (ARD). Kleinmann (1985) found that iron concentrations dropped from 20-25 mg/L to 1 mg/L, manganese concentrations dropped from 30-40 mg/L to 2 mg/L in a *Typha* wetland. *Sphagnum* spp. may also have a significant effect on concentrations of iron, manganese, sulfate, and other mineral concentrations (Kleinmann, 1985; Weider et al., 1985). Plant roots will retain arsenic and other metals (Sobolewski, 1997). Plants also generate microenvironments that assist in the reduction and oxidation processes (Wildeman et al., 1991).

Gabor et al. (2004) and others have demonstrated that wetlands can efficiently remove contaminants from runoff water. Gabor et al. (2004) reported that artificial wetlands have reduced total nitrogen (by 30 to 87%), total phosphorous (by 4 to 90%), suspended solids (by 45 to 99%) and pathogen contents (by 61 to 99%) in waters passing through them. Halverson (2004) reported that wetlands to reduced metal contents by 36 to 98% in runoff waters that contained Ag, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, and Zn.

The effect of discharging potentially contaminated pit water on receiving water quality conditions in the Oakley Creek is expected to be adverse, of low to moderate magnitude, local in extent, and far future in duration and ultimately reversible. Although the discharge of potentially contaminated pit water to surface waters is considered likely after the cessation of mine dewatering, the likelihood of a measurable adverse effect on surface water quality in Oakley Creek is unknown.

Water quality from the pit lake will be monitored to confirm the predictions. Adaptive management measures will be implemented as necessary and monitored. Based on the results of operations phase monitoring, post-closure monitoring may be required to confirm effectiveness of the proposed mitigative measures at closure.

7.6.11.4 Residual Project Effects and Significance

Groundwater Flow

Adverse residual project effects on groundwater will include reduced groundwater table and corresponding reduction in groundwater discharge to surface streams during operations. However, the pit dewatering will not have an effect on the Oakley Creek. At closure, the groundwater table will rise naturally to saturate the open pit.

The residual project effects of mine dewatering on groundwater in the surface streams is therefore characterized as low magnitude, site-specific, far future and reversible when the groundwater table will be restored. The residual project effects on groundwater flows in the Oakley Creek basin are determined to be not significant.

The ecological, social and cultural context of effects for groundwater relates to associated effects on aquatic habitat. Follow-up studies will improve understanding of these effects and the requirement for contingency measures, if any.

Pit Water Quality

Residual adverse project effects on surface water in the Oakley Creek basin are characterized as low to moderate magnitude, local, potentially far future and ultimately reversible. The wetlands will provide additional effluent (pit water) treatment before the water gets into the Oakley Creek and therefore, residual project effects of pit water flows on the Oakley basin are determined to be not significant.

The ecological, social and cultural context of project effects on groundwater quality relate to associated effects on surface water quality and aquatic habitat. If elevated concentrations of contaminants are noted, a corresponding surface water monitoring program will be initiated in Oakley Creek during operations. Monitoring results will improve the understanding of potential effects on aquatic habitat and the requirement for contingency measures, if any, to ensure acceptable water quality for the protection of aquatic life in Oakley Creek.

7.6.11.5 Cumulative Effects

There are no past, existing or foreseeable future activities that would result in effects on groundwater that could overlap with or add to project effects on groundwater. Accordingly, there will be no cumulative effects on groundwater in the project area.

7.6.11.6 Mitigation Measures

Table 7.6-11 presents a summary of potential mitigation measures for project effects on groundwater.

Table 7.6-11 Mitigation Measures for Project Effects on Groundwater

Potential Project Effect	Mitigation Measures
Reduced base flow in Oakley Creek resulting in impacts to aquatic habitat during low flow periods	• Based on follow up studies of effects of potential reduced low flows on fish habitat, evaluate options to reduce groundwater pumping or return more water from the Polishing Pond to the Oakley Creek.
Discharge of pit water contaminants to surface water in Oakley Creek during closure/post closure	• Monitor pit water quality. Based on results, initiate enhanced surface water quality monitoring in Oakley Creek as required. • Evaluate contingency measures for enhanced management of groundwater quality at closure/post closure.
Potential Cumulative Effect	**Mitigation Measures**
None identified.	None

7.6.11.7 Monitoring and Follow-up

Follow-up Studies

No follow-up studies are recommended for groundwater management related to pit dewatering or tailings management.

Monitoring Programs

Monitoring of flow and temperature in Oakley Creek will be done during the operational phase to assess the effects of pit dewatering on surface water hydrology and aquatic habitat. Monitoring of groundwater quality downstream of the pit and surface water quality in Oakley Creek will also be done during operations and following closure.

Ongoing water level monitoring of mine area piezometers and monitoring wells will be done to assess the effects pit dewatering is having on groundwater levels and provide advance warning of potential impacts to adjacent surface water systems. As the pit phases are advanced and mine development progresses, ongoing review of groundwater seepage into the pit and pumping rates will be conducted to refine pit inflow estimates, improve the hydrogeologic model and better assess potential impacts to adjacent surface water streams. In addition, collection of climate data such as precipitation and temperature will continue.

Table 7.6-12 presents a summary of the proposed monitoring and follow-up programs for groundwater.

7.6.11.8 Summary of Effects

Table 7.6-13 provides a summary of effects related to pit groundwater extraction.

Table 7.6-12 Monitoring and Follow-up Programs for Mine Groundwater

Potential Project Effect	Program Objectives	General Methods	Reporting	Implementation
Follow-Up Programs				
N/A	N/A	N/A	N/A	N/A
Monitoring Programs				
Reduced base flow in Oakley Creek resulting in impacts to aquatic habitat	Determine if mine dewatering is affecting water quantity and quality in Oakley Creek	Year-round (i.e., monthly) monitoring of flow, temperature and water quality in Oakley Creek.	Manitoba Gov.'t as required	Proponent
	Provide advance warning of impacts to surface water hydrology	Monitoring of water levels in mine area piezometers and recording of dewatering pumping rates.	Manitoba Gov.'t as required	Proponent
	Estimate infiltration and predict impacts to surface water hydrology	Recording of climate data such as precipitation and temperature.	Manitoba Gov.'t as required	Proponent
Discharge of contaminants to surface water in Oakley Creek watershed	Determine if water quality is being affected by discharge of pit water following closure	Monitoring of pit water and surface water quality in Oakley Creek.	Manitoba Gov.'t as required	Proponent
Follow-Up Programs				
N/A	N/A	N/A	N/A	N/A
Monitoring Programs				
N/A	N/A	N/A	N/A	N/A

Note: N/A not applicable

Table 7.6-13 Summary of Effects Related to Pit Groundwater Extraction

Potential Effect	Level of Effect[1]						Effect Rating	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Like-lihood	Project Effect	Cumulative Effect
Construction, Operations and Decommissioning								
Pit dewatering resulting in groundwater table depression and reduced base flows in Oakley Creek	Adverse	Low	Local	Long-term	Reversible	High	Not significant	N/A
Closure								
Flooding of Pit and gradual recovery of groundwater levels and base flows in Oakley Creek	Adverse	Low	Local	Long-term	Reversible	High	Not significant	N/A
Contaminated Pit water from flooded Pit discharging to Oakley Creek basin and ultimately to Oakley Creek	Adverse	Low to moderate	Local	Far future	Reversible	Unknown	Not significant	N/A

Notes: 1 Based on criteria in Table 7.6-10 (Effects Attributes for Pit Dewatering).

N/A = not applicable

7.7 Benthos, Periphyton and Sediment Quality

As part of the environmental baseline studies, natural background metal concentrations in sediments and benthic communities were determined as high metal concentrations are common in mineralized areas. Analysis of benthic invertebrates is typically conducted to determine longer term, sub-lethal impacts that may not be apparent using standard water quality monitoring programs. Establishing background concentrations is essential to ensure that the impact of mine development will be assessed properly.

Sediment quality and benthic communities were assessed in 2006, 2007 and 2008 at the Minago Property according to Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring (Environment Canada, 2002b). In 2006, Wardrop collected five (5) replicate sediment samples from Oakley Creek (at OCW-1, OCW-2, OCW-3) and Minago River (at MRW-1), identified all organisms in each sample to family, and calculated the Simpson's Index of Diversity, Evenness,Taxon Richness, and the Bray-Curtis distance (Table 7.7-1 and Figure 7.7-1) (Wardrop, 2007). URS conducted a stream sediment and benthic invertebrate sampling program at nine locations in the vicinity of the Minago Project in 2007 (URS, 2008h). The analysis of benthic invertebrate communities was conducted using a variety of biological indices and statistics to evaluate the difference between sampling sites and between populations as well as the general quality of the aquatic habitat. In 2008, Roche collected sediment samples from six (6) stations (Cross Lake (CLF1), Hill Lake (HLF1), Limestone Bay (LBF1), Minago River (MRF3), William River (WRF3) and Oakley Creek (OCF1)) (Table 7.7-1 and Figure 7.7-1) (Roche, 2008a). They collected benthic samples from the same locations, except from HLF1 and measured key parameters related to invertebrate habitats.

7.7.1 Relevant Guidelines

Relevant sediment guidelines for the Minago Project include the *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life* (CCME, 2002). The intent and application of these guidelines are summarized below, but detailed guideline concentration limits are presented as part of the discussion of sediment quality results.

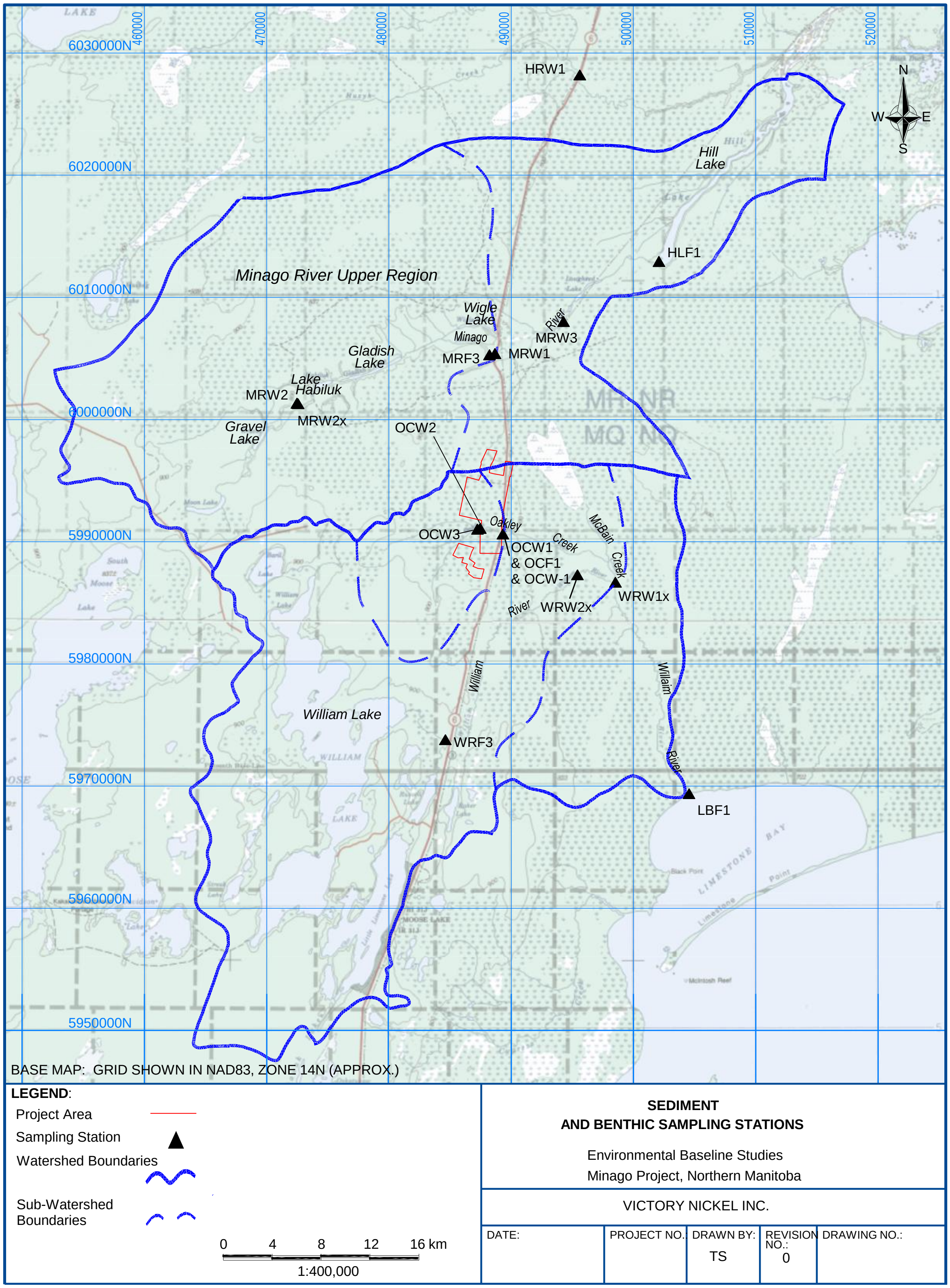
7.7.1.1 Canadian Sediment Quality Guidelines for the Protection of Aquatic Life

The *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life*, which includes the Interim Freshwater Quality Guidelines (ISQGs) and the Probable Effect Levels (PELs), provide a flexible interpretive tool for evaluating the toxicological significance of sediment chemistry data, as well as for prioritizing actions and management decisions (CCME, 2002). Sediment chemical concentrations below the Sediment Quality Guidelines are not expected to be associated with any adverse biological effects; however, concentrations above the probable effect levels are expected to be frequently associated with adverse biological effects. Chemical concentrations between the Sediment Quality Guidelines and probable effect levels represent the range in which effects are

Table 7.7-1 Nomenclature and Coordinates of Sediment and Benthic Invertebrates Monitoring Stations

Sample Location	UTM Northing	UTM Easting	Description	Sampled by: Wardrop (2007)	URS (2008h)	Roche (2008a)
OCW-1	5990528	489238	Oakley Creek immediately east of HW6	X		
OCW1, OCF1	5990510	489322	Oakley Creek east of HW6		X	X
OCW-2 & OCW2	5990974	487559	Approx. 2.2 km upstream of OCW-1	X	X	
OCW-3	5990931	487048	Oakley Creek upstream of confluence of tributary	X		
OCW3	5990892	487230	Oakley Creek upstream of confluence of north tributary		X	
MRW-1 & MRW1	6005275	488684	Minago River at the Highway 6 crossing, approximately 15 km north of Oakley Creek.	X	X	
MRW2	6001212	472476	Minago River near Habiluk Lake		X	
MRW3	6007895	494274	Minago River downstream of Highway 6 near powerline cut		X	
MRF3	6005308	488362	Minago River location upstream of Highway 6			X
HRW1	6028072	495606	Hargrave River immediately west of Highway 6		X	
WRW1x (formerly WRW2)	5986554	498523	William River approx. 100 m downstream of the Oakley Creek confluence		X	
WRW2x (formerly WRW1)	5987162	495416	William River approx. 6 km upstream of the Oakley Creek confluence		X	
WRF3	5973598	484762	William River immediately downstream of Little Limestone Lake outlet stream.			X
CLF1	6046198	555324	Cross Lake			X
HLF1	6012816	502060	Hill Lake			X
LBF1	5969136	503911	Limestone Bay			X

Source: Wardrop, 2007; URS, 2008h; Roche, 2008a



Source: adapted from URS, 2008h

Figure 7.7-1 Monitoring Locations for Sediments and Benthic Communities

occasionally observed. These two values provide practical means to characterize sites as of minimal, potential, or significant toxicological concern in order to focus further investigations.

The guidelines should not be regarded as blanket values for national sediment quality. Variations in environmental conditions across Canada will affect sediment quality in different ways and many of the guidelines may need to be modified according to local conditions such as assimilative capacity, sensitivity of endangered species and habitat (CCME, 2002).

7.7.2 Scope of Assessment

7.7.2.1 Scope and Methodology of 2006 Sediment and Benthic Invertebrates Assessments

In 2006, Wardrop collected bulk sediment samples at stations OCW-1, OCW-2, and OCW-3 using a stainless steel Ekman dredge (15.2 cm x 15.2 cm mouth size, 22.9 cm tall) (Table 7.7-1) (Wardrop, 2007). Samples for chemical analysis were taken from the bulk sediment samples using a 5 cm diameter cellulose-acetate-butyrate (CAB) core tube pressed 5 cm into the sediment in the dredge. Up to three core sub-samples were taken from each bulk dredge sample, with a total of eight core sub-samples taken and pooled to comprise a replicate sample for analysis. Five of these replicate samples were collected per station. The samples were kept refrigerated or on ice from the time of collection until delivery to Maxxam Analytics (Calgary, AB). Sediments were analyzed for total metals, moisture content, organic matter, total organic carbon, and hot water soluble boron.

Wardrop also collected five replicate sediment samples for benthic assessments at stations OCW-1, OCW-2, OCW-3 and MRW-1 using a stainless steel Ekman dredge (Table 7.7-1) (Wardrop, 2007). Samples were field-sieved using a 500-µm mesh-size screen to remove sediment. The retained organisms were transferred to a polyethylene zipper lock bag and preserved in 10% buffered formalin. Samples were sent to the ALS Laboratory Group in Winnipeg for analysis. All organisms in each sample were identified and counted. Organisms were typically identified to family, with the following exceptions:

- Hydracarina, Copepoda and Araneae were identified to order; and,
- Nematoda were identified to phylum.

Specimens damaged during sampling were identified to the nearest possible taxonomic level. The Simpson's Index of Diversity, Evenness, Taxon Richness, and the Bray-Curtis distance were calculated according to methods detailed in Environment Canada (2002b).

7.7.2.2 Scope and Methodology of 2007 Sediment and Benthic Invertebrates Assessments

In 2007, URS conducted a stream sediment and benthic invertebrate sampling program at nine locations in the vicinity of the Minago Project from August 13 to 16, 2007 (URS, 2008h). The overall scope of work for that program involved the following tasks:

- establishing pre-mining disturbance baseline conditions of existing stream sediment quality and benthic communities;
- establishing sediment quality and benthic invertebrate baseline condition for monitoring in future years during mine development and operation to assess potential impacts on the aquatic environment.

The analysis of benthic invertebrate communities was conducted using a variety of biological indices and statistics to evaluate the difference between sampling sites and between populations as well as the general quality of the aquatic habitat.

Field Methods:

From August 13 to 16, 2007, URS collected one sediment and three replicate benthic invertebrate samples at each of the nine sampling locations using a Ponar sediment sampler that had a sampling area of 0.02 m^2. To distinguish natural versus human influence, invertebrate samples were also collected at a reference site (HRW1 on Hargrave River) north of the project area (Table 7.7-1). Sampling methodology was based on the 'Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring' (Environment Canada, 2002b) and the field manual, entitled 'Field Guidelines - Benthic Sampling Protocol, Integrated Resources Consultants (IRC)', dated July 2007 and given in Appendix 7.7.

The monitoring sites are given below and more details are provided in Table 7.7-1:

- William River: WRW1X (downstream site), WRW2X (upstream site);
- Oakley Creek: OCW1 (downstream site), OCW2 (upstream site), OCW3 (upstream site);
- Minago River: MRW1 (downstream site), MRW2 (upstream site) and MRW3 (downstream site); and
- Hargrave River (Reference Site): HRW1.

Each sample was delicately transferred into 1 litre sampling containers provided by Integrated Resource Consultants Inc. (IRC) of Richmond, BC and preserved using 10% formaldehyde prior to shipping to IRC's laboratory for analysis. IRC analyzed the samples using their internal standard methods for preservation and identification. IRC tabulated benthic communities into the following taxons and their associated families: Insecta, Arachnida, Acarina, Crustacea, Annelida, Mollusca, Nematoda, and Cnidaria. Sediment samples collected during August 2007 in the

Minago Project Area were submitted to ALS Laboratories in Vancouver, BC, for analysis of moisture content, pH, total metals, organic carbon and particle size.

7.7.2.3 Scope and Methodology of 2008 Sediment and Benthic Invertebrates Assessments

The main objective of Roche's 2008 sediment and benthic invertebrates assessment program was to determine the actual specific composition of the sediments and benthic community living in the freshwater system (i.e., document the presence/absence of benthic families in water bodies that will likely be affected by the Minago Project) and to determine the basic biological characteristics of the benthic community (total invertebrate density, taxonomic richness, Simpson's diversity index, Bray-Curtis distance). Moreover, the basic biological characteristics of the major taxa were documented. The objectives, methodology and results of the program are detailed in Roche (2008a).

Roche collected sediment samples with a Ponar grab and a 500 µm strainer from an area of approximately 0.05 m^2 (Roche, 2008a). Their sampling methodology was based on the 'Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring' (Environment Canada, 2002b). Collected sediment samples were stored and preserved in bottles provided by Bodycote Laboratories. Sediment samples were tested for the following parameters: total organic carbon, particle size distribution and metal content (arsenic, cadmium, chromium, cobalt, copper, iron, manganese, magnesium, mercury, molybdenum, selenium, zinc, nickel and lead).

Roche collected sediment samples from the following six (6) locations: Cross Lake (CLF1), Hill Lake (HLF1), Limestone Bay (LBF1), Minago River (MRF3), William River (WRF3) and Oakley Creek (OCF1). Roche also collected samples for benthic assessments from all of these locations with exception of Hill Lake (HLF1) (Table 7.7-1 and Figure 7.7-1).

The benthic organisms, with exception of nematodes, were fixed for at least 72 hours in a 10% formaldehyde solution and then transferred in a 70% ethanol solution for preservation until their identification was done up to the family level, at an accredited laboratory. Laboratoires SAB Inc. was in charge of the analysis of all collected benthic samples. Methods and results, including for the quality control test, are detailed in Appendix 7.7 and laboratory certified reports are given in Appendix L7.7. A reference collection was built up for consistency in taxonomic identifications between benthic assessments.

For each replicate station sampled, key parameters related to invertebrate habitats were measured according to Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring. These parameters included:

- water depth.
- water temperature;
- pH;
- type of substratum (clay, silt, sand) gravel, organic);
- conductivity;
- dissolved oxygen;

- alkalinity;
- nutrients;
- riparian vegetation;
- turbidity;
- fine sediment particle size and total organic carbon;
- canopy cover (%).

In 2008, Roche implemented some specific measures to assess the biological characteristics of the benthic invertebrate communities. Nematodes were considered to be a distinct category as it is the case for the other families and an abundance of 1 was attributed to Spongillidae colonies.

7.7.2.4 Sediment Quality Results

7.7.2.4.1 Sediment Quality for the 2006 and 2007 Field Programs

The average sediment quality results for samples collected from watercourses surrounding the Minago Project in 2006 and 2007 are listed in Table 7.7-2. Detailed results, summarized in spreadsheet format, are given in Appendix 7.7 and detailed laboratory certified reports and quality control results are presented in Appendix L7.7.

Sediment pH levels ranged from 6.88 to 8.45 and the average pH was 7.8 (alkaline) (Wardrop, 2007). The only sediment that had a pH value less than 7 was located at OCW-3 (Table 7.7-2). In all rivers and creeks (Minago River, Oakley Creek and William River) in the Minago Project Area, the sediment pH was lowest at the upstream site and increased to the highest at the downstream site.

Average moisture content in tested sediment samples ranged from 42.4% to 82.6% (Table 7.7-2).

The organic matter content ranged from a minimum of 7.72% at OCW-1 to a maximum of 30.5% at OCW-3. The average total organic carbon (TOC) content ranged from a minimum of 4.5% at OCW-1 to a maximum of 17.7% at OCW-3 in 2006 (Table 7.7-2, Figure 7.7-2). Based on 2006 results, the ratio of organic matter to total organic carbon ranged from 1.69 to 1.8 (Wardrop, 2007).

Only total chromium exceeded the CCME (2002) Interim Freshwater Sediment Quality Guidelines (ISQGs). Average chromium levels, based on 5 replicate samples, were higher than the ISQGs level of 37.3 mg/kg at OCW-1, OCW-2, OCW-3 and MRW-1 in 2006 (Table 7.7-2 and Figure 7.7-3). In 2006, average chromium concentrations were 38.4 mg/kg at OCW-2, 39.8 mg/kg at OCW-3, 69.2 mg/kg at MRW-1, and 71 mg/kg at OCW-1 (Wardrop, 2007). In 2007, the chromium level, based on one sample per monitoring station, exceeded the ISQG at MRW2. In 2007, the chromium concentration ranged from a minimum of 9.9 mg/kg at MRW3 to a maximum of 39.2 mg/kg at MRW2 (Appendix 7.7) (URS, 2008h). It is important to note that chromium did not exceed CCME (2007) criteria for surface water quality (Section 7.5).

Table 7.7-2 Average Sediment Quality in Watercourses surrounding the Minago Project

Sample ID / Sampling Date / COC Number / Lab ID		OCW-1 Average [1]	OCW-1 Coefficient of Variation	OCW-2 Average [1]	OCW-2 Coefficient of Variation	OCW-3 Average [1]	OCW-3 Coefficient of Variation	MRW-1 Average [1]	MRW-1 Coefficient of Variation	All 2007 Stations Average [1]	All 2007 Stations Coefficient of Variation %	REGULATIONS: Canadian Sediment Quality of Aquatic Life (CCME, 2002) ISQG	PEL
Sampling Date		19-20 Sept 2006	19-20 Sept 2006 %	19-20 Sept 2006	19-20 Sept 2006 %	19-20 Sept 2006	19-20 Sept 2006 %	19-20 Sept 2006	19-20 Sept 2006 %	16-Aug-07	16-Aug-07		
Depth	**Units**									0-0.2 m			
Moisture	%	47.8	38%	77.5	5%	81.4	4%	82.6	7%	42.4	56%		
pH										7.8	8%		
Organic Matter	%	7.72	99%	25.3	28%	30.5	18%	21.5	25%				
Total Organic Carbon (C)	%	4.48	99%	14.7	27%	17.7	18%	12.5	25%	7.2	113%		
Soluble (Hot water) Boron (B)	mg/kg	0.4	47%	0.8	17%	1.0	13%	1.9	26%				
Elements													
Total Aluminum (Al)	mg/kg	15,498	31%	3,970	14%	4,252	22%	12,050	32%				
Total Antimony (Sb)	mg/kg	0.5	0%	0.5	0%	0.5	0%	0.5	0%	0.5	0%		
Total Arsenic (As)	mg/kg	2.8	53%	0.7	39%	1.4	39%	2.8	39%	2.5	0%	**5.9**	**17**
Total Barium (Ba)	mg/kg	131	21%	61	9%	94	21%	112	34%	74.5	60%		
Total Beryllium (Be)	mg/kg	0.78	36%	0.2	0%	0.2	0%	0.58	49%	0.4	50%		
Total Boron (B)	mg/kg	9.4	19%	5.8	8%	9	24%	12.4	19%				
Total Cadmium (Cd)	mg/kg	0.68	32%	0.34	16%	0.4	31%	0.54	43%	0.25	0%	**0.6**	**3.5**
Total Chromium (Cr)	mg/kg	**71**	17%	**38.4**	9%	**39.8**	7%	**69.2**	17%	21.6	55%	**37.3**	**90**
Total Cobalt (Co)	mg/kg	13	30%	4	18%	5	12%	11	33%	6	62%		
Total Copper (Cu)	mg/kg	18	40%	3	0%	3	37%	14	39%	10	56%		
Total Iron (Fe)	mg/kg	17,140	25%	6,036	7%	7,954	13%	14,640	27%				
Total Lead (Pb)	mg/kg	10	32%	3	0%	4	22%	10	32%	15	0%	**35**	**91.3**
Total Lithium (Li)	mg/kg	22	31%	1	0%	1	0%	17	36%				
Total Manganese (Mn)	mg/kg	381	24%	244	30%	319	35%	294	49%				
Total Mercury (Hg)	mg/kg	0.025	0%	0.025	0%	0.13	34%	0.032	49%	0.026	74%	**0.17**	**0.486**
Total Molybdenum (Mo)	mg/kg	0.2	0%	0.2	0%	0.2	0%	0.32	51%	2	0%		
Total Nickel (Ni)	mg/kg	34	32%	8	14%	11	17%	28	32%	15	61%		
Total Phosphorus (P)	mg/kg	404	15%	313	9%	459	11%	567	27%				
Total Selenium (Se)	mg/kg	0.25	0%	0.54	50%	0.96	42%	0.25	0%	1.4	47%		
Total Silver (Ag)	mg/kg	0.5	0%	0.5	0%	0.5	0%	0.5	0%	1	0%		
Total Strontium (Sr)	mg/kg	30	33%	17	5%	23	17%	24	22%				
Total Thallium (Tl)	mg/kg	0.18	37%	0.15	0%	0.15	0%	0.15	0%	0.5	0%		
Total Tin (Sn)	mg/kg	1.2	130%	0.5	0%	0.5	0%	1.1	50%	2.5	0%		
Total Uranium (U)	mg/kg	0.8	34%	0.7	39%	2	0%	2	35%				
Total Vanadium (V)	mg/kg	45	34%	10	15%	10	20%	37	33%	23	54%		
Total Zinc (Zn)	mg/kg	67	18%	23	16%	35	22%	76	31%	32	56%	**123**	**315**

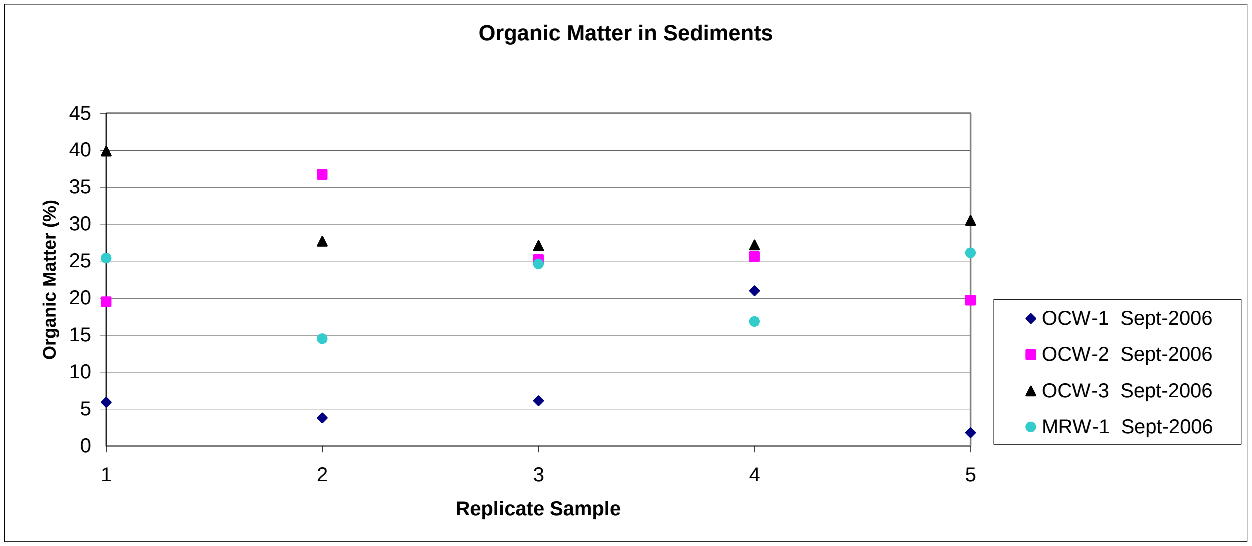
NOTES:

1 If the sample concentration was less than the detection limit, half the detection limit was used to compute the average.

ISQG Interim freshwater sediment quality guidelines

PEL Probable effects levels

0.0056 Bold and underlined number is exceeding guideline value.



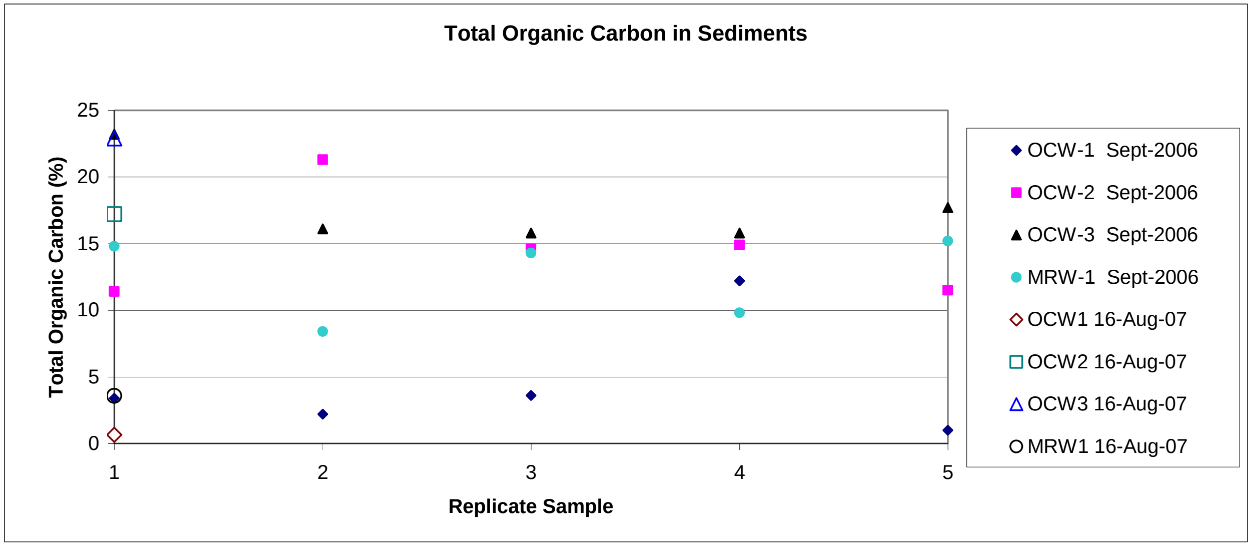


Figure 7.7-2 Organic Matter and Total Oganic Carbon in Watercourse Sediments

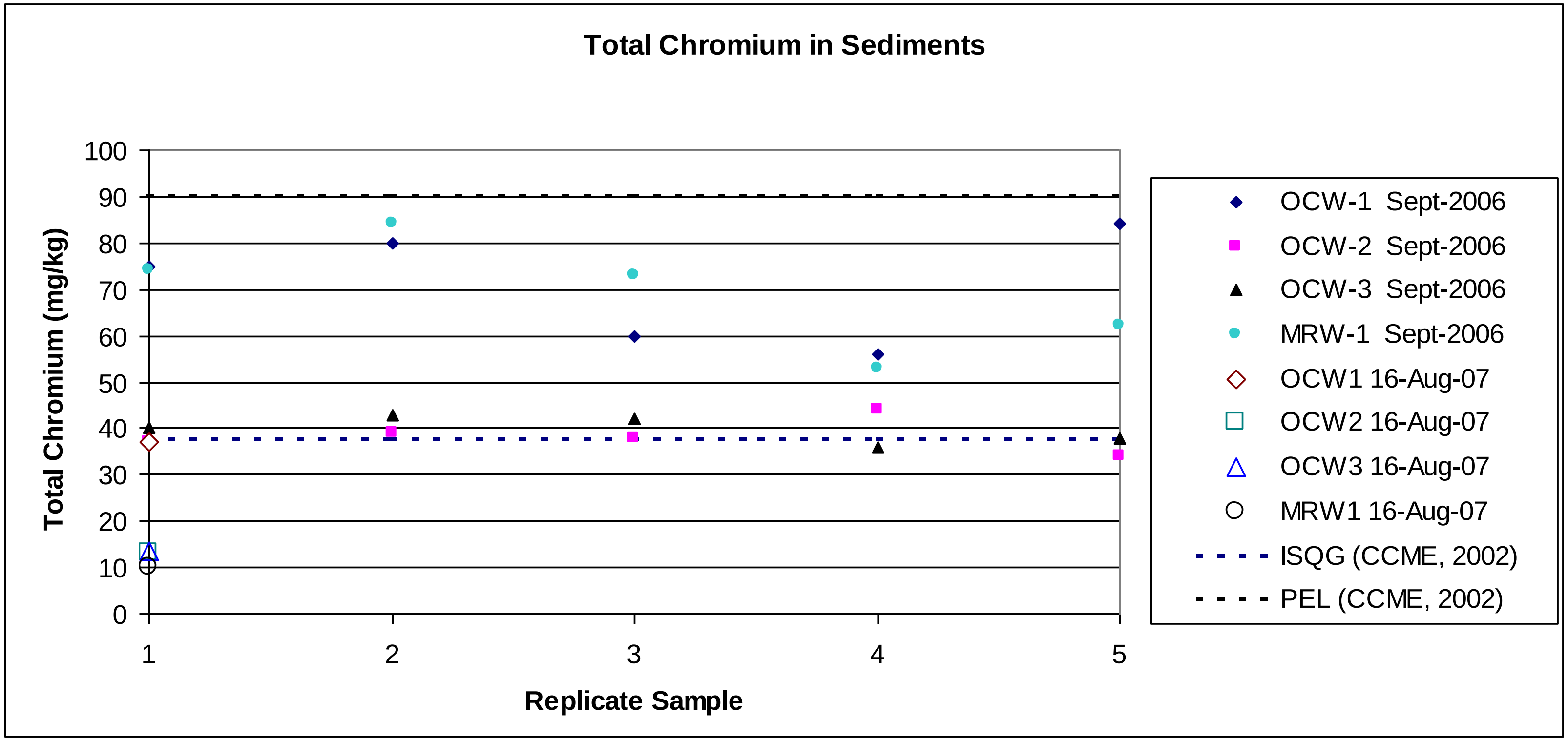


Figure 7.7-3 Total Chromium in Watercourse Sediments (mg/kg)

Chromium (Cr) is an essential trace element that can be toxic to aquatic biota at elevated concentrations. Chromium exists in two oxidation states in aquatic systems: hexavalent Cr (i.e., Cr^{6+}) and trivalent Cr (i.e., Cr^{3+}). Independent assessments of the potential for toxicity of Cr^{6+} and Cr^{3+} in the Canadian environment were carried out according to the *Canadian Environmental Protection Act* (CEPA). The CEPA assessment reported that dissolved and soluble forms of Cr^{6+} may have, a harmful effect on the environment (Government of Canada, 1994). However, for Cr^{3+}, the CEPA assessment reported that it was not possible to determine whether dissolved and soluble forms were entering the Canadian environment according to the above conditions (Government of Canada, 1994).

The majority of the data used to derive ISQGs and probable effects levels (PELs) for Cr are from studies on field-collected sediments that measured concentrations of Cr, along with concentrations of other chemicals, and associated biological effects, as compiled in the Biological Effects Database for Sediments (BEDS) (Environment Canada, 1998). In most studies that evaluated the distribution of Cr in the environment, only total Cr was measured; little information was provided on the species of Cr present in the sediment. However, results of recent studies in Canada and other countries, indicate that Cr^{6+} is the dominant form in the dissolved phase, whereas nearly all of the Cr in sediments (excluding that immediately below the sediment–water interface with overlying aerobic waters) is likely present in the form of Cr^{3+} (Government of Canada, 1994).

Concentrations of Cr in marine and freshwater sediments vary substantially across Canada (Environment Canada, 1998). In the National Geochemical Reconnaissance (NGR) program database by the Geological Survey of Canada (GSC) (Friske and Hornbrook, 1991), the mean background concentrations in lake and stream sediments are 47 mg/kg and 81 mg/kg, respectively (CCME, 1999). When compared with concentrations in the combined lake and stream NGR database (n = 51,311), the freshwater ISQG and PEL for Cr fall at percentiles 38.6 and 83, respectively, of background concentrations (CCME, 1999). Background concentrations of Cr across most of Canada are higher than the ISQG of 37.3 mg/kg. This situation may be explained in part by the different digestion methods used in deriving ISQGs and PELs versus those used in determining concentrations of metals for the NGR database.

Currently, the degree to which Cr will be bioavailable at particular sites cannot be predicted conclusively from the physicochemical characteristics of the sediments or the attributes of endemic organisms (Environment Canada, 1998).

The average aluminum concentrations in Minago sediments were 15.5 mg/kg at OCW-1, 12.1 mg/kg at MRW-1, 4 mg/kg at OCW-2, and 4.3 mg/kg at OCW-3 in 2006 (Table 7.7-2). The average iron concentrations in the sediments were 17.1 mg/kg at OCW-1, 14.6 mg/kg at MRW-1, 8 mg/kg at OCW-3 and 6 mg/kg at OCW-2.

More than 95% of the mineral fractions of examined sediments were finer than 2 mm. Only two locations, OCW1 (downstream) on Oakley Creek and MRW1 (downstream) on the Minago River, contained substrate coarser than sand (> 2 mm) (Figure 7.7-4).

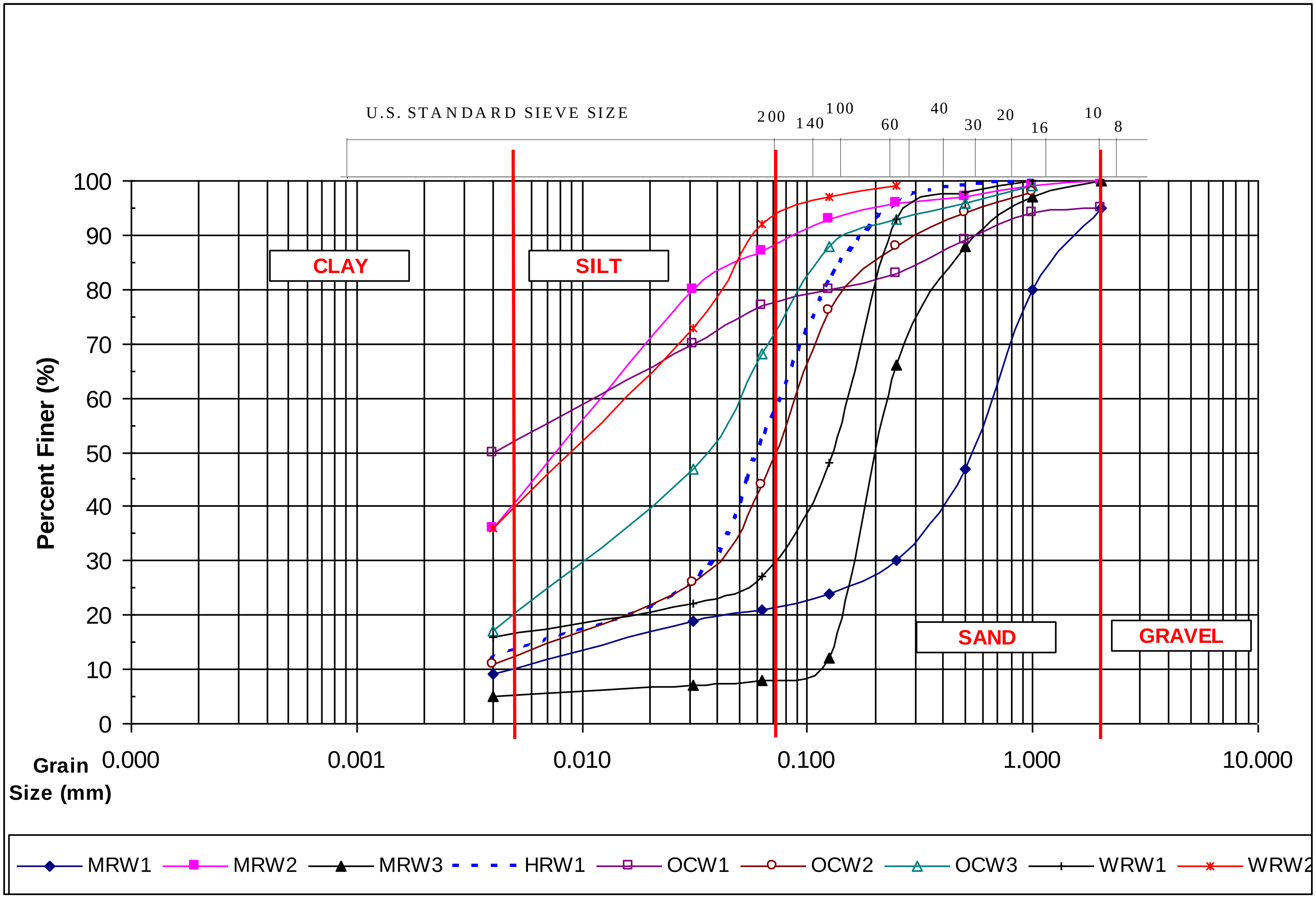


Figure 7.7-4 Particle Size Distribution of Watercourse Sediments in the Vicinity of the Minago Project

(using AASHTO classification for clay, silt, sand and gravel)

7.7.2.4.2 Sediment Quality for the 2008 Field Program

Table 7.7-3 shows key parameters of the 2008 sediment and benthic monitoring locations (Figure 7.7-1). None of the measured water quality parameters for surface water exceeded CCME (2007) criteria for the protection of aquatic life. However, at the Minago River sampling station, arsenic and chromium contents in sediments exceeded Interim Freshwater Sediments Quality Guidelines (ISQGs). In both cases, concentrations were lower than the probable effect level (PEL). At MRF3, other metals concentrations were also higher.

Total organic carbon (TOC) has a major influence on both the chemical and biological processes that take place in sediments. The amount of organic carbon influences the redox potential in sediments, thus regulating the behaviour of other chemical species such as metals. Since organic matter is a primary source of food for benthic organisms, it is important in maintaining a viable ecosystem. However, too much organic matter can lead to the depletion of oxygen in the sediments and overlying water, which can have a deleterious effect on benthic and fish communities (Hyland et al., 2000).

At Minago, TOC values were in most cases under 4% and sediment quality did not appear to be a limiting factor for the viability of benthic communities. However, in Limestone Bay and Oakley Creek, TOC concentrations ranged from 19.4 to 23.3%, indicating a possible deleterious effect on benthic invertebrates (Roche, 2008a).

7.7.3 Baseline Conditions - Benthic Invertebrates and Periphytons

The benthic invertebrate communities collected in samples for the Minago Project were enumerated using a variety of statistics and indices, detailed below, in order to assess the aquatic habitat quality, as well as to identify differences between sampling sites, and populations. The analysis of benthic invertebrate communities permits an assessment of long-term, sub-lethal effects that cannot be determined using standard water quality sampling as the sole indicator.

7.7.3.1 Biological Indices and Data Interpretation

A benthic community may be analyzed and interpreted in terms of general health using indicators of abundance and metrics of richness.

Dominance - Natural biological communities include groups of organisms that are not equally successful. This variability is a function of competition for biotic/abiotic resources in the environment. A few organisms may dominate a community with the spectrum extending to groups of intermediate abundance and, finally, to rare organisms. In order to measure the relevant abundance of biological samples a Dominance Index was proposed by Simpson in 1949. The output of the Simpson Index is used to evaluate the dominance of one taxonomic group over the rest of the population data.

Table 7.7-3 Surface Water and Sediments Quality Results for the 2008 Program

Parameters	Units	Method detection limit	Canada: Surface water quality criteria for the protection of aquatic life (CCME) [1]	Canada - CCME [2] Sediment Quality Guidelines for the protection of aquatic life: Interim freshwater sediment quality guidelines (ISQGs)	Canada - CCME [2] Sediment Quality Guidelines for the protection of aquatic life: Probable Effect Level (PEL)	Stations: LBF-1	OCF-1	MRF-3	WRF-3	CLF-1
Station characteristics										
Sampling site						Limestone Bay	Oakley Creek	Minago River	William River	Cross Lake
Certificate of analysis number						08-259707	08-259707	08-259707	08-259707	08-261093
Sample number				-		1184152	1184154	1184155	1184156	1188980
Sampling Date						2008-05-08	2008-05-08	2008-05-08	2008-05-08	2008-05-09
UTM (NAD 83) East						503911	489238	488362	484762	555324
UTM (NAD 83) North						5969136	5990528	6005308	5973598	6046198
***In situ* measurements (Surface water)**										
Depth of the station	meters	-	-	-	-	0.74	0.64	0.61	0.61	4.20
Sample collection depth	meters	-	-	-	-	0.74	0.64	0.61	0.61	4.20
Dissolved oxygen	mg/L	-	<5.5-9.5	-	-	12.10	10.83	10.27	10.35	11.91
Dissolved oxygen	%	-	narrative	-	-	94.8	81.1	83.2	84.8	91.7
Water temperature	°C	-	narrative	-	-	5.0	3.1	6.8	6.6	4.2
Conductivity	µS/cm	-	-	-	-	240.0	230.0	134.0	290.0	178.3
pH	pH units	-	6.5 - 9	-	-	7.98	7.65	7.53	8.27	7.85
Particle size distribution (Sediments)										
< 4 µm clay	%	-	-	-	-	2.2	14.4	24.6	2.0	25.5
4 to 60 µm silt	%	-	-	-	-	28.4	31.8	33.5	6.6	38.7
60 to 200 µm fine sand	%	-	-	-	-	58.2	23.1	16.2	13.0	24.6
200 to 2000 µm coarse sand	%	-	-	-	-	11.2	23.3	11.7	27.4	10.2
> 2000 µm gravel	%	-	-	-	-	0.0	7.4	14.0	51.0	1.0
Organic compounds (Sediments)										
Total organic carbon	%C	0.01	-	-	-	23.30	19.40	3.82	0.74	1.61
Metals and metalloids (Sediments)										
Arsenic	mg/kg	0.5	-	5.9	17	1.9	2.1	**5.9**	1.3	4.4
Cadmium	mg/kg	0.4	-	0.6	3.5	0.09	0.12	0.20	0.04	0.05
Chromium	mg/kg	2	-	37.3	90	12	27	**51**	14	37
Cobalt	mg/kg	2	-	-	-	4	9	15	5	13
Copper	mg/kg	1	-	35.7	197	5	11	23	6	16
Iron	mg/kg	10	-	-	-	6800	17000	32000	7800	24000
Lead	mg/kg	5	-	35.0	91.3	< 5	9	34	<5	11
Magnesium	mg/kg	5	-			7400	9700	24000	12000	14000
Manganese	mg/kg	1	-	-	-	200	710	830	170	560
Mercury	mg/kg	0.01	-	0.17	0.486	0.03	0.05	0.04	0.02	0.04
Molybdenum	mg/kg	2	-	-	-	< 1	< 1	< 1	< 1	< 1
Nickel	mg/kg	2	-	-	-	8	17	35	9	25
Selenium	mg/kg	0.1	-	-	-	0.3	0.5	0.3	0.1	0.1
Zinc	mg/kg	5	-	123	315	21	59	110	23	58
Total volatile solids (wet weight)	mg/kg	1000	-	-	-	87000	96000	59000	16000	-
Total volatile solids (wet weight)	%	0.1	-	-	-	8.7	9.6	5.9	1.6	-
Total volatile solids (dry weight)	mg/kg	1000	-	-	-	210000	350000	110000	19000	-
Total volatile solids (dry weight)	%	0.1	-	-	-	21.0	35.0	11.0	1.9	-

(shaded box) Value does not respect the canadian guideline for the protection of aquatic life - surface water

Bold Value exceeding criteria for the protection of aquatic life - Sediments (ISQGs)

[1] Canadian Council of the Ministers of Environment. 2007. Canadian Guidelines for the Protection of Environment.

[2] Canadian Council of the Ministers of Environment. 2002. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life.

Source: adapted from Roche, 2008a

Simpson's Index – The Simpson's index depends on both the abundance and the taxonomic richness. It is calculated using the following formula:

$$D = 1 - \sum_{i=1}^{S} (p_i)^2$$

with *D* corresponding to Simpson's index, *S* being the total amount of taxa at the station and p_i being the relative abundance of the i^{th} taxa at the station.

The Simpson's index ranges from 0 to 1. A community with only one taxa would score 0 while a community showing an infinite number of taxa all being equally abundant would score 1. The maximal value which can be obtain is proportional to the amount of taxa (for example, 4 taxa with a relative abundance of 25%, *D* = 0.75 and 5 taxa with a relative abundance of 20%, *D* = 0.8). The advantage of employing this index is that it provides a single objective value describing proportionate relationships of various categories of invertebrates being considered in the analysis.

Density and Relative Abundance - For each taxa, the density was calculated using the average amount of invertebrates and the sampled area. The total density (all taxa) was also calculated for each sampling station. Taxa's relative abundance at each station may be calculated by dividing one taxa's density by the total density.

Shannon-Weaver Diversity Index - The Shannon-Weaver diversity index provides a valuable tool to evaluate community complexity, which can be expressed as equitability, evenness, or diversity of a population (URS, 2008h). The Shannon-Weaver Diversity Index is an adaptation of the communication engineering theories created by Shannon-Weaver (1949), Margalef (1958) and MacArthur (1955), which is applied to biological systems such as benthic invertebrate communities. The Shannon-Weaver function is based on the theory that the greater the source of information is, the greater the resulting variability will be.

Equitability Index – The measures of community complexity (equitability, evenness, or diversity of a population) are calculated based on how the individuals in a population are distributed between the sampled taxa and how many different taxa are found in each sample. Pielou (1966) found that increasingly equitable distribution of individuals in the taxa sampled indicates a community that is not dominated by one specific taxon and therefore indicates community stability. In general, population stability is important because complex communities can be expected to respond favourably to changes in environmental conditions over time.

Taxonomic Richness Index - The richness of a population is a measure of the variety of taxa encountered regardless of the total individuals found. The Richness Index indicates the relative wealth of a taxa or species found in a community (Peet, 1974). The Richness Index created by Margalef (1958) is considered the most appropriate measure of Richness because it includes the effect of numerical abundance in a population on its output.

Bray-Curtis Distance – The similarity of a population is a measure of how a population compares on a species by species basis with another population or a reference population. The Bray-Curtis distance has a maximum value of 1 and a minimum value of 0. A pair of communities that are mathematically identical has a Bray-Curtis distance of 0. The advantage of the Bray-Curtis distance is that it provides a single numerical evaluator that describes the similarity of two populations (URS, 2008h).

Bray-Curtis distance is calculated using the following formula (Roche, 2008a):

$$B-C=\frac{\sum_{i=1}^{n}\left|y_{i1}-y_{i2}\right|}{\sum_{i=1}^{n}\left(y_{i1}+y_{i2}\right)}$$

with $B-C$ representing the Bray-Curtis distance between two stations, y_{i1} being the density of the i^{th} taxa at station 1, y_{i2} being the density of the i^{th} taxa at station 2 and n being the total number of taxa observed at both stations.

EPT/EPT+Chironomid Ratio biometric - This biometric may be used to provide a general indicator of the health of each site. The ratio of EPT (Ephemeroptera, Plecoptera and Trichoptera taxa) to chironomids is a common biometric that measures the abundance ratio of the two groupings and indicates the balance of the benthic community diversity. A healthy community should have a high proportion of EPT individuals relative to chironomids. The proportions of chironomids generally rise with increasing pollution, replacing the more sensitive EPT species. Therefore, since EPT taxa are known to be mostly intolerant and the family Chironomidae (at least as a whole) is generally considered tolerant to contaminants, the ratio of EPT taxa to the total of EPT + Chironomidae becomes lower as the environment becomes more polluted.

In this report, the biological indices were calculated using the methods outlined in Environment Canada (2002b).

7.7.3.2 Benthic Invertebrates Results for the 2006 Assessment Program

Table 7.7-4 presents a summary of zoobenthos encountered at Oakley Creek stations OCW-1, OCW-2, and OCW-3 in September 2006. Detailed results for these stations are presented in Appendix 7.7 and detailed laboratory certified reports are given in Appendix L7.7.

The highest density of benthic organisms occurred at OCW-2 (9,555 ind/m^2) with community densities at OCW-3 (3,775 ind/m^2) and OCW-1 (2,451 ind/m^2) approximately 30% of that at OCW-2. Taxon richness was also highest at OCW-2, with a mean of 16 taxa/sample with similarly lower values of 10 taxa/sample at OCW-1 and 11 taxa/sample at OCW-3 (Table 7.7-4).

The numerically dominant (i.e., most abundant) organisms at all stations were midge larvae (Chironomidae), which represented 31% to 64% of the community (Table 7.7-4). The Ceratopogonidae was the only sub-dominant (>5% of community density) taxon common to all three stations (Wardrop, 2007). The Tubificidae were sub-dominants at OCW-2 and OCW-3 and the Sphaeriidae were sub-dominants at both OCW-1 and OCW-3. Other sub-dominant taxa included the Elmidae and Caenidae at OCW-1 and the Hydroptilidae at OCW-2 (Table 7.7-4).

The mean value of Simpson's Index of Diversity was highest at OCW-1 (0.801) and lowest at OCW-2 (0.610) (Table 7.7-4). Evenness was low at all stations, with the mean value ranging

Table 7.7-4 Summary of Zoobenthos Community Composition and Abundance at Oakley Creek Stations in September 2006

				OCW-1			OCW-2			OCW-3		
Phylum	**Class**	**Order**	**Family**	**Mean**	**SD**	**% of Community**	**Mean**	**SD**	**% of Community**	**Mean**	**SD**	**% of Community**
Annelida	Hirudinea	Acanthobdellida	Glossiphonidae	0.6	0.9	1.1	3	2.4	1.4	1.2	1.6	1.4
		Arhynchobdellida	Erpobdellidae	0.4	0.5	0.7	1.2	1.3	0.5	0	-	0
	Oligochaeta	Lumbriculida	Lumbriculidae	1	1.7	1.8	4	1.9	1.8	3	2.4	3.4
		Tubificida	Naididae	1.4	1.9	2.5	4.2	3.9	1.9	0.2	0.4	0.2
			Tubificidae	1.4	1.9	2.5	12.2	13	5.5	8	10.4	9.1
Arthropoda	Arachnida	Araneae		0	-	0	0.4	0.9	0.2	0	-	0
	Hydracarina			0	-	0	0.4	0.9	0.2	0	-	0
Crustacea	Amphipoda	Gammaridae		0	-	0	0.4	0.5	0.2	1.2	1.8	1.4
		Hyalellidae		0	-	0	0.2	0.4	0.1	0.4	0.9	0.5
	Copepoda			0	-	0	1.6	2.1	0.7	1.4	1.5	1.6
Insecta	Coleoptera	Elmidae		9	4.5	15.8	0	-	0	0	-	0
		Haliplidae		0	-	0	0.4	0.5	0.2	0.2	0.4	0.2
		Hydraenidae		0	-	0	0	-	0	0.2	0.4	0.2
		Staphylinidae		0.2	0.4	0.4	0	-	0	0	-	0
	Diptera	Ceratopogonidae		6.2	2.2	10.9	18.6	12.8	8.4	15.2	6.4	17.3
		Chironomidae		**17.8**	**15.9**	**31.2**	**142.8**	**99.8**	**64.3**	**32.8**	**36.9**	**37.4**
		Empididae		0.2	0.4	0.4	0.4	0.5	0.2	0	-	0
		Tabanidae		0.2	0.4	0.4	0.2	0.4	0.1	0.4	0.5	0.5
		Tipulidae		0	-	0	0.4	0.5	0.2	0	-	0
	Ephemeroptera	Damaged		0.2	0.4	0.4	2	2.3	0.9	1	1.7	1.1
		Caenidae		5.4	5.2	9.5	1	1.2	0.5	0	-	0
		Ephemerellidae		0	-	0	2	3.9	0.9	1.4	1.5	1.6
		Ephemeridae		4.6	4.6	8.1	0	-	0	0	-	0
		Heptageniidae		0	-	0	0.2	0.4	0.1	0	-	0
		Leptophlebiidae		0	-	0	1	1.7	0.5	2.2	3.2	2.5
	Hemiptera	Corixidae		0	-	0	0	-	0	2.6	5.3	3
	Lepidoptera	Pyralidae		0.2	0.4	0.4	0	-	0	0	-	0
	Odonata-Anisoptera	Corduliidae		0	-	0	0.4	0.5	0.2	0.2	0.4	0.2
	Plecoptera	Capniidae		0	-	0	0	-	0	0.2	0.4	0.2
		Chloroperlidae		0	-	0	0.8	1.1	0.4	0	-	0
	Trichoptera	Damaged		0	-	0	0.2	0.4	0.1	0	-	0
		Hydroptilidae		1.6	3	2.8	11.4	14.4	5.1	0.6	0.9	0.7
		Lepidostomatidae		0	-	0	0	-	0	0.4	0.9	0.5
		Leptoceridae		0	-	0	0.4	0.9	0.2	0	-	0
		Limnephilidae		0.6	0.9	1.1	0.2	0.4	0.1	0	-	0
		Molannidae		0	-	0	0	-	0	0.2	0.4	0.2
		Phryganeidae		0.2	0.4	0.4	0.4	0.9	0.2	0	-	0
		Polycentopodidae		0.2	0.4	0.4	0	-	0	0	-	0
Mollusca	Bivalvia	Veneroida	Sphaeriidae	5	6.4	8.8	5.2	4.2	2.3	12.4	12.6	14.1
	Gastropoda	Ctenobranchiata	Valvatidae	0	-	0	0.2	0.4	0.1	0	-	0
		Pulmonata	Ancylidae	0	-	0	0.4	0.9	0.2	0.2	0.4	0.2
			Lymnaeidae	0	-	0	0.2	0.4	0.1	0	-	0
Nematoda				0.6	0.9	1.1	5.8	10.3	2.6	2.2	4.9	2.5
	Total Number of Organisms			57			222	128		88	50	
	Density (ind/m^2)			2451			9,555	5,491		3,775	2,153	
	Taxon Richness			10			16	5		11	5	
	Evenness			0.118			0.036	0.060		0.067	0.048	
	Simpson's Index of Diversity			0.801			0.610	0.139		0.722	0.110	
	Bray-Curtis Index			0.539			0.622	0.190		0.453	0.171	

Source: Wardrop, 2007

from 0.036 at OCW-2 to 0.118 at OCW-1 (Table 7.7-4). This is the result of the strong dominance of the Chironimidae at each station (Wardrop, 2007).

The reference median for the Bray Curtis distance calculation was based on the pooled data from all three Oakley Creek stations. The resulting Bray Curtis distances ranged from 0.453 to 0.622 (Table 7.7-4) and provide a numerical demonstration of the moderate similarity in the composition and structure of the three communities on Oakley Creek.

7.7.3.3 Benthic Invertebrates Results for the 2007 Assessment Program

Following is a summary of the 2007 invertebrate results. Detailed results are presented in Appendix 7.7 and detailed laboratory certified reports are given in Appendix L7.7.

Table 7.7-5 lists the number of invertebrates collected in August 2007 (URS, 2008h). The average total numbers of organisms/m^2 ranged from 1,400 at MRW1 to 27,550 at MRW3 (URS, 2008h). The average number of taxonomic groups ranged from 6 at OCW2 to 12.3 at MRW3. Results from the reference site HRW1 had an average of 3,700 total numbers of organisms/m^2 and 7 taxonomic groups.

William River

The average number of organisms found in replicates collected from sites WRW1 and WRW2 was 2,858 ind/m^2 consisting of an average number of 8.33 taxa. The dominant taxon at this site was the *Hexagenia* sp. comprising 33% of the population sampled. The other species found in significant numbers were Tubificidae comprising 19% of the population sampled.

Oakley Creek

The average number of organisms found in replicates collected from sites OCW1, OCW2 and OCW3 was 7,856 ind/m^2 consisting of an average number of 8 taxa. The dominant taxon at these sites were the *Rheotanytarsus* sp., comprising 20 and 33% of the population sampled for OCW1 and OCW2, and chironomids, representing 29% at OCW3. Other species found in significant numbers were Tubificidae, *Ephemeroptera caenis*, *Phaenospectra* sp., *Pisidium* sp., *Cricotopus* sp. and the *Trichoptera hydroptila*.

Minago River

The average number of organisms per m^2 increased from 1,400 at MRW1 to 6,850 at MRW2 and 27,550 at MRW3 in Minago River. The average number of taxa also increased from 7 at MRW1 to 8.67 at MRW2 and 12.33 at MRW3. The dominant taxa at these sites were the *Pisidium* sp. (MRW1), Tubificidae (MRW2) and *Ceriodaphnia* sp. (MRW3). Other species found in significant numbers were *Hyalella azteca*, *Thienemannimyia* sp., and *Rheotanytarsus* sp.

Table 7.7-5 Summary of Invertebrates Collected at the Minago Project, Manitoba - August 2007

	OCW1	OCW1	OCW1	OCW2	OCW2	OCW2	OCW3	OCW3	OCW3	WRW1	WRW1	WRW1	WRW2	WRW2	WRW2	MRW1	MRW1	MRW1	MRW2	MRW2	MRW2	MRW3	MRW3	MRW3	HRW1	HRW1	HRW1
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
INSECTA																											
Insecta Larva dam														1									1				
Ephemeroptera - mayflies	10	3		2			17	3	10	30	10	17	25	20	21	4	1	3	20	4	2	3	33	37	3	3	
Odonata - dragonflies								1		1		1												1			
Plecoptera - stoneflies																											
Trichoptera - caddisflies	16	1	2			1	2	4	9		1		3	5	2		1	1	3	1			2		4	3	
Diptera - true flies	27	4	15	86	77	228	245	98	219	10	23	21	2	12	13	11	1	24	11	27	8	4	74	42	23	4	13
Coleoptera - beetles	2	1	1				2						1	1		1	1					2	2	1			
Collembola - springtails Unid											1																
Hemiptera		1					3	1			1						1			5				1			
Lepidoptera - butterflies & moths Larva									1		1		1		1												
ARACHNIDA - spiders			1										1							1					1	1	
ACARINA - mites and ticks			1				2	1	3						1							1	5	1			
CRUSTACEA - crustaceans																2		7	92	3	5	6	61	43		1	
Amphipoda, sideswimmers, or scuds	2		3		1		1							2													
Cladocera - water fleas								1						1						6		221	772	6			
Copepoda - microcrustaceans	1		2	1			8	4	2	1	1				1				6	13	1	18	76	36		1	2
ANNELIDA - segmented worms																											
Oligochaeta - segmented worms	13	2	9	8	10	11	16	8	9	4	13	8	13	27	4	2	5		46	83	12	12	48	44	106	33	11
Hirudinea - leeches Unid Juv		1				2	2	2							1		2					2					
MOLLUSCA - clams, snails, etc.																											
Bivalvia - clams	2			13	19	23	14	29	29					3	1	9	4		22	21	8	3	11	12		1	3
Gastropoda - snails			4			2	1		6					1	2	2	1			8		4	37	15	2		
NEMATODA - roundworms		1	1	1	2	3	22	15	8	4	4	5	3	8	8	1			2	1		2	13		1	2	4
CNIDARIA - hydroids, jellies, etc.													1										1				
Total Number per 0.02 m^2	73	14	39	111	109	270	335	167	296	50	55	52	50	81	55	32	17	35	202	173	36	278	1,136	239	140	49	33
Average Number per Location per 0.02 m^2		42			163			266			52			62			28			137			551			74	
Average Number per Location per m^2		2,100			8,167			13,300			2,617			3,100			1,400			6,850			27,550			3,700	
Number of Taxa	8	8	10	6	5	7	13	12	10	6	9	5	9	10	11	8	9	4	8	12	6	12	13	12	7	9	5
Average Taxa Per Location		8.67			6.00			11.67			6.67			10.00			7.00			8.67			12.33			7.00	

Source: adapted from URS, 2008h

Hargrave River (Reference Site)

The average number of organisms found in the three replicates collected from Reference Site HRW1 was 3,700 ind/m^2 consisting of an average number of 7 taxa. The dominant taxon at this site was Tubificidae comprising 66% of the population sampled.

7.7.3.3.1 Community Indices for the 2007 Program

Following is a summary of community indices that were calculated for the invertebrates collected in August 2007 (Table 7.7-6). The highest benthic invertebrate densities were found in Minago River at MRW3 (27,550 ind/m^2) and the lowest invertebrate density in 2007 was also encountered in Minago River at MRW1 (1,400 ind/m^2) (Table 7.7-5). Benthic invertebrate densities in Oakley Creek showed similar variability with the highest numbers found at OCW3 (13,300 ind/m^2) and much lower numbers at OCW2 (8,716 ind/m^2) and OCW1 (2,100 ind/m^2). Results for the William River were similar for both locations WRW1 (2,617 ind/m^2) and WRW2 (3,100 ind/m^2).

Dominance and Equitability

Dominance values generated in the August 2007 samples were low to moderate for all sites ranging from 0.06 to 0.45 (URS, 2008h) (Table 7.7-6). Lower dominance values were determined for sites MRW1 (0.06) and OCW1 (0.09) while moderate values were determined for sites MRW3 (0.37) and HRW1 (0.45). These values were much lower than those determined from the 2006 data, which showed Simpson's Index values between 0.61 at OCW-2 and 0.80 at OCW-1.

Equitability is a measure of evenness in the distribution of taxa and is inversely related to dominance. Equitability is related to the dominance values indicated above but is compared to a standard of 1, which represents an equal distribution. If a given taxonomic group dominates samples, this condition tends to decrease the equitability factor. All of the August 2007 sediment samples indicated high evenness values ranging from 0.55 to 0.94 (URS, 2008h).

Richness

Richness compares the number of taxa present at a particular site to population density. Richness values ranged from 13.3 at MRW1 to 142 at MRW3 in 2007 benthic samples (Table 7.7-6).

Diversity

Species diversity was measured using the Shannon-Weaver and Margalef equations. The Shannon-Weaver Diversity index values were lowest for samples collected at HRW1 (1.57) and highest at MRW1 (3.05). The Margalef index values were lowest for samples collected at site OCW2 (0.75) and highest at site WRW2 (1.66).

Similarity

The reference site used for the Bray-Curtis distance calculations in the 2007 assessment program was based on pooled data from the location HRW1 on Hargrave River. This location was

Table 7.7-6 Summary of Invertebrates Indices for the 2007 Benthic Survey

Location		Simpson's Dominance	Richness	Shannon Weaver	Margalef's	EPT/EPT+Chironomid Ratio
HARGRAVE RIVER	HRW1	0.45	32	1.57	1.11	0.68
MINAGO RIVER	MRW1	0.06	13	3.05	1.20	0.77
	MRW2	0.17	49	2.38	1.22	0.79
	MRW3	0.37	142	1.94	1.44	0.83
WILLIAM RIVER	WRW1	0.17	24	2.23	1.12	0.78
	WRW2	0.18	19	2.31	1.66	1.00
OAKLEY CREEK	OCW1	0.09	16	2.83	1.45	0.84
	OCW2	0.18	86	2.15	0.75	0.03
	OCW3	0.14	77	2.50	1.40	0.16

Source: adapted from URS, 2008h

chosen because it is outside of the watershed connected to the future mining operations. The Bray-Curtis distance provides a numerical assessment of the similarity of the structure and composition of the nine locations sampled in 2007. Bray-Curtis distances ranged from 0.24 to 0.90, indicative of low to moderate similarity between populations (Table 7.7-7).

Table 7.7-7 Bray Curtis Distances for Benthic Invertebrates for the 2007 Survey

STATIONS	OCW1	OCW2	OCW3	WRW1	WRW2	MRW1	MRW2	MRW3	HRW1
OCW1		0.74	0.75	0.38	0.44	0.41	0.60	0.89	0.49
OCW2			0.24	0.73	0.78	0.78	0.70	0.82	0.76
OCW3				0.73	0.73	0.83	0.68	0.79	0.80
WRW1					0.27	0.55	0.64	0.83	0.56
WRW2						0.60	0.61	0.82	0.50
MRW1							0.68	0.90	0.60
MRW2								0.67	0.35
MRW3									0.82
HRW1									

STREAMS	OC	WR	MR	HR
OC (Oakley Creek)		0.64	0.71	0.71
WR (William River)			0.70	0.49
MR (Minago River)				0.67
HR (Hargrave River)				

Source: Roche Ltd. recalculated all Bray Curtis Distances originally given in URS, 2008h in March 2010.

EPT/EPT+Chironomid Ratio biometric

The general health of encountered benthic communities was evaluated using the EPT/EPT+Chironomid Ratio biometric. The EPT/EPT+Chironomid Ratio values were lowest for the samples collected at sites OCW2 (0.03) and OCW3 (0.16). The highest values were determined for the samples collected from site WRW2 (1.0). Overall the sampling sites had low numbers of chironomids, which is a general indicator of community health and little or no pollution levels.

The low ratios calculated for the two locations upstream of Highway #6 on Oakley Creek were the result of high chironomid numbers and may represent a natural characteristic of Oakley Creek in this area due to the high percentage of organic carbon found in the sediment at these locations compared to other sites in the area. Sites OCW2 and OCW3 also had low results for dominance and diversity (Table 7.7-6).

7.7.3.4 Benthic Invertebrates Results for the 2008 Assessment Program

In 2008, a total of 25 taxa (24 families and one phylum) of benthic invertebrates were identified among the 5 samples collected within the study area (Table 7.7-8; Roche, 2008a). Five phyla were identified: Porifera (sponges), Nematoda (roundworms), Mollusca,

Table 7.7-8 Densities and Relative Abundances per Taxa (2008 Assessment Program)

TAXA				DENSITY (individuals/m^2)					RELATIVE ABUNDANCE (%)				
				CLF-1	LBF-1	MRF-3	OCF-1	WRF-3	CLF-1	LBF-1	MRF-3	OCF-1	WRF-3
PORIFERA													
	Demospongiae												
			Spongillidae	19	19				1.1	0.8			
NEMATODA				57	858		76	38	3.3	34.6		5.7	0.9
MOLLUSCA													
	Prosobranchia												
			Hydrobiidae	191		38		839	10.9		4.3		19.5
	Pulmonata												
			Ancylidae					57					1.3
	Bivalvia												
			Sphaeriidae	76	744	153	477		4.3	30.0	17.4	35.7	
ANNELIDA													
	Oligochaeta												
			Lumbriculidae		38	19		782		1.5	2.2		18.1
			Tubificidae	19	114	210		782	1.1	4.6	23.9		18.1
	Hirudinea												
			Glossiphoniidae			19					2.2		
ARTHROPODA													
Chelicerata													
	Arachnida												
		Acari											
			Unionicolidae	19					1.1				
Crustacea													
	Copepoda												
		Cyclopoida											
			Cyclopidae	19					1.1				
	Ostracoda												
		Podocopida											
			Candonidae			19					2.2		
	Malacostraca												
		Amphipoda											
			Hyalellidae	38		19		19	2.2		2.2		0.4
Uniramia													
	Insecta												
		Anisoptera											
			Corduliidae				57					4.3	
		Ephemeroptera											
			Ephemeridae	1030	19		19	381	58.7	0.8		1.4	8.8
			Leptophlebiidae				76					5.7	
		Megaloptera											
			Sialidae	76				19	4.3				0.4
		Hemiptera											
			Corixidae				19					1.4	
		Trichoptera											
			Hydroptilidae				76	19				5.7	0.4
			Leptoceridae		19	19		19		0.8	2.2		0.4
			Limnephilidae			38	38	57			4.3	2.9	1.3
		Coleoptera											
			Chrysomelidae			38		153			4.3		3.5
			Elmidae				153					11.4	0.0
			Haliplidae				19					1.4	0.0
		Nematocera											
			Ceratopogonidae	19	114	19	172	744	1.1	4.6	2.2	12.9	17.3
			Chironomidae (pupes)					38					0.9
			Chironomidae (larves)	191	553	286	153	362	10.9	22.3	32.6	11.4	8.4
			TOTAL	**1754**	**2479**	**877**	**1335**	**4310**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: Roche, 2008a

Annelida (segmented worms) and Arthropoda (including arachnids, insects and crustaceans).

Table 7.7-8 shows the abundance of benthic invertebrates at each of the sampling stations. Only Nematocera (Ceratopogonidae and Chironomidae) were observed at every station while the other 10 benthic invertebrates were only observed at one station: Ancylidae (WRF3), Glossiphoniidae (MRF3), Unionicolidae (CLF1), Cyclopidae (CLF1), Candonidae (MRF3), Corduliidae (OCF1), Leptophlebiidae (OCF1) Corixidae (OCF1), Elmidae (OCF1) and Haliplidae (OCF1). Out of 25 taxa, 16 were observed less than ten times and 14 at two or less sampling stations. William River station WRF3 had the highest total number of benthic invertebrates (4,310), followed by Limestone Bay station LBF1 (2,479) and Cross Lake station CLF1 (1,754) (Table 7.7-8 and Figure 7.7-5).

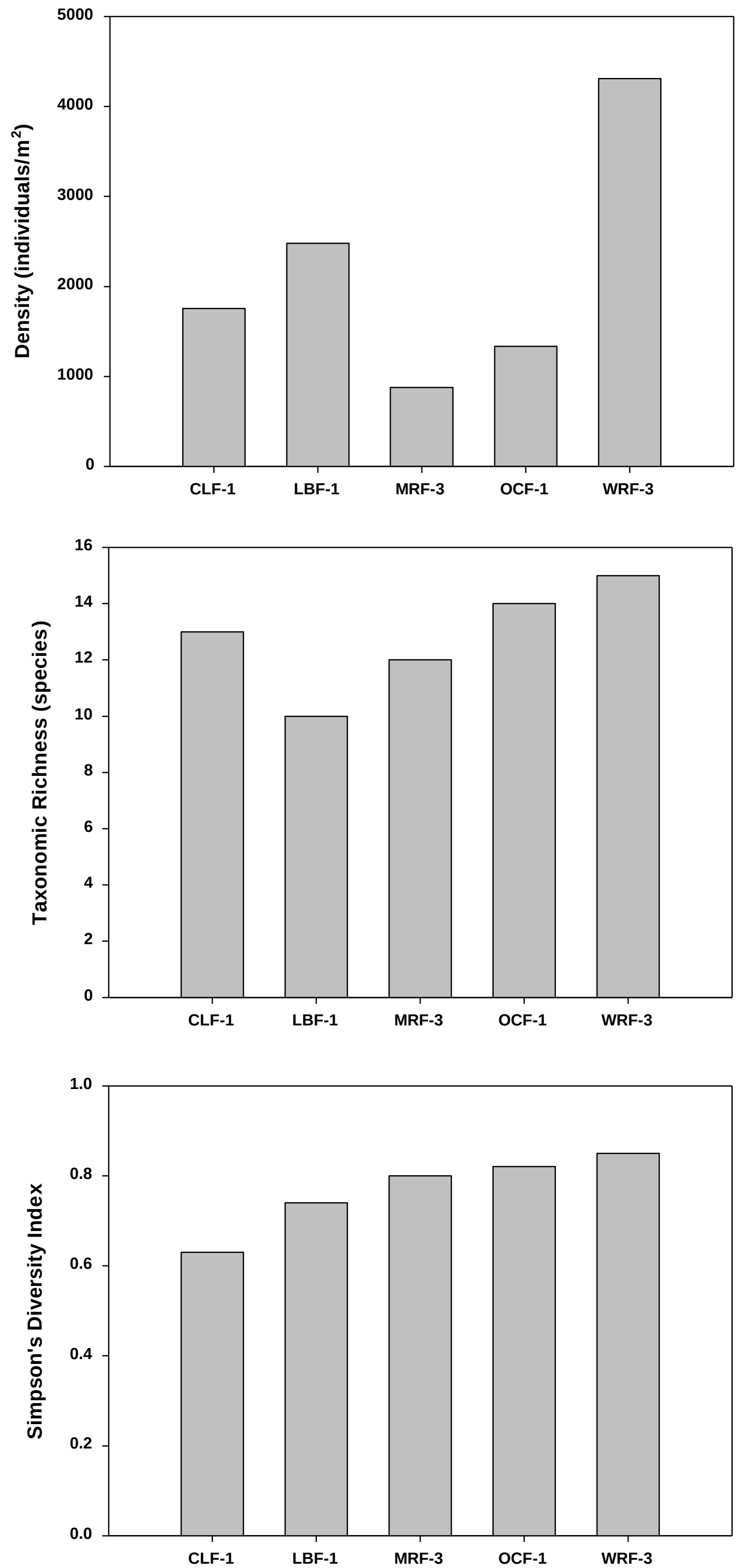
Taxonomic richness ranged from 10 to 15 species per stations (Table 7.7-8 and Figure 7.7-5). The lowest value was observed within Limestone Bay on Lake Winnipeg. Five taxa were denser than 100 individuals/m^2 for at least two stations, namely Sphaeriidae, Tubificidae, Ephemeridae, Ceratopogonidae and Chironomidae. The most abundant taxa (relative abundance higher than 20% for at least one station) were Chironomidae, Ephemeridae, Tubificidae, Sphaeriidae and Nematoda.

The Simpson's diversity index takes into account both the relative abundance and the taxonomic richness of a community. The Simpson's diversity index was highest in William River, where a maximum amount of species were observed and where four different taxa had a relative abundance higher than 15% (Figure 7.7-5). The Simpson's diversity index was lowest in Cross Lake, where one taxa represented almost 60% of all the benthic invertebrates collected.

Even though the Bray-Curtis distance is usually used to compare one site to a reference site, it was used by Roche to evaluate how benthic communities differed from each other in their composition. The investigated communities were quite different as no two stations had a Bray-Curtis distance lower than 0.56 (Tables 7.7-8 and 7.7-9) (Roche, 2008a).

The EPT/EPT+Chironomid Ratios were 0.06 at LBF1, 0.19 at MRF3, 0.58 at WRF3, 0.65 at OCF1, and 0.84 at CLF1. No Plecoptera species were identified. This indicates that Limestone Bay and Minago River experience deleterious impacts caused by pollution of some kind (Roche, 2008a). These two stations (LBF1 and MRF3) also showed the lowest values in terms of taxonomic richness, being both dominated by chironomids with relative abundances higher than 20%. In contrast, almost 60% of all species collected at Cross Lake station CLF1 were Ephemeridae, which indicates a low level of pollution.

A weak relation between the EPT/EPT+Chironomid Ratio and the total organic carbon (TOC) content was observed since the highest TOC value was observed in the Limestone Bay (Roche, 2008a). However, the second highest value was measured at MRF3 where the ratio was quite low. Total organic carbon content is known to have possible deleterious impacts on benthic invertebrate communities (Hyland et al., 2000).



Source: Roche, 2008a

Figure 7.7-5 2008 Benthic Invertebrate Communities

Table 7.7-9 Bray-Curtis Distance between 2008 Benthic Monitoring Sites

STATIONS	CLF1	LBF1	MRF3	OCF1	WRF3
CLF1		0.81	0.72	0.79	0.71
LBF1	0.81		0.64	0.56	0.79
MRF3	0.72	0.64		0.67	0.74
OCF1	0.79	0.56	0.67		0.84
WRF3	0.71	0.79	0.74	0.84	

Source: Roche, 2008

Even if the highest metal content values were measured for Minago River, which had a low EPT/EPT+Chironomid Ratio (0.19), metal content within sediments did likely not have any negative impacts on benthic invertebrates since the lowest EPT Ratio was measured for Limestone Bay where metal concentrations were among the lowest (Roche, 2008a).

7.7.3.5 Characteristics of the Dominant Taxa

Following is a description of taxa that had the highest relative abundance values in all environmental baseline studies, or a particularly high value in one of them.

Chironomidae

Chironomidae is the most important dipterans (flies, mosquitoes, deer flies) aquatic family. Even if adults are not aquatic, Chironomidae spend most of their life in freshwater at intermediate development stages (Wetzel, 2001). This family is considered as pollution resistant (Moisan, 2006). Most of its species can resist to lower dissolved oxygen level and some can even survive where oxygen content cannot be detected (Thorp and Covich, 1991). In fact, the blood of some Chironomidae contains a specific type of haemoglobin, which is efficient at low oxygen content (Thorp and Covich, 1991; Wetzel, 2001).

Chironomidae are a very important link in the aquatic food chain, acting as preys for many other insects and most of the fishes (Thorp and Covich, 1991). Chironomid larvae vary in their feeding habits with herbivorous-scavengers and carnivorous being well represented (Thorp and Covich, 1991).

Sphaeriidae

The Sphaeriidae, commonly known as “pea,” “pill,” “nut,” and “fingernail clams,” are an exclusively freshwater bivalve family. As their common names imply, sphaeriid clams are small: the adult shells length rarely exceed 25 mm. Yet, they play important roles in freshwater ecosystems. Sphaeriids often constitute a large proportion of the benthic biomass of freshwater habitats and play a key role in energy and nutrient cycling (Lee, 2001). Sphaeriid clams are important components in the diets of some fish, aquatic insects and waterfowl (Lee, 2001).

Sphaeriids display great intra- and interspecific variation in life-history characteristics. They are characterized by short life spans, early maturity, small adult size and increased energetic input to unstable habitats, as well as slow growth, low fecundity and release of extremely large, fully developed young associated with adaptation to highly stable habitats (Thorp and Covich, 1991).

Ephemeridae

Ephemeridae is a family of mayflies with about 150 described species. These are generally quite large mayflies (up to 35 mm) with either two or three very long tails. Many species have distinctively patterned wings.

Ephemerides breed in a wide range of waters, usually requiring a layer of silt as the nymphs have strong legs which are adapted for burrowing (the group is sometimes known as burrowing mayflies). It is considered a pollution-intolerant taxon. Larvae burrow into sand or eddies in riffle areas of small- to medium-sized streams or inhabit bottoms of medium to large streams. They also inhabit sandy or silt substrata in relatively clean lakes (Thorp and Covich, 1991). The nymphs are largely carnivorous and collect their food either through predation or scavenging.

Tubificidae

The Tubificidae are a family of clitellate oligochaete worms. They are key components of the benthic communities of many freshwater and marine ecosystems. These aquatic oligochaetes are resistant to pollution (Moisan, 2006). In fresh water, they are usually benthic inhabiting nearby bottoms or within the substratum (Hickman et al., 1997). Most of them are well adapted to substrata ranging from mud to sand (Thorp and Covich, 1991) and are important components in the diets of fishes (Hickman et al., 1997).

Tubificidae feed from surface sediments which contain organic matter colonized by bacteria and other microorganisms. Moreover, food availability seems to be the most important factor influencing their distribution and abundance (Wetzel, 2001).

Tubificidae are particularly abundant where organic pollution helps lowering the oxygen content (Wetzel, 2001). While many benthic invertebrates are quite sensible to low oxygen levels, many Tubificidae can tolerate anaerobic conditions for more than a month if they are periodically exposed to oxygen (Wetzel, 2001). Therefore, in these conditions and if toxic metabolites do not accumulate, the abundance of the food and the diminution of the interspecific competition enable a rapid growth of these oligochaete (Wetzel, 2001).

Daphniidae (Ceriodaphnia sp.)

This family is part of the Cladocera phylum, which is also known as the water flea group. Cladocera or cladocerans are small crustaceans commonly called water fleas, part of the class Branchiopoda. The most commonly known genus is *Daphnia* (freshwater water fleas), which is the most researched in this group. *Ceriodaphnia* is commonly used to test the toxicity of chemicals in solution or for water pollution, especially *Ceriodaphnia dubia*.

Daphniids are common inhabitants of the plankton and littoral zones of standing waters of all kinds. They function as grazers of bacteria and zooplankton, and provide a major food resource for young fishes.

7.7.4 Effects Assessment

This section examines potential effects of the Minago Project on benthos and periphyton. Existing conditions in the project area are characterized and effects of project activities predicted based on effects on water quality described in Section 7.5: Surface Water Quality and stream flows described in Section 7.4: Surface Water Hydrology. The findings of this section provide the basis for assessment of potential effects on fish (Section 7.8: Fish Resources). This section describes project effects under routine construction and operating conditions. Potential effects of project-related accidents and malfunctions are discussed in Section 8: Accidents and Malfunctions.

7.7.4.1 Scope of Assessment

Periphyton and benthic invertebrate communities have been identified as VECCs, given their role as primary and secondary producers and their sensitivity to changes in water chemistry and stream habitat. Many periphyton and benthic invertebrate taxa have low tolerances and respond to metals, nutrients and sediment quality, making them useful sentinels of changes related to mine operations. They also provide valuable links between water chemistry (Section 7.5) and the fish community (Section 7.8).

Periphyton and benthic invertebrates have been used as indicators of water quality since the early 1900s because of their known sensitivity to changes in nutrients, sediments (TSS) and metal levels. They are used in government biomonitoring programs in Canada (Environment Canada, 2002b) and the United States (Barbour et al., 1999). The benthic index of biotic integrity - a multi-metric assessment method - has also been developed for a variety of regions (Karr and Chu, 1999). Periphyton and benthos community composition and productivity are considered useful indicators of stream health, because they integrate individual effects of the project on aquatic resources, including physical habitat changes due to sedimentation as well as change in stream flows, temperature, and water quality. In addition, they provide an important link to fish resources. Changes in periphyton and benthos productivity can have effects on fish (abundance, size, bioaccumulation of metals in tissue), which can in turn affect birds and wildlife that consume fish.

Project components that have the potential to influence surface water and sediment quality are described below:

- **Polishing Pond Discharge to Oakley Creek and Minago River** – Discharge of mine effluent can have potentially positive and/or adverse effects on periphyton and invertebrates through toxicity of metals, nutrient enrichment, changes in pH, and release of suspended sediments. Documented effects include excessive periphyton growth, elimination of sensitive species, changes in community structure and morphological deformities of periphyton. VNI will discharge water from the Polishing Pond that meets MMER discharge criteria.

- **Changes to Oakley Creek and Minago River Flow Regimes** – Minago River will not be affected by any project related diversions as the project area is located in the Oakley Creek watershed. Streamflow in Oakley Creek will not be affected by site diversions as the diverted water will be returned to Oakley Creek.

- **Introduction of Sediments to Receiving Waters from Construction Runoff** – Sediment introduced to streams can smother habitat or damage sensitive gill structures of benthic invertebrates or reduce oxygen transport into the substrate. Changes in community structure and degraded habitat can have an effect on fish populations.

A list of aquatic VECCs has been defined for the project environmental assessment based on Baseline Studies presented to regulators and stakeholders by VNI. The VECCs and rationale for their selection are described in Table 7.7-10.

Temporal Boundaries

The temporal boundaries applicable to periphyton and benthic invertebrates include the period of record for the baseline data collection (2006-2008 to present) and all phases of the project. The potential for introduction of silt and sediment to area streams will be greatest during construction, but also exists during operation and decommissioning. The potential for introduction of metals or nitrate/ammonia to streams will be greatest during operation, but also exists during the other phases. The assessment of the closure phase assumes stabilization of water quality conditions and associated effects on benthos and periphyton. It is anticipated that this will be possible, based on operations phase monitoring and adaptive management to ensure effective long-term management of potential project effects originating from tailings and groundwater.

Study Area

The local and regional study areas for assessment of project effects on benthos and periphyton are identical to those established for water quality and fish resources. The current plans are for discharge of water to Minago River and Oakley Creek.

The local study area (LSA) includes all streams that may be influenced by the mine facilities. The LSA includes:

- the Oakley Creek watershed, which will be affected by diversions from the Tailings and Ultramafic Waste Rock Facility (TWRMF) and the Overburden Disposal Facility (ODF);
- the Minago River watershed, which will be affected by the Polishing Pond discharges; and
- the industrial area, which has no streams/creeks.

Table 7.7-10 Periphyton and Benthic Invertebrate VECCs, Selection Rationale and Data Sources

VECC	Rationale for Selection	Linkage to EAP Report Regulatory Drivers	Baseline Data for EAP
Periphyton abundance (*chlorophyll a*)	• Potential for project effects is unknown. • Respond to changes in water quality (metals, nutrients, sediment). • Changes in primary productivity, measured as *chlorophyll a,* can influence benthic invertebrate abundance and composition.	• Environmental Baseline Studies (EBS)	• 2007-2008 field data
Periphyton species composition/ diversity	• Potential for project effects is unknown. • Taxon-specific responses to changes in water quality (metals, nutrients, sediment). • Changes in composition may influence benthic invertebrates.	• Environmental Baseline Studies (EBS) • Environmental Impact Assessement guidelines	• 2007-2008 field data
Benthic invertebrate abundance	• Potential for project effects is unknown. • Respond to changes in water quality (metals, sediment) and primary production. • Important fish food.	• Environmental Baseline Studies (EBS) • Will be required for *Metal Mining Effluent Regulations* (MMER) environmental effects monitoring (EEM). [1]	• 2007-2008 field data
Benthic invertebrate species composition/ diversity	• Potential for project effects is unknown. • Species-specific responses and tolerances to changes in water quality (metals, sediment) and primary production. • Important fish food.	• Environmental Baseline Studies (EBS) • Will be required for MMER EEM. [1]	• 2007-2008 field data

Note:

1 The *Metal Mining Effluent Regulations* (MMER) under the *Fisheries Act* and associated Environmental Effects Monitoring (EEM) programs came into effect in 2002 and require three-year cycles of effluent and biological monitoring, including benthic communities. Environment Canada is responsible for the administration of MMER.

The regional study area (RSA) includes water bodies beyond the LSA that reflect the general region to be considered for cumulative effects and that provide suitable reference areas for monitoring potential project effects. Water bodies in the RSA include:

- Hargrave River, which flows to the Minago River; and
- William Lake and William River upstream of the William River / Oakley Creek confluence.

7.7.4.2 Effects Assessment Methodology

Project effects on periphyton and benthos VECCs have been assessed based on predicted residual effects on water and sediment quality, also discussed in Section 7.5: Surface Water Quality; Section 7.6: Hydrogeology and Groundwater Quality; and Section 7.4: Surface Water Hydrology. Potential effects on sediment quality are assessed in Section 7.5: Surface Water Quality. Potential effects on community composition and productivity were characterized based on the likelihood of toxic effects, nutrient enrichment and metals bioaccumulation, which are based on projected instream flow and water quality conditions at the effluent discharge locations and at the identified compliance points on the Minago River and Oakley Creek.

Project and cumulative effects on periphyton and benthic invertebrates were characterized on the based on effects attributes defined in Table 7.7-11. The ecological and social context of effects were integrated in the attributes for effect magnitude and are discussed in detail for each VECC in this report.

Determination of Effects Significance

A residual effect on periphyton or benthic invertebrates is considered significant for the project or cumulatively, based on the defined attributes, detailed in Table 7.7-11, if it is:

- a moderate magnitude adverse effect that is long-term or far future in duration; or
- a high magnitude adverse effect, unless it is site specific in geographic extent.

Otherwise, a residual effect will be rated as not significant.

The likelihood of occurrence of any significant adverse residual effects is stated with a supporting rationale in this document.

7.7.4.3 Project Effects

Potential project-VECC interactions during routine activities associated with construction, operations, decommissioning, and closure are identified in the following sections, based on assessments described in Section 7.4: Surface Water Hydrology and Section 7.5: Surface Water Quality. Interactions related to accidents and malfunctions are described in Section 8.

Table 7.7-11 Effect Atributes for Periphyton and Benthos

Attribute	Definition
Direction	
Positive	Condition of VECC is improving.
Adverse	Condition of VECC is worsening or is not acceptable.
Neutral	Condition of VECC is not changing in comparison to baseline conditions and trends.
Magnitude	
Low	Effect occurs that might or might not be detectable, but is within the range of natural variability, does not pose a serious risk to VECC, and does not compromise other environmental values.
Moderate	Clearly an effect, but unlikely to pose a serious risk to the VECC or represent a management challenge from an ecological, economic or social/cultural standpoint.
High	Effect is likely to pose a serious risk to the VECC and represents a management challenge from an ecological, economic or social/cultural standpoint.
Geographic Extent	
Site-specific	Effect on VECC confined to a reach of a stream in the LSA (*e.g.,* <500 m).
Local	Effect on VECC extends throughout the LSA.
Regional	Effect on VECC extents into the RSA.
Duration	
Short-term	Effect on VECC is limited to 1 year.
Medium term	Effect on VECC occurs between 1 and 5 years.
Long-term	Effects on VECC lasts longer than 5 years, but does not extend more than 10 years after decommissioning and the final reclamation.
Far future	Effect on VECC extends > 10 years after decommissioning and abandonment.
Frequency (Short-term duration effects that occur more than once)	
Low	Frequency within range of annual variability and does not pose a serious risk to the VECC.
Moderate	Frequency exceeds range of annual variability but is unlikely to pose a serious risk to the VECC.
High	Frequency exceeds range of annual variability and is likely to pose a serious risk to the VECC.
Reversibility	
Reversible	Effects on VECC will cease during or after the project is complete.
Irreversible	Effects on VECC will persist during and/or after the project is complete.
Likelihood of Occurrence	
Unknown	Effects on VECC are not well understood and, based on potential risk to the VECC or its economic or social/cultural values, effects will be monitored and adaptive management measures taken, as appropriate.
High	Effect on VECC is well understood and there is a high likelihood of effect on the VECC as predicted.

Most interactions are anticipated to be with stream rather than lake habitat. The following sections describe project actions and mitigation measures by phase and by affected stream basins.

7.7.4.3.1 Construction

Oakley Creek

Minesite facilities to be constructed in the Oakley Creek drainage and potential effects on water quality are described in Chapter 2. Oakley Creek is a short, low gradient stream, which has fish resources and drains to William River. The Oakley Creek basin has already been affected by periodic PTH6 road repairs. Potential effects on the Oakley Creek watershed during project construction include:

- increased suspended sediment in runoff from construction sites for various facilities in the basin;
- runoff from the Dolomite Waste Rock Dump (WRD) with potentially elevated metals, nitrate/ammonia and suspended sediments; and
- changes of flow regimes in Oakley Creek due to open pit dewatering.

Effects of sediment release on water quality, associated with ground disturbance during construction, have been rated as not significant (low magnitude, site-specific, short-term, moderate in frequency and reversible), as they will be mitigated through the VNI Erosion and Sediment Control Plan (Section 9: Environmental Management Plan). In addition, the muskegs will filter discharges by removing TSS and metals. Accordingly, no effects on benthic communities in Oakley Creek are expected during construction.

Introduction of metals or nitrate/ammonia from the Dolomite WRD to the Oakley Creek may be mitigated by wetlands (bogs). It is projected that there will be no adverse effects of such discharges on water quality in Oakley Creek, and no changes in the system are expected during the construction phase. As a result, no adverse effects on benthic communities are predicted during construction.

Nitrate levels may become elevated relative to baseline conditions throughout Oakley Creek downstream of the Oakley Creek discharge point. The 2007 CCME nitrate guideline level of 13 mg/L was established in relation to nitrate toxicity, rather than eutrophication potential and will not be exceeded in Oakley Creek. Nitrogen inputs from blasting will decrease over the operational phase and denitrification will reduce nitrate levels in the effluent and stream water. Aquatic plants in the creek will also take up and store nitrate during the growing season, and release it later during decomposition, resulting in lower nitrate levels. Nitrate levels are likely to stimulate periphyton growth in Oakley Creek. Nitrate levels tend to be very low in Oakley Creek rendering the stream sensitive to enrichment effects from nitrate. The magnitude and direction of the periphyton response to enrichment will depend on flows, light, temperature, and available phosphorus, as well as inorganic nitrogen. In oligotrophic systems, some nutrient enrichment can be considered beneficial to benthic communities.

The pumping test results (Section 7.6: Hydrogeology and Groundwater Quality) conducted in 2008 showed that the open pit dewatering program will not decrease flows in Oakley Creek. Therefore, there will be no adverse effect on periphyton and benthic invertebrate communities. There will be no stream flow reduction due to mine dewatering, and related effects on benthic habitat and productivity are expected to be low magnitude, site-specific, short-term, low frequency and reversible. Overall effects are rated as not significant, with a high likelihood of occurrence.

Minago River

No project related effects are anticipated for benthic communities in the Minago River, given that construction effects will be specific to the Oakley Creek watershed.

7.7.4.3.2 Operations

Discharges to Oakley Creek

Potential effects on water, sediment and benthic communities in Oakley Creek that were identified for the construction phase will continue during operations. Site water management to collect potentially contaminated runoff will continue to minimize potential impacts on water quality and benthic communities in Oakley Creek. Effects of Polishing Pond discharge to Oakley Creek will continue during operations. Potential adverse effects of project operations on periphyton and benthic invertebrates in Oakley Creek are characterized as low magnitude, site specific, long-term and reversible, therefore, not significant.

Discharges to Minago River

Discharge of Polishing Pond effluent in the upper watershed of the Minago River has the potential to have significant adverse effect on benthic communities through toxicity of metals, changes in pH and release of suspended sediments. Predicted effluent and receiving environment water quality are described in the Water Management Section. VNI will discharge effluent that meets MMER discharge criteria. The receiving environment and effluent will be subject to Environmental Effects Monitoring (EEM) under *Metal Mining Effluent Regulations* (MMER).

Project effects on benthic communities in the Minago River related to nitrate and ammonia (from blasting operations) discharge are rated as potentially positive (since it will meet MMER discharge criteria), moderate in magnitude, local, long-term in duration, moderate in frequency and reversible, with an unknown likelihood. VNI will ensure through the explosive contract that explosives spillage is controlled and minimized and that emulsion explosives will be used, where applicable. Potential effects are rated as not significant, but will be monitored in MMER EEM programs. If moderate adverse effects were to be identified during monitoring, VNI will be able to implement adaptive management strategies.

Given that most historic reports of effects on benthic communities are for streams with markedly elevated levels - for example, selenium in the range of 0.005-0.029 mg/L (Hamilton and Buhl, 2003) and cadmium in the range of 0.00001-0.050 mg/L (Goodyear and McNeill, 1999) - these reports are less relevant when assessing metal levels in the lower part of the range, as would be expected in the Minago River.

The accumulation of selenium and other metals in despositional areas has become an issue of concern for mines (McDonald and Strosher, 2000; Chapman, 2004), with research ongoing into the relationship between ambient levels and organism responses. Selenium has been noted to bio-accumulate in fish tissue, probably through consumption of benthic invertebrates that are in close contact with the metal-containing sediment. Current recommendations are for a maximum of 2 mg/kg in sediment (Engberg et al., 1998; Lemly, 2002). Selenium levels in the Minago River and Oakley sediment have been below that level (Table 7.7-2 and Table 7.7-3), but will be monitored during mine operations.

If selenium levels in sediment show an increasing trend and are approaching guideline levels, additional sampling of benthic invertebrates and fish (sculpin) for tissue metals analysis will be conducted in downstream fish-bearing areas. In the event of an increasing trend in sediment and tissue concentrations, adaptive management to reduce bio-available selenium levels will be implemented, when necessary.

Project effects on the Minago River and Oakley Creek benthic communities related to metals discharged in effluent are predicted to be adverse, low magnitude, local in extent, long-term in duration, moderate in frequency and reversible, but with an unknown likelihood in terms of extent. The effects will be monitored through MMER. As a result, effects are rated as not significant.

7.7.4.3.3 Decommissioning

The potential effects of mine closure will be more limited than during the construction phase. The Mine Closure Plan is described in Chapter 3. Effects on hydrology and water quality are described in other sections, Sections 7.4 and 7.5, respectively.

Oakley Creek

Potential adverse effects on benthic organisms in Oakley Creek related to sediment release in runoff during removal of facilities will be mitigated by implementing an Erosion and Sediment Control Plan, so that no significant adverse effect on periphyton and benthic invertebrate communities will occur.

The TWRMF will remain in place to provide permanent storage of tailings and ultramafic waste rock, which will be covered by at least 1.5 m of water. It is predicted that levels of most metals in supernatant water will be reduced within the time of closure. Supernatant water will be monitored following the end of operations. In combination with relatively small flows over the TWRMF spillway, this should result in no adverse effects on water quality or benthic communities in Oakley Creek.

Potential adverse effects in Oakley Creek during decommissioning include increased suspended sediment in runoff from the deconstruction of various facilities. These will be mitigated by the Erosion and Sediment Control Plan (Section 9.2) and site revegetation included in the Mine Closure Plan. Accordingly, no adverse effects on water quality or periphyton and benthic invertebrate communities in Oakley Creek are anticipated during decommissioning.

7.7.4.3.4 Closure

The Mine Closure Plan is described in Chapter 3 and in a separate report and project effects on surface water quality are described in Section 7.5.

Oakley Creek

Post-closure monitoring is proposed for Oakley Creek to assess the effects of pit discharges on Oakley Creek. The effect of discharges on receiving water or sediment quality in Oakley Creek has been rated as not significant, based on the characterization as being adverse, low to moderate magnitude, local extent, far future in duration and ultimately reversible.

At closure, the quality of TWRMF pond supernatant will not cause a change in the quality of Oakley Creek beyond the natural variability established over the period of baseline monitoring. Accordingly, there will be no further effects of the project on Oakley Creek at closure.

The TWRMF itself is unlikely to form suitable habitat for benthic organisms, given the lack of organic matter in the tailings to provide food for invertebrates. Although metal levels in the supernatant will stabilize at levels well below MMER, it is likely that levels in the tailings will remain elevated enough to discourage growth of algae and benthic organism. As a result, the likelihood for bio-accumulation of metals by aquatic plants and invertebrates in the TWRMF and their eventual consumption by birds and other wildlife would be small, and were not considered to be a potential adverse effect of the project. Additional design considerations, such as steep banks and shorelines unsuitable for plant growth in littoral areas, will also discourage bird populations from using the pond as habitat. A monitoring program for phytoplankton, benthic invertebrates and vegetation can be conducted during closure (i.e., five years after the end of the operations) to assess the colonization potential around the TWRMF, with additional management strategies to be put in place to discourage bird usage, if needed. Observations will be made during the operational phase to determine if birds usage will be an issue at closure.

7.7.4.4 Residual Project Effect and Significance

Effluent Discharge to Minago River

During operations, residual effects on benthic communities are expected to be related to metals in stream water and sediments deposited between the Polishing Pond discharge point and the compliance point in Minago River. Dilution in Minago River will be adequate for Contaminants of Concern (COC), which will reduce the magnitude of most potential effects to a low level in the Minago River. No adverse effects on benthic communities are anticipated downstream of the Minago River mixing zone, given that metal levels will remain below Manitoba Tier II and CCME water quality objectives for the protection of aquatic life.

Discharged effluent may also contain nitrogenous compounds (from blasting residues), which may stimulate periphyton growth, and suspended solids, which reduce benthic habitat quality (smothering, reduced oxygen transport) or damage organisms (e.g., abrasion of gills). There is a high likelihood that nitrate and ammonia levels in discharged effluent will result in increased periphyton growth throughout Minago River, with potential changes to benthic invertebrate populations. However, nutrient enrichment may be a positive rather than an adverse effect.

There may be potential for localized accumulation of metals in erosional or depositional sediment within the affected reach, with potential for uptake in periphyton and benthos. From an ecological perspective, elevated metals in benthic invertebrates that drift downstream into fish-bearing reaches could contribute to bioaccumulation of metals in fish, although the likelihood of this is low, given the intervening areas of beaver ponds and riffle habitat. Follow-up monitoring of metals in sediment and fish tissue will be undertaken to check predictions and improve mitigation, if necessary.

Baseline water chemistry in the Minago River and other streams is described in Section 7.5. Given that the likelihood of potential effects is unknown, VNI will be required to monitor effluent and the receiving environment using an EEM program. Benthic invertebrate and fish communities will be monitored on a multi-year cycle to provide data about the effectiveness of the Water Management Plan and the environmental effects of discharges on the benthic community of the Minago River. Results will guide decisions on mine practices and monitoring requirements.

At mine closure, the TWRMF will be maintained with a water layer over the tailings and ultramafic waste rock. TWRMF supernatant water will be discharged to the Polishing Pond (PP) and water in the PP will be monitored before it is discharged to the receiving environment, if needed, during the first six years. As a result, the likelihood of adverse effects of metals discharge on benthic communities is considered to be low.

The adverse effects of effluent discharge on benthic habitat, community composition and productivity are expected to be not significant, throughout all phases of the project and at closure. The likelihood of these effects is not clear and will be subject to monitoring.

Flow Regime Changes in Minago River

Small changes to flow regimes of the Minago River are anticipated as a result of discharges from the Polishing Pond. During operations, discharges to the Minago River will be approximately 36%, 10%, and 19% of the anticipated average flows in the winter months (Nov.-Apr.), during the freshet (May), and in the summer months (Jun. – Oct.), respectively. Details are provided and discussed in Section 2.14 (Site Water Management). Higher water flow and thus water level will help maintain the existing stream habitat types and limit changes in water quality that can occur during low flow periods, therefore limiting seasonal stresses for periphyton, benthic invertebrates and other biota.

The impacts of a reduction in the water flow on stream habitats would be more significant after closure of the Nickel Processing Plant and the Frac Sand Plant, especially in winter low flow conditions. Lower water flow and thus water level reduces stream habitat types and increases the risk of changes in water quality, increasing seasonal stresses for fish and other biota.

Therefore, mitigation measures will have to be implemented in order to limit the potential impacts of such a change in water level conditions, meaning that discharge from the Polishing Pond has to be gradually reduced and not drastically as operations wind down. This would enable a comeback to pre-mining conditions. Depending on the PP capacity, a gradual reduction over one or two years is planned as the operations transition from full production in years 1 through 8 when both of the Nickel Processing Plant and the Frac Sand Plant are operating, to partial production in years 9 and 10 when the Nickel Processing Plant will be closed and the Frac Sand Plant will be operating, to finally no production starting in year 11. Details of the site water management program are given in Section 2.14.

As discussed in the previous sections, the impacts of increasing or decreasing the water flow in the Minago River will be low, or not significant after closure, in terms of hydrology since they are within the natural variation occurring in this region.

Effluent Discharge to Oakley Creek

During operations, residual effects on benthic communities are expected to be limited to those related to metals in stream water and sediments deposited between the Polishing Pond discharge point and the compliance point in Oakley Creek. Dilution in Oakley Creek will be adequate for Contaminants of Concern (COC), which reduces the magnitude of most potential effects to a low level in Oakley Creek. No adverse effects on benthic communities are anticipated downstream of the William River/Oakley Creek confluence, given that metal levels will remain below Manitoba Tier II and CCME water quality objectives for the protection of aquatic life.

Discharged effluent may also contain nitrogenous compounds (from blasting residues), which may stimulate periphyton growth, and suspended solids, which reduce benthic habitat quality (smothering, reduced oxygen transport) or damage organisms (e.g., abrasion of gills). There is a high likelihood that nitrate and ammonia levels in discharged effluent will result in increased periphyton growth throughout Oakley Creek, with potential changes to benthic invertebrate populations. Given the current low productivity in Oakley Creek, nutrient enrichment may be a positive rather than the adverse effect.

There may be potential for localized accumulation of metals in erosional or depositional sediment within the affected reach, with potential for uptake in periphyton and benthos. This is considered unlikely due to the annual freshet, which will mobilize and disperse stream sediments. From an ecological perspective, elevated metals in benthic invertebrates that drift downstream into fish-bearing reaches could contribute to bioaccumulation of metals in fish, although the likelihood of this is low, given the intervening areas of beaver ponds and riffle habitat. Follow-up monitoring of metals in sediment and fish tissue will be undertaken to check predictions and improve mitigation, if necessary.

Baseline water chemistry in Oakley Creek and other streams is described in Section 7.5. Given that the likelihood of potential effects is unknown, VNI will be required to monitor effluent and the receiving environment using an EEM program. Benthic invertebrate and fish communities will be monitored on a multi-year cycle to provide data about the effectiveness of the Water Management Plan and the environmental effects of discharges on the benthic community of Oakley Creek. Results will guide decisions on mine practices and monitoring requirements.

At mine closure, the TWRMF will be maintained with a water layer over the tailings and ultramafic waste rock. TWRMF supernatant water will be discharged to the Polishing Pond (PP) and water in the PP will be monitored before it is discharged, if needed, during the first six years. As a result, the likelihood of adverse effects of metals discharge on benthic communities is considered to be low.

The adverse effects of effluent discharge on benthic habitat, community composition and productivity are expected to be not significant, throughout all phases of the project and at closure. The likelihood of these effects is not clear and will be subject to monitoring.

Flow Regime Changes in Oakley Creek

Small changes to flow regimes of Oakley Creek are anticipated as a result of discharges from the Polishing Pond. During operations (year 1 through 8), discharges to the Oakley Creek will be approximately 0%, 10%, and 31% of the anticipated average flows in the winter months (Nov.-Apr.), during the freshet (May), and in the summer months (Jun. – Oct.), respectively. Details, including PP discharge flows during year 1 through 8 operations, year 9 and year 10 operations, closure and post closure and are provided and discussed in Section 2.14 (Site Water Management). No water will be discharged to Oakley Creek in the winter months as it is typically frozen solid.

Higher water flow and thus water level will help maintain the existing stream habitat types and limit changes in water quality that can occur during low flow periods, therefore limiting seasonal stresses for periphyton, benthic invertebrates and other biota.

The adverse effects of effluent discharge on benthic habitat, community composition and productivity are not expected to be significant throughout all phases of the project and at closure. The likelihood of effects occurring as predicted is high.

7.7.4.5 Cumulative Effects and Significance

It is not expected that multiple localized project impacts on periphyton and benthic invertebrate communities will result in a measurable effect on habitat quality and populations in the regional drainages (Minago River, Cross Lake, William Lake and Limestone Bay).

Other activities within the mine site that may combine with project effects to influence periphyton and benthic invertebrate communities include:

- increased traffic on the PTH6 due to the project with potential for introduction of contaminated runoff (due to potential spills, accidents, and road maintenance) to rivers and creeks such as the William River, the Oakley Creek and the Minago River;
- effects of future mining projects in the same drainages (there are currently no mining projects under review that would incur cumulative effects on periphyton and benthic invertebrate communities in the area); and
- increased risk of forest fires due to mining activity with the potential for sedimentation of instream habitat.

Such effects will be described in more detail in Section 7.8: Fish Resources.

7.7.4.6 Mitigation Measures

Mitigation measures to minimize effects on benthos and periphyton are described in Table 7.7-12.

7.7.4.7 Monitoring and Follow-up

The 2006/2007/2008 benthic and sediment quality baseline studies resulted in the compilation of relevant data for benthic invertebrates and periphyton, as samples were collected from natural substrates at an ecologically relevant time of year and a suitable location within the Local Study Area (LSA) and Regional Study Area (RSA).

Table 7.7-12 Mitigation Measures for Effects in Benthic Invertebrates and Periphyton

Potential Project Effect	Mitigation Measures
Construction	
• Changes in water and sediment quality in Oakley Creek from contaminated construction site runoff, waste rock storage, ore stockpiles	• Implement the Erosion and Sediment Control Plan (Section 9: Environmental Management Plan) and Site Water Management Plan (Section 2.14: Site Water Management) to ensure no contaminated drainage water enters Oakley Creek. Wetlands (bogs) will act as filters.
Operations	
• Changes in Minago River flow regime related to Polishing Pond discharge	• Implement Approved Water Management Plan based on approvals from federal and provincial governments regarding flow conditions in Minago River.
• Changes in water and sediment quality from potential TWRMF seepage to Minago River (metals TSS, nutrient, SO_4)	• Intercept seepage in collection ditches, and recycle back to the TWRMF. Discharge to Minago River will be via the Polishing Pond (PP). • Monitor effluent and receiving water quality and initiate adaptive management as required.
• Changes in water and sediment quality in Minago River from Polishing Pond effluent discharges (metals, TSS, nutrients, SO_4)	• Ensure effluent quality meets MMER objectives for the protection of aquatic life. • Discharge wastewater in accordance with Manitoba and Federal regulations. • Monitor effluent and receiving water quality and initiate adaptive management as required.
• Accumulation of metals in sediment of Minago River with increased potential for bioaccumulation	• Monitor water and sediment quality concentrations in Minago River. If results indicate (an) increasing trend(s), initiate collection of benthic invertebrates and fish for tissue metals analysis. • Apply adaptive management measures, if necessary.
• Changes in Oakley Creek flow regime related to Polishing Pond discharge	• Implement Approved Water Management Plan based on approvals from federal and provincial governments regarding flow conditions in Oakley Creek.
• Changes in water and sediment quality from potential TWRMF seepage to Oakley Creek (metals TSS, nutrient, SO_4)	• Intercept seepage in collection ditches, and recycle back to the TWRMF. Discharge to Oakley Creek will be via the Polishing Pond (PP). • Monitor effluent and receiving water quality and initiate adaptive management as required.
• Changes in water and sediment quality in Oakley Creek from Polishing Pond effluent discharges (metals, TSS, nutrients, SO_4)	• Ensure effluent quality meets MMER objectives for the protection of aquatic life. • Discharge wastewater in accordance with Manitoba and Federal regulations. • Monitor effluent and receiving water quality and initiate adaptive management as required.
• Accumulation of metals in sediment of Oakley Creek with increased potential for bioaccumulation	• Monitor water and sediment quality concentrations in Oakley Creek. If results indicate (an) increasing trend(s), initiate collection of benthic invertebrates and fish for tissue metals analysis. • Apply adaptive management measures, if necessary.

Table 7.7-12 (Cont.'d) Mitigation Measures for Effects on Benthic Invertebrates and Periphyton

Potential Project Effect	Mitigation Measures
Decommissioning	
• Changes in sediment quality in Minago River and Oakley Creek from site runoff where facilities have been removed and/or the ground has been recontoured.	• Implement the Erosion and Sediment Control Plan and Site Water Management Plan (Section 2.14) to ensure no contaminated drainage water enters Oakley Creek or the Minago River. • Reseed recontoured areas as soon as possible.
• Changes in water and sediment quality in Oakley Creek from Polishing Pond effluent discharges (metals, TSS, nutrients, SO_4)	• Ensure effluent quality meets MMER objectives for the protection of aquatic life. • Discharge wastewater in accordance with Manitoba and Federal regulations. • Monitor effluent and receiving water quality and initiate adaptive management as required.
Closure	
• Changes in water and sediment quality of Oakley Creek from ongoing TWRMF	• Adhere to the Mine Closure Plan requirements. • Test of water quality during decommissioning to confirm effectiveness of adaptive management. • Maintain water cover over the disposed tailings and ultramafic waste rock as designed.
All Phases	
• Long-distance transport of metals from effluent discharge, and potential introduction of sediment or contaminants from affected area streams.	• Implement mitigation measures for project-related effects to ensure effects in water and sediment quality are localized and minimize the potential for cumulative effects.

Monitoring Programs

A monitoring program for benthos and sediment quality is proposed in Table 7.7-13. The main monitoring program will be the EEM program required under MMER to determine project effects on benthic communities from the construction, operation and closure phases, and cumulative effects. Periphyton monitoring will be conducted concurrent with the EEM program to provide further description of ecological health. Additional monitoring programs will be undertaken to monitor effects outside the EEM program.

Construction monitoring for release of sediment (TSS) to streams will be conducted as part of the Erosion and Sediment Control Plan (Section 9: Environmental Management Plan) during facility and access road construction, to monitor the effectiveness of mitigation measures.

Oakley Creek and Minago River streamflows will be monitored to assess predicted effects of hydrologic changes. Monitoring of metal levels in benthic invertebrate tissue will also be undertaken.

7.7.4.8 Summary of Effects

Project and cumulative effects are summarized in Table 7.7-14.

Table 7.7-13 Monitoring and Follow-up Programs for Benthic Invertebrates and Periphyton

Potential Project Effect	Program Objectives	General Methods	Reporting	Implementation
Follow-up Programs				
None				
Monitoring Programs				
Construction monitoring for sediments	• To confirm effectiveness of mitigation measures and to address compliance issues immediately.	• Monitor TSS at settling basins and in receiving waters according to the Environmental Protection Plan schedule.	• To Manitoba Gov.'t as required following environmental assessment guidelines	• Proponent
Effects of Polishing Pond effluent discharge on benthic invertebrates	• To identify effects of metals and nutrients.	• Conduct an EEM program on 3-year cycle following EEM methods.	• Following reporting schedule according to *Metal Mining Effluent Regulations* (MMER)	• Proponent
Effects of effluent discharges on periphyton	• To provide supporting environmental information for EEM studies and ecological health indicator.	• Concurrent with EEM program, periphyton collection from natural substrates (using same methods as were used during the baseline studies).	• Following reporting schedule according to MMER	• Proponent
Accumulation of selenium and other metals in depositional habitat	• To check the potential for bioaccumulation. As needed, initiate contingency plans to address unexpected effects.	• Concurrent with EEM program on three-year cycle. • Initiate benthic invertebrate or fish tissue sampling based on results of sediment analysis.	• To Manitoba Gov.'t as required • Following reporting schedule according to MMER	• Proponent
Ability of TWRMF pond to support aquatic life	• To identify potential for bioaccumulation of metals in birds and wildlife.	• Assess phytoplankton, invertebrates and plants in TWRMF pond at closure.	• To Manitoba Gov.'t as required	• Proponent

Table 7.7-14 Summary of Effects on Benthic Invertebrates and Periphyton

Potential Effect	Level of Effect						Effect Rating	
	Direction	Magnitude	Extent	Duration/Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Construction								
Altered benthic communities resulting from changes in water and sediment quality in Oakley Creek from contaminated construction site runoff, waste rock storage, and ore stockpiles.	Adverse	Low	Site-specific	Short-term, Moderate frequency	Reversible	Unknown	Not significant	N/A
Operations								
Altered benthic communities in Oakley Creek and Minago River from Polishing Pond discharges (metals, TSS).	Adverse	Low	Local	Long-term, Moderate frequency	Reversible	Unknown	Not significant	N/A
Increased benthic productivity in Oakley Creek and Minago River from nitrate and ammonia in effluent discharges.	Positive	Low to Moderate	Local	Medium term, Moderate frequency	Reversible	Unknown	Not significant	N/A

Table 7.7-14 (Cont.'d) Summary of Effects on Benthic Invertebrates and Periphyton

Potential Effect	Level of Effect						Effect Rating	
	Direction	Magnitude	Extent	Duration/Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Decommissioning								
Reduced benthic productivity in Oakley Creek resulting from changes in water quality from site runoff where facilities have been removed and/or the ground has been recontoured.	Adverse	Low	Site-specific	Short-term	Reversible	High	Not significant	N/A
Reduced benthic productivity in Oakley Creek resulting from changes in water quality related to Polishing Pond effluent treatment and discharges (metals, nutrients).	Adverse	Low	Site-specific	Medium term	Reversible	High	Not significant	N/A
Closure								
Uptake of metals by invertebrates in the TWRMF, and their consumption by birds and other wildlife.	Adverse	Low	Site-specific	Far future	Reversible	Unknown	Not significant	N/A
Reduced wetted habitat and benthic productivity in Oakley Creek and the Minago River resulting from flow changes related to discontinued discharge of Polishing Pond effluent at closure.	Adverse	Low	Site-specific	Long-term, Moderate frequency	Reversible	High	Not significant	N/A

7.8 Fish Resources

This section describes the fish resources of the project area and potential project and cumulative effects on fish. The assessment of effects on fish is based on the assessment of project effects, detailed in Section 7.5: Surface Water Quality; Section 7.7: Periphyton and Benthos; Section 2.16: Transportation; and commitments to environmental protection during construction and operation as outlined in Section 9: Environmental Protection Plan. The potential social and cultural implications of project effects on fish resources are discussed in Section 7.11: Land Use and Tenure (effects on non-traditional fishing activities) and in Section 7.12: First Nations and Traditional Use.

This section discusses the effects of routine project construction and operations on fish resources. Potential effects of accidents and malfunctions are discussed in Section 8: Accidents and Malfunctions.

Fish habitat assessment in rivers, creeks and lakes surrounding the Minago Project was undertaken to determine the presence/absence of fish populations in water bodies and streams likely to be affected by the Minago Project. Fish assessments (fish habitat and abundance) were undertaken by Wardrop (2007) in May and August 2006, by URS (2008b) in May/June 2007, and by Roche Consulting Group (Roche) in May 2008.

Wardrop undertook fisheries assessments at three stations on Oakley Creek and at one station on Minago River in 2006. URS assessed fish habitat and abundance on Oakley Creek, Minago River, and William River at three stations per watercourse. Fish samples were also collected for baseline measurements of metal concentrations in fish in 2007. Roche's work included the installation of two to three bait traps in Oakley Creek, Minago River, and William River and one bait trap and one experimental net each in Cross Lake, Hill Lake and Limestone Bay on Lake Winnipeg. Roche also collected tissue samples in order to evaluate total metal content for 20 individuals (13 predator and 7 prey fish specimens) (Roche, 2008a).

Minago River and Oakley Creek were sampled, because treated effluent from the proposed mining operation may be discharged into the Minago River and Oakley Creek. The William River was surveyed above and below its confluence with Oakley Creek to establish baseline conditions and to determine potential future impacts on William River and Limestone Bay at the north end of Lake Winnipeg.

Table 7.8-1 lists the GPS coordinates (UTM; NAD83) of all fish sampling and monitoring stations. Figure 7.8-1 illustrates the 2006-2008 fish sampling locations on an aerial map, while Figure 7.8-2 provides a close-up view of the sampling locations.

7.8.1 Scope of Fisheries Assessments

The scope of the assessments included inventorying fish habitats in water bodies around the Minago Project, including the Minago, William, and Hargrave Rivers and Oakley Creek. In

Table 7.8-1 Coordinates of Minago 2006-2008 Fish Sampling Locations

Sample Location	UTM Northing	UTM Easting	Description	Sampled by: Wardrop (2007)	URS (2008b)	Roche (2008a) Nets	Roche (2008a) Bait trap
OCF1 & OCW-1	5990528	489238	Oakley Creek immediately east of HW6	X	X		X
OCW-2	5990974	487559	2.2 km upstream of OCW-1	X			
OCF2 - 2007	5990978	487136	Oakley Creek immediately downstream of tributary stream entering from the north		X		
OCF2 - 2008	5990908	487235	approximately 125 m downstream of OCF2-2007				X
OCF3 & OCW-3	5990931	487048	Oakley Creek upstream of confluence of tributary (~ 550 m upstream of OCW-2)	X	X		
MRW2x	6001209	472465	Minago River near Habiluk Lake				X
MRF1 & MRW-1	6005275	488684	Minago River at the Highway 6 crossing, approximately 15 km north of Oakley Creek.	X	X		
MRF2 - 2007	6004902	488527	Minago River tributary immediately west of HW6		X		
MRF2 - 2008	6005007	488562	approximately 25 m downstream of MRF2-2007				X
MRF3	6005308	488362	Minago River location upstream of HW6		X		X
WRF1	5987166	495419	William River approximately one kilometre upstream of Oakley Creek		X		X
WRF2	5986330	498578	William River immediately downstream of Oakley Creek		X		X
WRF3	5973598	484762	William River immediately downstream of Little Limestone Lake outlet stream.		X		X
CLF1	6046198	555324	Cross Lake			X	X
HLF1	6012816	502060	Hill Lake			X	X
LBF1	5969136	503911	Limestone Bay			X	X

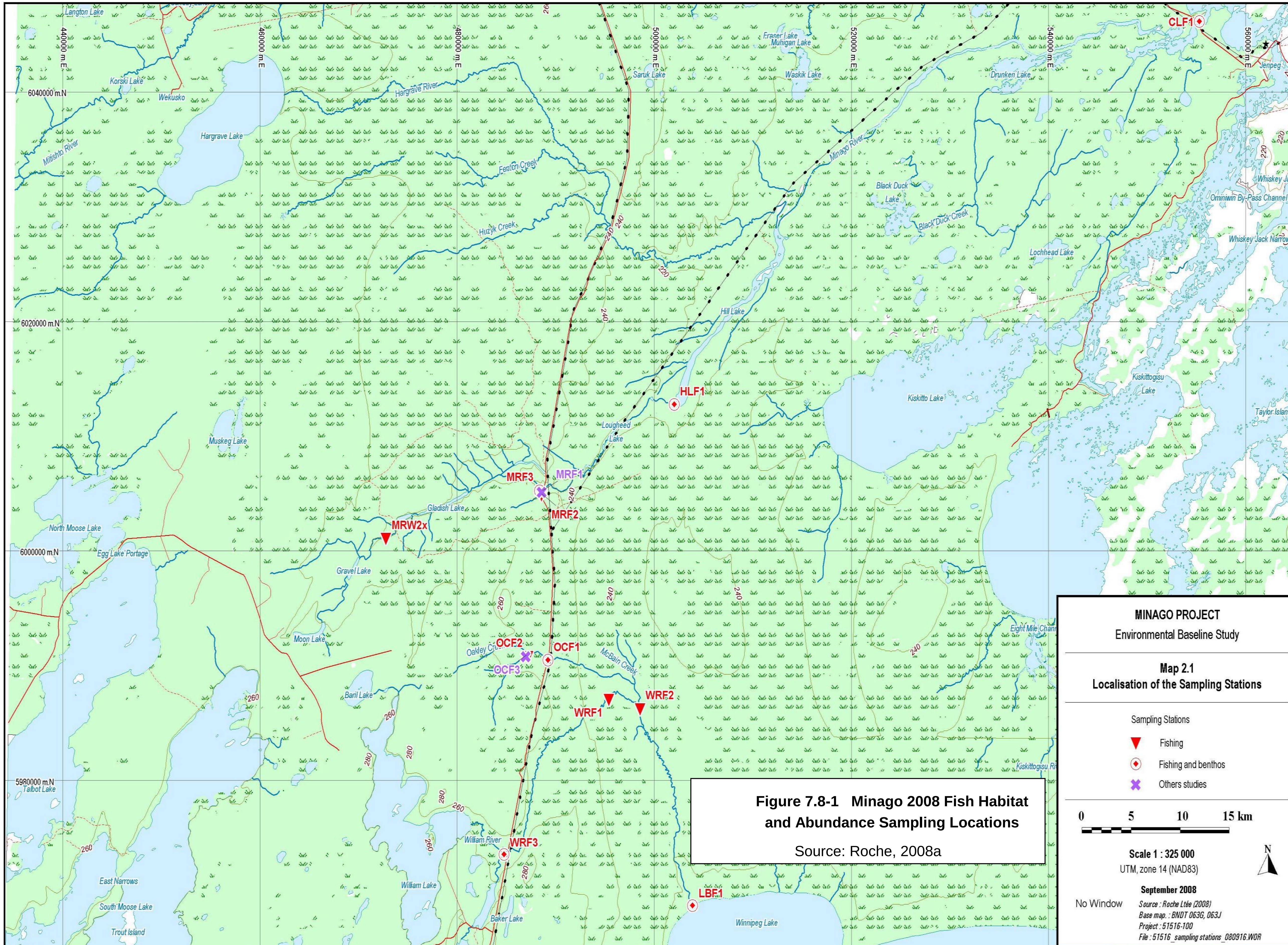
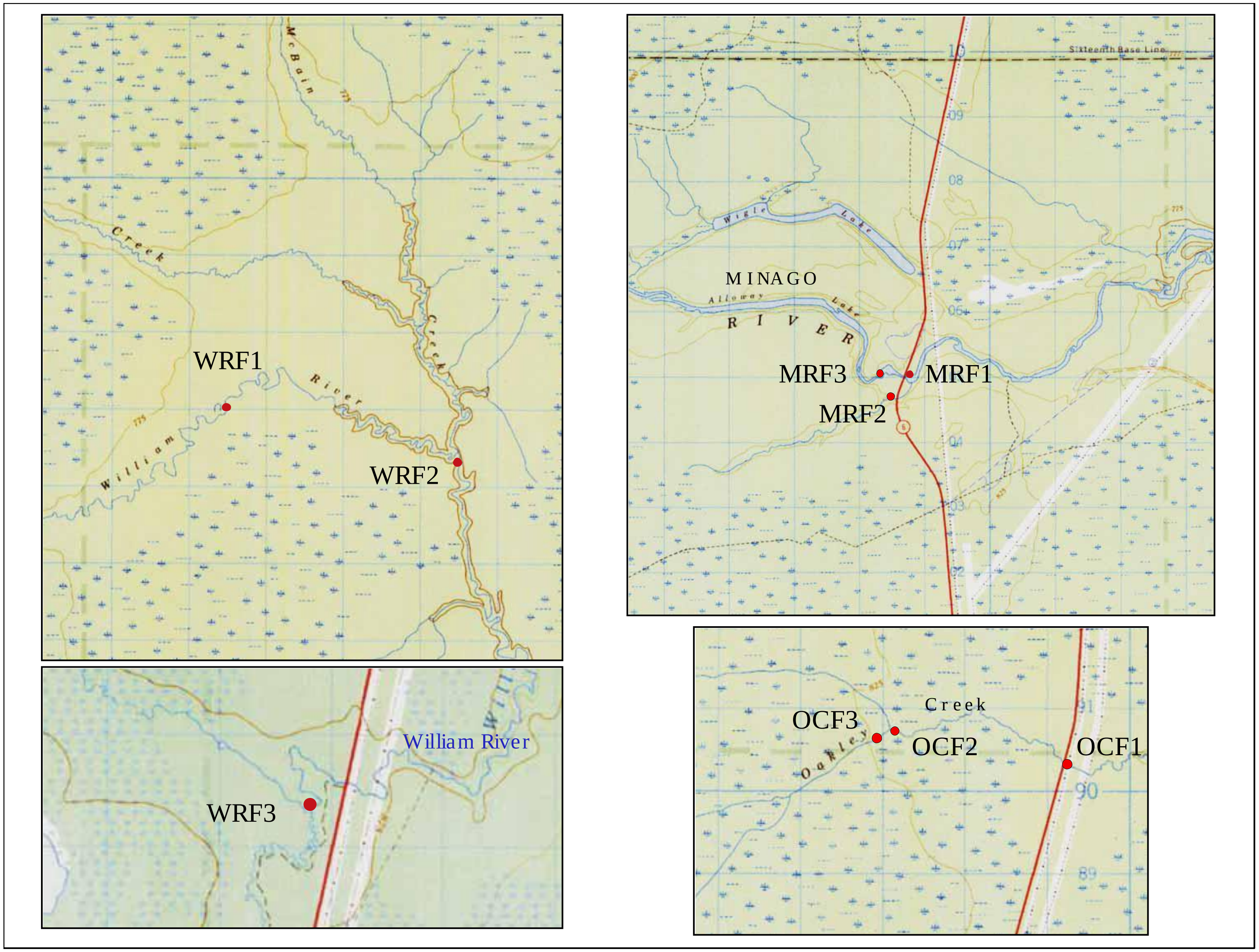


Figure 7.8-1 Minago 2008 Fish Habitat and Abundance Sampling Locations

Source: Roche, 2008a



Source: adapted from URS, 2008b

Figure 7.8-2 Close-up View of the 2007 Fish Sampling Locations

addition, Limestone Bay, Cross Lake, Hill Lake, Little Limestone Lake and William Lake were assessed.

7.8.1.1 Scope of Fisheries Assessments - 2006

Wardrop assessed fish communities at OCW-1 in May 2006 and at OCW-1, OCW-2, OCW-3, and MRW-1 in August 2006 (Table 7.8-1). Electrofishing was conducted by surveying all varieties of habitat present at each sampling station. The length of the survey section and the number of seconds of electrofishing were recorded. Habitat features for each survey length were inventoried. The Catch Per Unit Effort (CPUE) was calculated for each sampling station by dividing the number of fishes caught by the fishing time.

7.8.1.2 Scope of Fisheries Assessments -2007

URS conducted fish habitat and distribution surveys of Oakley Creek (OCF1, OCF2 and OCF3) upstream of Highway 6 and south of the Minago Project area, habitat characterization and fish distribution survey of the Minago (MRF1, MRF2 and MRF3) and William (WRF1, WRF2 and WRF3) Rivers, and an analysis of fish tissue for metals (full ICP scan) from specimens collected at selected sites on Minago River, William River, and Oakley Creek. These fish surveys were undertaken by URS in May and June 2007.

7.8.1.3 Scope of Fisheries Assessments - 2008

Roche Consulting Group assessed fish habitat and abundance by installing eleven (11) bait traps and three experimental nets in areas surrounding the Minago Project (Table 7.8-1 and Figure 7.8-1) (Roche, 2008a).

Three lakes (Cross Lake, Hill Lake and Limestone Bay of the Lake Winnipeg) were sampled in order to establish background levels of contamination for fishes collected within the study area. Fish captured were counted, sacrificed and identified to species. Tissue samples were collected in order to evaluate total metal content (As, Pb, Se and Hg) for twenty specimens. These twenty specimens were also measured, weighed, sexed and their stage of gonad development was determined based on the Nikolsky scale (Appendix 7.8).

Eleven Cuba-Franklin (45 x 20 cm) bait traps were distributed within the study area, one each in Cross Lake, Hill Lake and Limestone Bay of Lake Winnipeg and two to three in each sampled stream (Minago River, Oakley Creek and William River) (Table 7.8-1).

7.8.1.4 Fish Survey Methodologies

Fish survey methodologies are summarized in the Sections below. Details pertaining to specific methodologies are given elsewhere (Wardrop, 2007; URS, 2008b; Roche, 2008a).

7.8.1.4.1 Fisheries Survey - 2006

Wardrop (2007) surveyed fish communities at OCW-1 on May 16, 2006 and at OCW-1, OCW-2, OCW-3, and MRW-1 on August 22-23, 2006, using a Smith-Root LR-24 Electrofisher (Table 7.8-1). Electrofishing was conducted by surveying all varieties of habitat present at each sampling station. The field crew began sampling downstream and worked upstream, dipnetting any stunned fishes. The length of the survey section and the number of seconds of electrofishing were recorded. Fishes were placed in a bucket during the survey and later fixed in 10% buffered formalin. Samples were returned to the Winnipeg Wardrop office for fish identification to species, enumeration, and preservation in 60% isopropyl alcohol. Habitat features for each survey length were inventoried. The Catch Per Unit Effort (CPUE) was calculated for each sampling station by dividing the number of fishes caught by the fishing time.

7.8.1.4.2 Fisheries Survey - 2007

Existing habitat and fish distribution reports, aerial photographs, and topographic maps were used to create maps, which helped determine where field surveys should occur. Topographic maps of the area were downloaded from Topoweb Canada: Manitoba (Softmap 2007), converted to a PathAway 4.0 (Muskoka Tech 2007) file format and loaded onto a Palm Treo 680 PDA. The PathAway mapping application on the Treo 680 was used in conjunction with an EMTAC mini Bluetooth GPS unit to locate positions in the field and record their coordinates.

A Smith-Root 12-B Backpack Electrofisher was used to sample for fish presence/absence at each of the nine sample locations and along roadside ditches and small drainages flowing through the Minago Project area (URS, 2008b). A 100 m reach downstream from each sampling location was electrofished to collect fish specimens.

Fish in all drainages were relatively rare and unevenly distributed. Sample locations selected on Oakley Creek and the Minago River locations had solid substrates or were readily accessible from the bank. The William River had a mud and loose sand substrate at all sample locations, and steep banks that quickly dropped-off into turbid water. Sampling on the William River was confined to carefully sampling from the banks, particularly on side channels and near weed beds. Sampling was opportunistic, because of the uneven distribution of fish and their relative scarcity.

Fish attracted to the anode ring or stunned were dipnetted and placed in a bucket of stream water to which a few drops of clove oil were added to tranquilize the fish. This made it easier to take measurements of the fish. Fish specimens were placed on ice and frozen upon return from the field for later delivery to an accredited laboratory (URS, 2008b). Fish were collected for baseline measurements of metal concentrations in fish tissues at each of the nine sampling locations according to the EPA (2000) protocol. The sampling protocol for fish tissues is provided in Appendix 7.8.

During the 2007 fisheries survey, water temperature and stream flow data were recorded at every sample location. Temperature was recorded in centigrade with a William Joseph digital thermometer. Streamflow measurements in Oakley Creek, William River, and Minago River watersheds were recorded using a Global Water FP101 Flow Probe. Details of the streamflow measurement program are presented in Appendix 7.8.

Collection of fisheries field data began on May 16, 2007, but was interrupted on the first day by equipment failure that required leaving the field and returning on May 31, 2007 (URS, 2008b). Field data collection was completed on June 7, 2007. The fisheries field study was led by Dr. Rob Nielsen (Fish and Wildlife Scientist, URS) and assisted by Bill Kidder (Wetland and Wildlife Scientist, URS) and Ken Budd (Field Assistant from Norway House representing Victory Nickel Inc.). Photographs of the 2007 fisheries assessment are presented in Appendix 7.8.

7.8.1.4.3 Fisheries Survey - 2008

Roche's fisheries survey was completed according to a scientific collection permit (#10-08), issued on April 14, 2008 (Appendix 7.8), under the authority of the *Fisheries Act* (Manitoba) and the Fishing License Regulation and Fishing License Fee Regulation. The inventory was performed by Simon Thibault and Brigitte Dutil from Roche Ltd. for VNI (Roche, 2008a).

Roche characterized fish habitats in terms of:

- water depth;
- substrate characterization;
- Secchi disk water transparency measurements;
- water temperature and pH;
- water conductivity; and
- oxygen concentration in water.

Nine substrate classes were used to characterize the fish habitat: clay, silt, sand, gravel, pebble, cobble, boulder, large boulder, and bedrock. Every substrate size class that was present at a sampling location was noted and reported in order of importance. The distribution and presence of organic detritus, wood debris, aquatic vegetation and algae were also noted.

The shore characteristics were also recorded in May 2008. However, since shores were still covered with snow or ice, their description was not as precise as it could have been during summer months. The height of the embankment was visually estimated. Vegetation present on the shore was briefly described. Surface materials (using the above mentioned substrate classes) and dead trees present on the shore were characterized and reported in order of importance.

Experimental nets were installed at three different stations, one each in Cross Lake, Hill Lake and Limestone Bay of Lake Winnipeg (Figure 7.8-3). The experimental gill nets used were 45.7 m long, 1.8 m high, and were made of six consecutive panels of equal length (7.6 m) with stretched mesh size varying between 25 and 102 mm. The nets in Hill Lake and Limestone Bay were installed on May 6, 2008 while the net in Cross Lake was installed on May 8, 2008. All nets were left in place for one night (Roche, 2008a).

Source: Roche, 2008a

Figure 7.8-3 Bait Trap Set at MRW2x (Minago River; left) and Experimental Net Set at LBF1 (Limestone Bay; right)

Eleven Cuba-Franklin (45 x 20 cm) bait traps were distributed within the study area (Figure 7.8-3). The Cuba-Franklin bait traps had a circular aperture of 4 cm at each extremity. Bread and cat food (salmon-flavoured) were put in the traps as bait. One bait trap each was installed in Cross Lake, Hill Lake and in Limestone Bay of the Lake Winnipeg and two to three in each of the sampled streams (Minago River, Oakley Creek and William River) (Table 7.8-1). The bait traps were left in place for one night (Roche, 2008a).

Fish captured were counted, scarificed and their respective species were identified. Twenty specimens were measured, weighed, sexed and their stage of gonad development was determined based on the Nikolsky scale before their flesh was collected (Figure 7.8-4). The twenty specimens consisted of 13 predators (4 Walleyes, 7 Northern pikes, 2 Yellow perch) and seven preys (3 White suckers, 4 Longnose suckers). Tissue samples were collected from these specimens in order to evaluate total metal content (As, Pb, Se, and Hg) (Roche, 2008a).

7.8.2 Baseline Conditions

Baseline conditions for the waterbodies around the Minago Project were assessed to determine the pre-development environmental conditions and fisheries inventories in terms of population size and species distribution.

Source: Roche, 2008a

Figure 7.8-4 Fish Dimensional Measurements

7.8.2.1 Baseline Fish Habitat

Fish habitat surveys were undertaken in the waterbodies around Minago Project. The water bodies included Oakley Creek, Minago River, William River, Hargrave River, Cross Lake, Limestone Bay of Lake Winnipeg, Cross Lake, Hill Lake, Little Limestone Lake and William Lake.

7.8.2.1.1 Fish Habitat Survey - 2006

Wardrop found that fish habitat at OCW-1 was the most diverse and provided the best quality in relation to the other Oakley Creek stations OCW-2 and OCW-3 (Wardrop, 2007). The streambed at OCW-1 was dominated by cobble, gravel, and boulder substrate with smaller proportions of sand, bedrock, and fines. Habitat components, cover, and substrate at OCW-1 were diverse, providing potential spawning, rearing, migration, and adult feeding habitat for large-bodied fishes. Upstream of Highway 6, the stream gradient decreased and the stream was characterized by numerous channels and ponds. As well, intense beaver activity had resulted in 14 dams between Highway 6 and OCW-3. Habitat upstream of Highway 6 was relatively consistent, characterized by beaver ponds and deep, narrow channels predominantly underlain by a substrate of organic matter and fines. Areas of sand, gravel, and cobble occurred incidentally. Habitat quality was below that of OCW-1, with low quality habitat for adult, large-bodied fishes, particularly with respect to spawning, and adult feeding.

The Minago River at MRW-1 is characterized by a broad, deep flat streambed that discharges over a shelf of bedrock, through a short set of rapids, into a downstream flat (Wardrop, 2007; Appendix 7.8). The rapids are formed by large, angular boulders that form a riffle in high water and a boulder garden in low water. The substrate at station MRW-1 is primarily bedrock covered with large (> 100 mm) angular rocks.

Photographs of the 2006 fish monitoring locations are given in Appendix 7.8.

7.8.2.1.2 Fish Habitat Survey - 2007

Oakley Creek

The stream channel of Oakley Creek primarily exists as a deep and sinuous, steep-sided channel (glide) traversing beaver ponds and areas of floodplain that were created by former beaver ponds that have become vegetated with a shrub habitat. With the exception of a few patches of cobble at riffles, the substrate consists entirely of mud and silt. Aquatic plants, such as spatter-dock (*Nuphar luteum*) are relatively common in the channel, but aquatic weed beds are only present in the beaver ponds (URS, 2008b).

The surveyed portions of Oakley Creek were divided into 9 stream reaches, based on changes in physical characteristics, such as average channel width or depth and average floodplain width. A total of 15 beaver dams were recorded by URS (2008b). The locations of the stream reaches are presented in Figures 7.8-5 and 7.8-6. Survey data for the 9 stream reaches and the surface channel of the north tributary is given in Table 7.8-2. The locations of the beaver dams is detailed in Table 7.8-3.

With the exception of reaches 1 and 9, which have a mix of riffle and glide habitat, riffle habitat is confined to immediately below beaver dams. Beaver dams often were broad, crossing much of the floodplain and with several outlets. Although deep (up to 3.6 m deep) at the dams, the ponds quickly became shallow and filled with emergent wetland vegetation and multiple side channels (URS, 2008b).

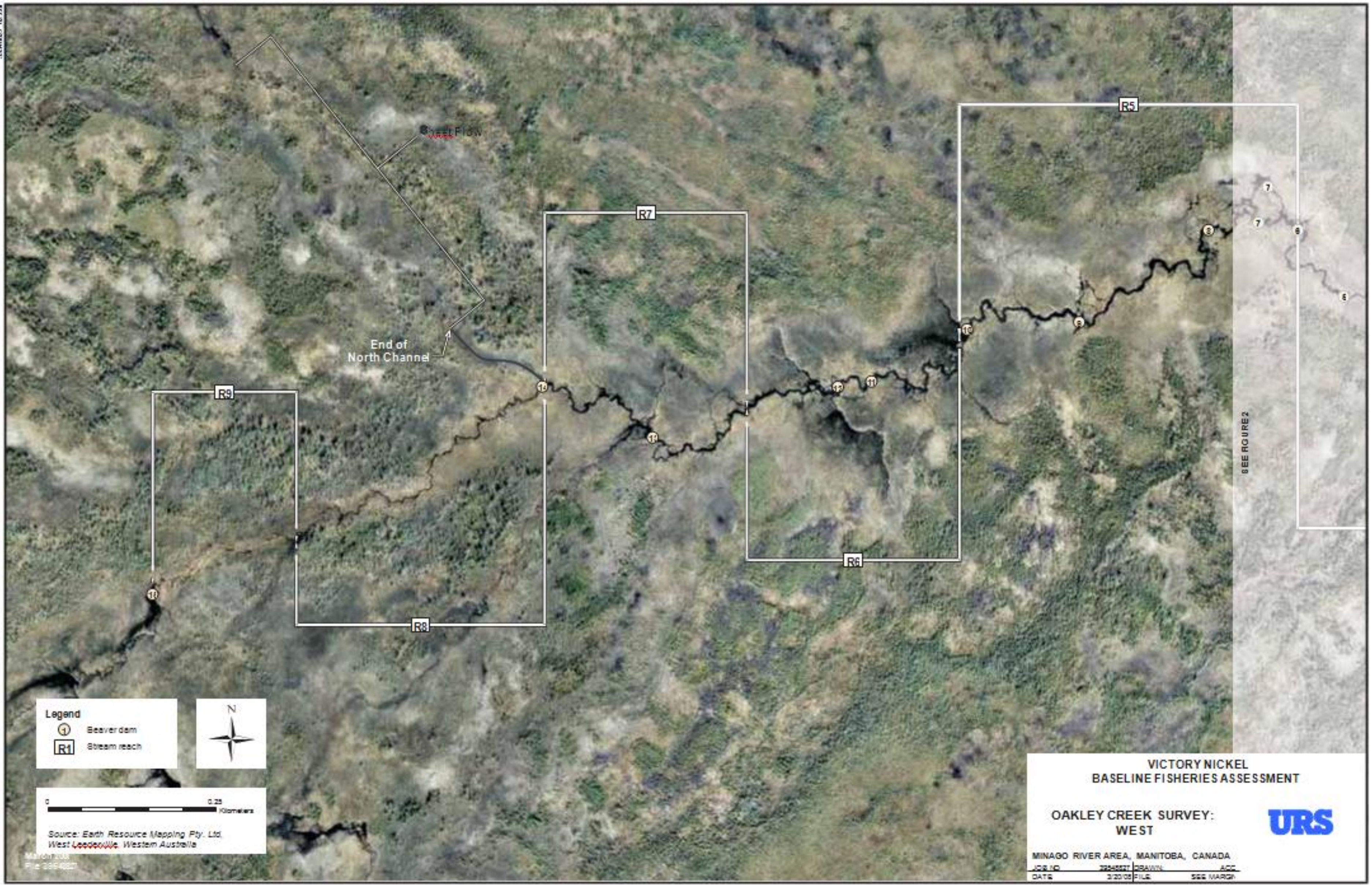
With the exception of areas in the back of larger beaver dams that were vegetated with emergent wetland vegetation of sedge, rushes, herbs, and grasses; the broad floodplain was vegetated primarily by a deciduous shrub vegetation dominated by myrtle-leaved willow (*Salix myrtillfolia*). The emergent wetland vegetation was dominated by beaked sedge (*Carex ultriculata*) and water sedge (*Carex aquatilis*). The edge of the floodplain consisted of intermediate closed evergreen forest dominated by black spruce with some tamarack (*Larix laricina*) present and a shrub community of diamond leaf willow (*Salix planifolia*), green alder (*Alnus crispa*), and small paper birch (*Betula papyrifera*) (URS, 2008b).

William River

At all three William River stations (WRF1, WRF2, WRF3) surveyed in 2007, William River has relatively steep streambanks and the stream channel floodplain is incised about 1.2 to 2.4 m below the surrounding forested area (URS, 2008b). The river flows through a closed canopy

Source: URS, 2008b

Figure 7.8-5 Oakley Creek Fish Survey Reaches (East)



Source: URS, 2008b

Figure 7.8-6 Oakley Creek Fish Survey Reaches (West)

Table 7.8-2 Oakley Creek Stream Reach Data (May and June, 2007)

Oakley Creek Stream Reach	Length (m)	Distance Endpoint is Upstream of Highway 6 (m)	Bank Full Width (m)	Average Depth (m)	Glide/Riffle ratio	Length of side channels (m)	Average Floodplain Width (m)
1	551	106	3.2	0.8	50/50	160	90
2	383	489	8	0.8	100/0	110	120
3	698	1,187	4.8	1.3	100/0	488	120
4	708	1,895	3.5	1.1	100/0	230	140
5	893	2,788	6.5	1.2	100/0	670	250
6	558	3,346	6.5	0.7	100/0	1,030	290
7	479	3,825	5	0.6	95/5	890	185
8	587	4,412	2.5	0.5	90/10	40	60
9	275	4,687	1	0.3	60/40	271	30
North Tributary	59	3,884	1	0.15	95/5	0	22

Source: URS, 2008b

Table 7.8-3 Location of Oakley Creek Beaver Dams

Beaver Dam No.	Distance upstream of Highway 6 (m)
1	106
2	237
3	371
4	1454
5	1691
6	1895
7	1992
8	2151
9	2527
10	2788
11	3073
12	3154
13	3573
14	3825
15	4687

Source: URS, 2008b

Note: Beaver dam locations are illustrated in Figures 7.8-5 and 7.8-6.

forest dominated by black spruce (*Picea mariana*) and white spruce (*Picea glauca*). The floodplain was mostly nonexistent, but where present, consisted of a shrub community. The river channel is a deep and sinuous, steep-sided channel (glide) with a substrate composed primarily of silt and organic debris at sample locations WRF1 and WRF2 and silt and sand at sample location WRF3 (URS, 2008b). The river channel varies between about 8 and 14 m in width and 1 to 2 m in depth. Streambanks are steep and there were no gravel bars and few side channels present. Perhaps due to the close proximity of large streambank trees, log-jams and large wood debris are common throughout the river. Aquatic plants are abundant and weedbeds occur frequently, wherever the river becomes less than a metre deep.

Due to a high silt load, the William River has relatively high turbidity during high flows. During the late spring and summer months, the outlet stream of Little Limestone Lake (a large marl lake) discharges a heavy load of calcite precipitates into the William River (URS, 2008b).

Minago River

The sample locations chosen by URS for the Minago River fish monitoring stations were clustered near Highway 6 (Figures 7.8-1 and 7.8-2) (URS, 2008b). Sample location MRF1 was located in the pool and riffle immediately downstream from the Highway 6 Bridge. Sample location MRF2-2007 was on a small tributary of the Minago River just west of Highway 6 and MRF3 was located at the head of a large pool approximately 550 m west of Highway 6.

The Minago River flows through a broad floodplain with an average width of about 500 m. At the Minago River sampling locations MRF1 and MRF3, the river flows over limestone cobble into a large pool. Substrate consists of large limestone cobble in the riffles and sand and silt in the pools. Riffle habitat has an average width of about 40 m and a depth of up to about 1 m. Pool habitat had an average width of about 90 m and a depth of up to 3 m (URS, 2008b).

Minago River flows through a burn area, with deciduous forest along the riparian zone/floodplain and a jack pine (*Pinus banksiana*) forest above the floodplain incision. The shoreline frequently has shallow areas filled with aquatic vegetation along both the riffle and pool habitat. Riffle and pool habitat in the vicinity of Highway 6 was roughly evenly divided, but much of the river observed from a helicopter over-flight consisted of glide and pool habitat, with several long, narrow lakes. No barriers to fish migration were observed on the Minago River in the vicinity of the project area (URS, 2008b).

The small tributary of the Minago River at sample location MRF2-2007 flows out from a burned-over jack pine plateau to the Highway 6 roadside and then into the Minago River. The reach that was sampled flows through an area of deciduous forest and shrubs. The tributary has an average width of 3 metres and an average depth of about 0.5 metre. The pool/riffle ratio was about 50/50, with many of the pools filled with aquatic weeds. The stream channel was relatively straight, with a gravel and cobble substrate in the riffles and a combination of cobble gravel, sand, and silt in the pools.

Table 7.8-4 presents the streamflow and temperature conditions encountered during the 2007 fisheries program.

Table 7.8-4 Flow and Temperature Data for the 2007 Fisheries Program

SAMPLE LOCATION	DATE	FLOW (m^3/s)	TEMPERATURE (^oC)
OCF1	30-May-07	2.0	16.0
OCF2-2007	03-Jun-07	1.7	19.6
OCF3	03-Jun-07	0.8	20.2
MRF1	30-May-07	7.9	15.8
MRF2-2007	30-May-07	0.33	17.4
MRF3	04-Jun-07	7.9	15.8
WRF1	06-Jun-07	3.2	18.0
WRF2	06-Jun-07	5.0	17.8
WRF3	04-Jun-07	3.0	17.8

Source: URS, 2008b

7.8.2.1.3 Fish Habitat Survey - 2008

Table 7.8-5 describes the main fish habitat encountered by Roche in 2008.

7.8.2.2 Baseline Fish Distribution

Detailed results of the 2006, 2007 and 2008 fish distribution surveys are presented and discussed below. A complete list of fish potentially present in the William and Minago River watersheds is presented in Tables 7.8-6 and 7.8-7. Table 7.8-6 summarizes the scientific and common names of these fishes and Table 7.8-7 details their trophic guild and approximate distribution.

Most of the fishes listed in Tables 7.8-6 and 7.8-7 are small, stream resident insectivors (insect eaters) or Omnivores (eating plants and small insects or crustaceans). The Channel catfish and the Northern pike are the only resident Piscivores (fish eating) fish to occur in the streams. Resident Northern pike are probably confined to the mainstream rivers, with Northern pike entering tributary streams to spawn in the early spring, soon after ice-out.

In addition to the above documented distribution of fishes in the three surveyed streams, additional information is available from two major Manitoba or Lake Winnipeg specific references, entitled ‘The fish and fishes of Lake Winnipeg, the first 100 years’ (Franzin *et al*. 2003) and ‘The freshwater fishes of Manitoba’ (Stewart and Watkinson 2004). These references document the presence of stream resident carp (*Cyprinus carpio*), Fathead minnow (*Pimephales promelas*), and Channel catfish (*Ictalurus punctatus*) in the lower reaches of the William River. They also indicate that resident stream populations of Blackchin shiner (*Notropis heterodon*), Spottail shiner (*Notropis hudsonius*), Longnose dace (*Rhinichthys catractae*), Trout-perch (*Percopsis omiscomaycus*),

Table 7.8-5 *In Situ* Physical Parameters for the 2008 Fish Survey Program

Stations	Water Body	Fishing Equipment	Geographical Coordinates X (mE)	Geographical Coordinates y (mN)	Type of Substrate	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	Temperature (°C)	Secchi Disk (m)	Water Depth (m)
CLF1	Cross Lake	Net	555 324	6 046 198	Mud, clay	91.7	11.91	178.3	7.9	4.2	1.08	4.20
		Bait trap									-	0.77
HLF1	Hill Lake	Net	502 060	6 012 816	Mud, clay	91.8	10.85	151.7	7.7	8.1	1.70	1.70
		Bait trap									-	0.80
LBF1	Limestone Bay	Net	503 911	5 969 136	Organic, clay	94.8	12.10	240.0	8.0	5.0	0.29	1.20
		Bait trap									-	0.70
MRF2	Minago River	Bait trap	488 562	6 005 007	Mud, herbs	54.5	6.57	124.5	7.5	7.2	-	0.58
MRF3	Minago River	Bait trap	488 362	6 005 308	Mud, dead trunk	83.2	10.27	134.0	7.5	6.8	-	0.54
MRW2x	Minago River	Bait trap	472 465	6 001 209	Mud, clay	88.4	10.20	300.0	7.8	9.0	-	0.32
OCF1	Oakley Creek	Bait trap	489 238	5 990 528	Mud, clay, herbs	81.1	10.83	230.0	7.7	3.1	-	0.66
OCF2	Oakley Creek	Bait trap	487 235	5 990 908	Mud, clay, herbs	73.0	9.16	290.0	7.7	5.9	-	0.75
WRF1	William River	Bait trap	495 419	5 987 166	Mud, clay, herbs	95.7	11.50	360.0	8.2	7.4	-	0.27
WRF2	William River	Bait trap	498 578	5 986 330	Mud, clay, herbs	93.9	11.49	260.0	8.2	6.7	-	0.34
WRF3	William River	Bait trap	484 762	5 973 598	Mud, gravel, herbs	84.8	10.35	290.0	8.3	6.6	-	0.26

Source: adapted from Roche, 2008a

Table 7.8-6 Scientific and Common Names of Fish Potentially Present in William and Minago River Watersheds

SCIENTIFIC NAME	COMMON NAME
Cyprinidae: Minnows	
Cyprinus carpio	Common carp
Margariscus margarita	Pearl dace
Notropis atherinoides	Emerald Shiner
Notropis heterodon	Blackchin shiner
Notropis heterolepis	Blacknose shiner
Notropis hudsonius	Spottail shiner
Pimephales promelas	Fathead minnow
Rhinichthys cataractae	Longnose dace
Catostomidae: Suckers	
Catostomus catostomus	Longnose sucker
Catostomus commersoni	White sucker
Ictaluridae: Catfishes	
Ictalurus punctatus	Channel catfish
Esocidae: Pikes	
Esox lucius	Northern pike
Umbridae: Mudminnows	
Umbra limi	Central mudminnow
Osmeridae: Smelts	
Osmerus mordax	Rainbow smelt
Percopsidae: Trout-perches	
Percopsis omiscomaycus	Trout-perch
Gasterosteidae: Sticklebacks	
Culaea inconstans	Brook stickleback
Cottidae: Sculpins	
Cottus bairdi	Mottled sculpin
Cottus cognatus	Slimy sculpin
Percidae: Perches	
Etheostoma exile	Iowa darter
Etheostoma nigrum	Johnny darter
Sander vitreus	Walleye

Source: URS, 2008b

Note: Common and Scientific names derived from Nelson et al. (2004)

Table 7.8-7 Trophic Guild and Approximate Distribution of Fish Potentially Present in the William and Minago Rivers

COMMON NAME	TROPHIC GUILD	DISTRIBUTION
Common carp	Omnivore	Resident in low velocity habitat of lower William River
Pearl dace	Insectivore	Resident in surveyed portion of Oakley Creek and associated beaver ponds. Captured in Minago River in large pool upstream of Highway 6.
Emerald Shiner	Zooplanktivore	Lake Winnipeg Emerald shiners spawn in low velocity habitat of the William River.
Blackchin shiner	Insectivore	May occur as resident in low velocity habitat in William River.
Blacknose shiner	Insectivore	Resident in William River and Oakley Creek.
Spottail shiner	Insectivore	Resident in mainstem William and Minago Rivers (associated with weedbeds).
Fathead minnow	Omnivore	Resident in low velocity habitat of lower William River.
Longnose dace	Insectivore	May occur as resident in William and Minago Rivers (associated with riffle habitat).
Longnose sucker	Omnivore	Resident and lake-run in William and Minago Rivers.
White sucker	Omnivore	Lake Winnipeg fish spawn throughout William, Minago, and Oakley Creek drainages. Resident fish occur in mainstem William and Minago Rivers.
White sucker (dwarf)	Omnivore	Resident fish in headwater streams and ponds.
Channel catfish	Piscivore	Low velocity habitat in lower William River.
Northern pike	Piscivore	Resident fish occur in Minago and William Rivers and may occur in lower Oakley Creek. Lake Winnipeg fish spawn in William River and Oakley Creek.
Central mudminnow	Insectivore	Resident fish in low velocity habitat of William R., Minago R. & Oakley Creek.
Rainbow smelt	Zooplanktivore	Introduced pelagic fish in Lake Winnipeg, documented to spawn in William River.
Trout-perch	Insectivore	Resident in mainstem Minago and William Rivers (associated with rocky substrates).
Brook stickleback	Insectivore	Resident in low velocity habitat of William R., Minago R. and Oakley Creek.
Mottled sculpin	Insectivore	May occur as resident in riffle habitat of lower William River.
Slimy sculpin	Insectivore	May occur as resident in lower William and Minago Rivers.
Iowa darter	Insectivore	Resident in the Minago River and possibly William River drainage.
Johnny darter	Insectivore	Resident in the William and Minago River drainages.
Walleye	Piscivore	Pelagic fish in Lake Winnipeg, William Lake, and Minago River Lakes. Lake-run fish spawn in William and Minago Rivers and reported to occur in Oakley Creek.

Source: URS, 2008b

Note: Distribution data from project surveys, Wardrop (2007), Crossman and Scott (1973), Stewart and Watkinson (2004), Franzin et al. (2003), and Anderson (2008).

Mottled sculpin (*Cottus bairdi*), and Slimy sculpin (*Cottus cognatus*) are likely to occur within either the William and Minago River drainages (Table 7.8-6).

The 2006-2008 fisheries results are discussed in chronological order in the next sections. A summary of all fishes caught or observed during the 2006-2008 fisheries surveys is presented in Table 7.8-8.

7.8.2.2.1 Fish Community Results (2006 Program)

Wardrop captured a total of 90 fishes on May 16, 2006 (Tables 7.8-8 and 7.8-9) (Wardrop, 2007). Brook stickleback (*Culaea inconstans*) were the dominant species followed by Pearl dace (*Margariscus margarita*) and White sucker (*Catostomus commersoni*; Table 7.8-9). Two adult White suckers were captured and released. Adult suckers (*Catostomus* spp.) were observed in deeper pools of Oakley Creek as far upstream as OCW-2 on 17 May, 2006.

On 22-23 August 2006, Wardrop captured fishes at all sites surveyed (OCW-1, OCW-2, OCW-3 and MRW-1) (Wardrop, 2007). Forty-nine fishes were captured at OCW-1 and species richness increased from three species in May to six in August 2006. Central mudminnow (*Umbra limi*) dominated the catch followed by Brook stickleback, Pearl dace, White sucker, Blacknose shiner (*Notropis heterolepis*) and Johnny darter (*Etheostoma nigrum*). At OCW-2, a total of 49 fishes were captured with Central mudminnow being the dominant species followed by Brook stickleback and Pearl dace. At OCW-3, a total of 17 fishes were captured with the catch being dominated by Brook stickleback followed by Central mudminnow and Pearl dace.

At MRW-1, a total of 56 fishes were captured, with Johnny darter being the dominant species followed by Central mudminnow, White sucker, Iowa darter (*Ethiostoma exile*), and Longnose sucker (*Catostomus catostomus*) (Wardrop, 2007).

Overall, species diversity was greatest at OCW-1 in August 2006, with six species from five families captured (*Umbridae, Cyprinidae, Catostomidae, Gasterosteidae*, and *Percidae*). Five species were captured at MRW-1, representing three families (*Umbridae, Catostomidae*, and *Percidae*). Three species, representing three families (*Umbridae, Cyprinidae, Gasterosteidae*) were captured at OCW-3 in August, 2006 (Table 7.8-9) (Wardrop, 2007).

The order of fish abundance (from high to low) for the Minago fish monitoring stations was as follows: OCW-2, OCW-1 (May, 2006), OCW-3, OCW-1 (Aug., 2006), and MRW-1 (Table 7.8-9).

The greatest Catch Per Unit Effort (CPUE) for a species (5.70 fish/min) was recorded for Brook stickleback at station OCW-1 in May 2006 (Table 7.8-9). However, CPUE decreased to 0.81 fish/min in late summer (August 2006). The CPUE for the other two species present in May 2006, Pearl dace and White sucker, did not differ greatly between May and August 2006. The lowest CPUE for a species (0.05 fish/min) occurred at MRW-1 where a single Longnose sucker was captured in August 2006. At OCW-1 in August, 2006, two species were represented by a single capture: Blacknose shiner (0.07 fish/min) and Johnny darter (0.07 fish/min).

Table 7.8-8 Summary of Fish Species Encountered During Various Surveys (2006, 2007 and 2008)

		OCW-1	OCW-1	OCF-1	OCW-2	OCF2 2007	OCF2 2008	OCW-3	OCF-3	MRW-1	MRF1	MRF2	MRF3	WRF1	WRF2	WRF3	Hill Lake	Limestone Bay	Cross Lake
Scientific Name	**Common Name**	**16 May, 2006**	**22-23 August, 2006**	**May 16 & 31 & Jun. 7, 2007**	**22-23 August, 2006**	**May 16 & 31 & Jun. 7, 2007**	**May 6-8, 2008**	**22-23 August, 2006**	**May 16 & 31 & Jun. 7, 2007**	**22-23 August, 2006**	**May 16 & 31 & Jun. 7, 2007**	**May 16 & 31 & Jun. 7, 2007**	**May 16 & 31 & Jun. 7, 2007**	**May 16 & 31 & Jun. 7, 2007**	**May 16 & 31 & Jun. 7, 2007**	**May 16 & 31 & Jun. 7, 2007**	**May 6-8, 2008**		
Umbra limi	Central mudminnow		19	Present	20			5	Present	13	Present	Present		Present					
Notropis heterolepis	Blacknose shiner		1													Present			
Notropis atherinoides	Emerabld shiner													Present	Present				
Margariscus margarita	Pearl dace	9	11		13	Present	4	4			Present		Present						
Catostomus commersoni	White sucker	3	5	Present		Present			Present	8		Present					7		
Catostomus catostomus	Longnose sucker									1								5	
Culaea inconstans	Brook stickleback	78	12	Present	16	Present	3	8	Present					Present	Present				
Etheostoma nigrum	Johnny darter		1							28				Present	Present	Present			
Etheostoma exile	Iowa darter									6			Present						
Notropis atherinoides	Emerabld shiner													Present	Present				
Osmerus mordax	Rainbow smelt														Present		2	1,028	
Esox lucius	Northern pike																19	67	27
Sander vitreus	Walleye																19	1	
Perca flavescens	Yellow perch																2		6
Sculpin sp.																	1		

Source: Wardrop, 2007; URS, 2008b; Roche, 2008a.

Table 7.8-9 Summary of Fish Community and Abundance for the 2006 Survey

Scientific Name	Common Name	OCW-1 Number Captured	OCW-1 Catch per Unit Effort (fish/min)	OCW-1 Number Captured	OCW-1 Catch per Unit Effort (fish/min)	OCW-2 Number Captured	OCW-2 Catch per Unit Effort (fish/min)	OCW-3 Number Captured	OCW-3 Catch per Unit Effort (fish/min)	MRW-1 Number Captured	MRW-1 Catch per Unit Effort (fish/min)
		16 May, 2006		22-23 August, 2006		22-23 August, 2006		22-23 August, 2006		22-23 August, 2006	
			Fishing Time: 821 min		Fishing Time: 890 min		Fishing Time: 304 min		Fishing Time: 271 min		Fishing Time: 1294 min
Umbra limi	Central mudminnow			19	1.28	20	3.95	5	1.11	13	0.6
Notropis heterolepis	Blacknose shiner			1	0.07						
Margariscus margarita	Pearl dace	9	0.66	11	0.74	13	2.57	4	0.89		
Catostomus commersoni	White sucker	3	0.22	5	0.34					8	0.37
Catostomus catostomus	Longnose sucker									1	0.05
Culaea inconstans	Brook stickleback	78	5.7	12	0.81	16	3.16	8	1.77		
Etheostoma nigrum	Johnny darter			1	0.07					28	1.3
Etheostoma exile	Iowa darter									6	0.28
	Total	90	**6.58**	49	**3.3**	49	**9.67**	17	**3.76**	56	**2.6**
	Mean		**2.19**		**0.55**		**3.22**		**1.25**		**0.52**

Source: adapted from Wardrop, 2007

7.8.2.2.2 Fish Community Results (2007 Program)

URS found that lake-run White suckers (*Catostomus commersoni*) were abundant throughout the distance of Oakley Creek surveyed by canoe and schools of large adult White sucker spawners were observed during an over-flight by helicopter as far upstream as the end of stream reach 8 (URS, 2008b). URS (2008b) assumed that lake-run White suckers spawn as far upstream as beaver dam 15 at the end of reach 9 (Table 7.8-3 and Figure 7.8-6). No schools of large White suckers were observed from the air in beaver ponds or channels above beaver dam 15, but resident fishes may be present. Large lake-run White suckers were not observed in the mainstream William and Minago Rivers and it is possible that most of them may have been spawning in more headwater reaches of those rivers or their tributary streams. In addition to large White sucker spawners from Lake Winnipeg (and possibly the lower William River), field crews captured a dwarf resident form of the White sucker that occurs in headwater streams and beaver ponds. Dwarf White suckers were captured in both the Oakley Creek and in the tributary of the Minago River at sample location MRF2-2007.

Other than White suckers, the only other lake-run fish captured were Emerald shiners (*Notropis atherinoides*), which were collected at sample locations WRF1 and WRF2. A single Rainbow smelt (*Osmerus mordax*) was also collected at sample location WRF2.

With the exception of Walleye, Northern pike, Rainbow smelt, Emerald shiner, White sucker, and longnosed sucker (*Catostomus catostomus*), all other fish species present in the sampled watersheds are resident (non-migratory) fish. Although the two sucker species and the Northern pike may also be residents in larger streams; Rainbow smelt are strictly a lake species and Walleye and Emerald shiners are probably confined to lakes within the surveyed drainages.

The spawning migrations of Walleye (*Sander vitreus*) and Northern pike (*Exox lucius*) from Lake Winnipeg (Oakley Creek and the William River) and Hill Lake (Minago River) were over before URS began sampling in May/June 2007. Lake-run fish of these two species were not present at the locations sampled. Walleye enter the streams in the surveyed watersheds for a few weeks in early spring to spawn and quickly migrate back down to Lake Winnipeg or Hill Lake (or other lakes in the Minago River system).

Following is a list of species collected during the 2007 fish sampling program by URS:

- OCF1: Central mudminnow, Brook stickleback (*Culaea inconstans*), and White sucker (both lake-run and dwarf resident);
- OCF2-2007: Brook stickleback, White sucker (both lake-run and dwarf resident), and Pearl dace (*Margriscus margrita*);
- OCF3: Central mudminnow, Brook stickleback, and lake-run White sucker,
- MRF1: Central mudminnow and Pearl dace;
- MRF2-2007: Central mudminnow and dwarf White sucker;
- MRF3: Pearl dace and Iowa darter (*Etheostoma exile*);

- WRF1: Central mudminnow, Brook stickleback, Emerald shiner, and Johnny darter (*Etheostoa nigrum*);
- WRF2: Brook stickleback, Johnny darter, Emerald shiner, and Rainbow smelt; and
- WRF3: Johnny darter and Blacknose shiner (*Notropis heterolepis*).

Anecdoctal Observations

Mr. Jonathan Anderson (2008), a trapper and commercial fisherman whose trap line is within the project area, observed Walleye in Oakley Creek immediately below Highway 6 in the spring of 2006. This indicates that spawning Walleye from Lake Winnipeg travel as far upstream in the Oakley Creek drainage as Highway 6. Mr. Greg King (2007) (a retired Manitoba Conservation employee who owns a boat repair shop in Grand Rapids, Manitoba) stated that the majority of north basin Lake Winnipeg Walleye spawn over clean sandy substrates in Limestone Bay, but that some Walleye also spawn in the William River drainage. Mr. Don MacDonald (2007), a biologist with the Manitoba Conservation Northeastern Region at Thompson, Manitoba, confirmed this and stated that Northern pike are also resident in the William and Minago Rivers and that Walleye are present in Hill Lake and other Minago River lakes.

7.8.2.2.3 Fish Community Results (2008 Program)

Roche caught a total of 1184 fishes using experimental nets installed in Cross Lake, Hill Lake and Limestone Bay of Lake Winnipeg between May 6-9, 2008 (Table 7.8-10) (Roche, 2008a). Rainbow smelts (*Osmerus mardax*) represented 86.8% of all fishes caught at station LBF1 and 86.99% of the overall May 2008 catch. Northern pikes (*Esox lucius*) were the second most abundant species, representing 9.5% of the overall catch. Northern pikes represented 73.3% of the non rainbow smelt species caught.

Table 7.8-10 Fishing Net Results for the 2008 Program

Species	Hill Lake		Limestone Bay		Cross Lake	
	Number	%	Number	%	Number	%
Northern pike	19	38.0	67	6.1	27	81.8
Walleye	19	38.0	1	0.1	0	0.0
Yellow perch	2	4.0	0	0.0	6	18.2
White sucker	7	14.0	0	0.0	0	0.0
Rainbow smelt	2	4.0	1,028	93.4	0	0.0
Sculpin sp.	1	2.0	0	0.0	0	0.0
Longnose sucker	0	0.0	5	0.5	0	0.0
TOTAL	50	100	1,101	100	33	100

Source: Roche, 2008a

During the 2008 fish survey, only 3 Brook sticklebacks (*Culaea inconstans*) and 4 Pearl daces (*Margariscus margarita*) were caught using bait traps. These species were all caught at station OCF2-2008.

7.8.2.3 Fish Tissue Metal Concentrations

This section discusses the metal concentrations in fish tissues for the baseline program. Detailed 2007 and 2008 baseline fish tissue metal concentrations are presented after these introductory remarks.

To assess the effects of contaminants on tissues, the critical body residue is frequently used. The tissue body burden or critical body residue (CBR) is based on the premise that toxicity occurs when the concentration of a chemical reaches a certain critical value. However, the CBR concept is supported only by studies of organic chemicals that exert their toxicity by narcosis. With metals, there is less of a relationship between tissue residue concentrations and effects (URS, 2008b). In addition, studies conducted on laboratory test species cannot be generalized to other species because different organisms have different sensitivities. Nevertheless, the U.S. Army Corps of Engineers (USACE) has compiled a database of information on CBRs, which includes metals. This database is the Environmental Effects Residue Database (ERED) (USACE, 2008). The ERED contains concentrations of metals as well as other chemicals associated with effects and no-effects from selected bioassays (URS, 2008b).

Several metals, such as chromium, cobalt, copper, manganese, molybdenum, nickel, selenium, and zinc are essential trace elements that can cause symptoms of deficiency when present below minimum daily requirements (MDRs) and can be toxic when exposures exceed physiological needs. The chemicals antimony, arsenic, cadmium, lead, mercury, strontium, thallium, and vanadium have no known metabolic requirements. Such chemicals produce toxicity by supplanting essential micronutrients from their normal roles. Nevertheless, non-essential chemicals have always been components of the environment without apparent adverse effects. This is because small amounts are insufficient to disrupt normal physiological functions and the body has also evolved other mechanisms for dealing with non-essential metals. Toxicity only occurs when the capacity of the body to adapt is overwhelmed by the dose received. It should be noted that the dose to body tissues is dependent to a large extent on the bioavailability of the contaminant (URS, 2008b).

The following facts should be kept in mind when reviewing measured concentration and effects levels (URS, 2008b):

- all organisms acquire larger concentrations of non-essential metals as they age, but concentrations of essential elements typically do not increase with age;
- some organisms are better regulators of essential element concentrations than others;
- normal concentrations of essential and non-essential elements vary in different organisms;

- there is no causal relationship between whole body metal concentration in an organism and adverse effects because metal-binding proteins and amino acids are produced as required, except when overwhelmed by acutely toxic conditions;
- elements tend to accumulate in particular target organs; and
- metal cations compete for uptake sites and single metal body residues cannot be causally related to effects from multiple metal exposures.

7.8.2.3.1 Fish Tissue Metal Concentrations for the 2007 Program

Results of 2007 Minago fish tissue analyses are presented in Table 7.8-11 for Oakley Creek, in Table 7.8-12 for Minago River, and in Table 7.8-13 for William River (URS, 2008b). A summary of 2007 fish tissue metal concentrations and published toxicity threshold levels is given in Table 7.8-14. Laboratory certified reports for metals present in fish tissues are presented in Appendix L7.8.

All species examined during the 2007 fisheries program exhibited concentrations of aluminum (Al), barium (Ba), manganese (Mn), and zinc (Zn) within the effects range of these elements and these levels of concentrations were found in all three watersheds sampled (Table 7.8-14). Only aluminum and zinc concentrations in examined specimens exceeded published threshold levels. None of the concentrations measured exceeded the 2007 Canadian Food Inspection Guidelines for Chemical Contaminants and Toxins in Fish and Fish Products (Table 7.8-14). All examined fish tissue samples were relatively small with a maximum weight of 45.4 g.

The concentrations did not significantly increase as sample locations moved downstream. It is likely that in most cases, concentrations of the four elements (Al, Ba, Mn, and Zn) exceeding thresholds for sublethal effects may be due to ingestion of stream sediments. The four metals are frequently found in fine stream sediments and might have been ingested by small fish while foraging.

An examination of metal concentrations in local stream sediments would likely find a lot of naturally occurring metals that can elevate concentrations in whole fish tissue samples (URS, 2008b). Aluminum, in particular, would likely show elevated concentrations if high levels of aluminum oxyhydroxides or hydroxysilicates are present in stream water and sediments (URS, 2008b). This often also applies to barium (URS, 2008b). Bradley (1977) found zinc concentrations in zinc-sensitive whole fish to be no different from those in zinc-insensitive whole fish. Therefore, tissue residues are not causally associated with toxicity.

As discussed in the surface water quality section of this report, aluminum concentrations are indeed elevated in watercourses surrounding the Minago Project.

Table 7.8-11 Summary of Oakley Creek Fish Tissue Analysis (2007 Program)

Location Code	**OCF3**	**OCF3**	**OCF2**	**OCF2**	**OCF2**	**OCF1**	**OCF1**	**OCF1**
Species Code	**MM**	**BS**	**PD**	**BS**	**WS**	**MM**	**BS**	**WS**
Species	**Central mudminnow**	**Brook stickleback**	**Pearl dace**	**Brook stickleback**	**White sucker**	**Central mudminnow**	**Brook stickleback**	**White sucker**
Number in sample	3	2	4	1	2	2	3	2
Sample weight (g)	4.6	2.8	14.9	1.7	27	15.6	2	31.7
Aluminum (Al)	2.0	<1.31	5.0	16.8	<2.08	7.2	11.5	4.0
Antimony (Sb)	<0.00925	<0.00655	<0.0132	<0.010	<0.0104	<0.01085	<0.010	<0.011
Arsenic (As)	0.044	0.009	<0.0132	0.042	<0.0104	<0.01085	0.060	<0.011
Barium (Ba)	0.48	0.36	0.36	2.30	0.43	0.53	1.56	0.35
Beryllium (Be)	<0.0555	<0.0393	<0.0792	<0.10	<0.0624	<0.0651	<0.10	<0.066
Bismuth (Bi)	<0.0555	<0.0393	<0.0792	<0.030	<0.0624	<0.0651	<0.030	<0.066
Cadmium (Cd)	<0.00555	<0.00393	<0.00792	0.0238	<0.00624	<0.00651	0.0165	<0.0054
Chromium (Cr)	<0.0925	<0.0655	<0.132	<0.10	<0.104	<0.1085	<0.10	<0.11
Cobalt (Co)	<0.0185	<0.0131	<0.0264	<0.020	<0.0208	<0.0217	<0.020	<0.022
Copper (Cu)	0.213	0.148	0.237	1.34	0.185	0.184	1.26	0.220
Lead (Li)	0.033	<0.0131	<0.0264	<0.020	<0.0208	<0.0217	<0.020	<0.022
Lithium (Pb)	<0.0925	<0.0655	<0.132	<0.10	<0.104	<0.1085	<0.10	<0.11
Mangnese (Mn)	0.95	3.94	0.97	10.1	0.61	4.10	11.7	0.82
Mercury (Hg)	0.0453	0.0073	0.0136	0.0322	0.0254	0.0170	0.0562	0.0205
Molybdenum (Mo)	<0.00925	<0.00655	0.013	0.037	<0.0104	<0.01085	0.032	<0.011
Nickel (Ni)	<0.0925	<0.0655	<0.132	<0.10	<0.104	<0.1085	<0.10	<0.11
Selnium (Se)	<0.185	<0.131	<0.264	0.20	<0.208	<0.217	0.26	<0.22
Strontium (Sr)	0.67	0.60	0.74	3.93	0.92	0.84	2.79	0.83
Thallium (Tl)	<0.00555	<0.00393	<0.00792	<0.010	<0.00624	<0.00651	<0.010	<0.0066
Tin (Sn)	<0.037	<0.0262	<0.0528	<0.050	<0.0416	<0.0434	<0.050	<0.044
Uranium (U)	<0.00185	<0.00131	<0.00264	0.0028	<0.00208	<0.00217	<0.0020	<0.0022
Vanadium (V)	<0.0925	<0.0655	<0.132	<0.10	<0.104	<0.1085	<0.10	<0.11
Zinc (Zn)	35.3	5.4	9.1	33.2	4.1	35.6	31.3	4.2

Source: URS, 2008b

Notes: Concentrations expressed in mg/kg wwt. Laboratory certified data is presented in Appendix L7.8.

Table 7.8-12 Summary of Minago River Fish Tissue Analysis (2007 Program)

Location Code	**MRF3**	**MRF3**	**MRF2**	**MRF2**	**MRF1**	**MRF1**
Species Code	**ID**	**PD**	**MM**	**WS**	**MM**	**PD**
Species	**Iowa darter**	**Pearl dace**	**Central mudminnow**	**White sucker**	**Central mudminnow**	**Pearl dace**
Number in sample	2	5	1	6	5	2
Sample weight (g)	1.0	2.1	3.9	22.1	45.4	0.6
Aluminum (Al)	26.5	27.8	12.8	4.7	2.4	47.3
Antimony (Sb)	<0.010	<0.010	<0.01125	<0.00945	<0.0107	<0.010
Arsenic (As)	0.123	0.123	0.024	0.013	0.015	0.166
Barium (Ba)	1.04	2.46	0.58	0.35	0.32	2.66
Beryllium (Be)	<0.10	<0.10	<0.0675	<0.0567	<0.0642	<0.10
Bismuth (Bi)	<0.030	<0.030	<0.0675	<0.0567	<0.0642	<0.030
Cadmium (Cd)	0.0142	0.0124	<0.00675	<0.00567	<0.00642	0.0581
Chromium (Cr)	<0.10	<0.10	<0.1125	<0.0945	<0.107	<0.10
Cobalt (Co)	0.033	0.020	<0.0225	<0.0189	<0.0214	0.034
Copper (Cu)	1.08	1.01	0.261	0.285	0.227	1.09
Lead (Li)	<0.020	<0.020	<0.0225	<0.0189	<0.0214	0.039
Lithium (Pb)	<0.10	<0.10	<0.1125	<0.0945	<0.107	<0.10
Mangnese (Mn)	8.54	6.35	6.68	3.36	0.81	11.9
Mercury (Hg)	0.0495	0.0807	0.0101	0.0067	0.0113	0.0538
Molybdenum (Mo)	0.034	0.025	<0.01125	0.011	<0.0107	0.025
Nickel (Ni)	<0.10	<0.10	<0.1125	<0.0945	<0.107	<0.20
Selnium (Se)	<0.20	0.30	<0.225	<0.189	<0.214	0.34
Strontium (Sr)	3.84	7.05	0.99	1.44	1.22	9.28
Thallium (Tl)	<0.010	<0.010	<0.00675	<0.00567	<0.00642	<0.010
Tin (Sn)	<0.050	<0.050	<0.045	<0.0378	<0.0428	0.059
Uranium (U)	<0.0020	<0.0020	<0.00225	<0.00189	<0.00214	0.0033
Vanadium (V)	0.11	0.10	<0.1125	<0.0945	<0.107	0.17
Zinc (Zn)	31.1	50.2	17.4	4.2	14.7	69.9

Source: URS, 2008b

Note: Concentrations expressed in mg/kg wwt. Laboratory certified data is presented in Appendix L7.8.

Table 7.8-13 Summary of William River Fish Tissue Analysis (values expressed in mg/kg wwt) for the 2007 Field Program

Location Code	**WRF3**	**WRF3**	**WRF1**	**WRF1**	**WRF1**	**WRF1**	**WRF2**	**WRF2**	**WRF2**	**WRF2**
Species Code	**JD**	**BS**	**ES**	**BS**	**JD**	**MM**	**RS**	**BS**	**ES**	**JD**
Species	**Johnny darter**	**Blacknosed shinner**	**Emerald shinner**	**Brook stickleback**	**Johnny darter**	**Central mudminnow**	**Rainbow smelt**	**Brook stickleback**	**Emerald shinner**	**Johnny darter**
Number in sample	7	1	1	1	1	1	1	3	10	2
Sample weight (g)	3.6	0.2	0.4	0.4	0.2	0.8	8.7	1.7	5.6	0.8
Aluminum (Al)	8.1	16.5	105	11.1	95.4	79.6	2.1	2.3	11.2	53.9
Antimony (Sb)	<0.009	<0.010	<0.010	<0.010	<0.010	<0.010	<0.00945	<0.0076	<0.01305	<0.010
Arsenic (As)	0.019	0.078	0.165	0.037	0.037	0.107	0.016	0.012	0.043	0.157
Barium (Ba)	0.44	7.42	4.57	1.93	3.14	2.74	0.28	0.33	0.78	2.27
Beryllium (Be)	<0.054	<0.10	<0.10	<0.10	<0.10	<0.10	<0.0567	<0.0456	<0.0783	<0.10
Bismuth (Bi)	<0.054	<0.030	<0.030	<0.030	<0.030	<0.030	<0.0567	<0.0456	<0.0783	<0.030
Cadmium (Cd)	0.0164	0.0308	0.103	0.0362	0.0426	0.0483	0.0081	<0.00456	0.0084	0.0536
Chromium (Cr)	<0.09	<0.10	0.20	<0.10	0.20	0.15	<0.0945	<0.076	<0.1305	<0.10
Cobalt (Co)	<0.018	<0.020	0.052	<0.020	0.064	0.082	<0.0189	<0.0152	<0.0261	0.087
Copper (Cu)	0.200	0.851	1.10	0.548	1.31	1.13	0.091	0.144	0.208	1.45
Lead (Li)	<0.018	0.028	0.061	<0.020	0.063	0.037	<0.0189	<0.0152	<0.0261	0.045
Lithium (Pb)	<0.09	<0.10	0.19	<0.10	0.16	0.12	<0.0945	<0.076	<0.1305	0.12
Mangnese (Mn)	0.82	2.36	8.80	4.71	7.95	9.22	0.43	2.60	1.38	17.5
Mercury (Hg)	0.0086	0.0801	0.0387	0.0396	0.0191	0.0146	0.0074	0.0042	0.0120	0.0258
Molybdenum (Mo)	<0.009	0.014	0.022	0.021	0.014	0.025	<0.00945	<0.0076	<0.01305	0.030
Nickel (Ni)	<0.09	0.12	<0.20	<0.10	0.35	<0.30	<0.0945	<0.076	<0.1305	0.15
Selnium (Se)	<0.18	0.47	0.55	<0.20	0.26	0.35	<0.189	<0.152	<0.261	0.37
Strontium (Sr)	0.50	6.47	19.2	2.96	3.82	5.69	1.70	0.69	3.76	3.02
Thallium (Tl)	<0.0054	<0.010	<0.010	<0.010	<0.010	<0.010	<0.00567	<0.00456	<0.00783	<0.010
Tin (Sn)	<0.036	<0.050	<0.050	<0.050	<0.050	<0.050	<0.0378	<0.0304	<0.0522	<0.050
Uranium (U)	<0.0018	0.0021	0.0051	<0.0020	0.0076	0.0044	<0.00189	<0.00152	<0.00261	0.0038
Vanadium (V)	<0.09	<0.10	0.25	<0.10	0.24	0.18	<0.0945	<0.076	<0.1305	0.19
Zinc (Zn)	6.1	58.7	78.9	25.9	35.3	112	5.7	6.1	14.1	34.3

Source: URS, 2008b

Notes: Concentrations expressed in mg/kg wwt.

Laboratory certified data is presented in Appendix L7.8.

Fish samples WRF3-JD and WRF3-BS submitted to ALS Laboratory Group were mislabeled as MRF3-JD and MRF3-BS.

Table 7.8-14 Summary of Fish Tissue Residue Data Compared to Effects Levels

Parameter		Summary of Data			ERED*			Guidelines for Chemical Contamiants and Toxins in Fish and Fish Products (Canadian Food Inspection Agency, 2007)
		Min	Average	Max	Effects Range	Survival	Toxicity Threshold**	
Aluminum (Al)	mg/kg wwt	1.31	23.19	105.00	12-100	12-50		
Antimony (Sb)	mg/kg wwt	0.01	0.01	0.01	no data	no data		
Arsenic (As)	mg/kg wwt	0.01	0.06	0.17	1-100	>12	5.4-11.6	3.5
Barium (Ba)	mg/kg wwt	0.28	1.57	7.42	0.2-8	insuff. data		
Beryllium (Be)	mg/kg wwt	0.04	0.06	0.08	no data	no data		
Bismuth (Bi)	mg/kg wwt	0.04	0.06	0.08	no data	no data		
Cadmium (Cd)	mg/kg wwt	0.00	0.02	0.10	0.8-600	12-100	2-8	
Chromium (Cr)	mg/kg wwt	0.07	0.12	0.20	1-80	30		
Cobalt (Co)	mg/kg wwt	0.01	0.03	0.09	6	6		
Copper (Cu)	mg/kg wwt	0.09	0.62	1.45	>10 - 1000	100	11.1-11.7	
Lead (Li)	mg/kg wwt	0.01	0.03	0.06	0.5-250	>100	0.4	0.5
Lithium (Pb)	mg/kg wwt	0.07	0.11	0.19	no data	no data		
Manganese (Mn)	mg/kg wwt	0.43	5.28	17.50	2-230	230		
Mercury (Hg)	mg/kg wwt	0.00	0.03	0.08	6	12	0.1-0.3	0.5
Molybdenum (Mo)	mg/kg wwt	0.01	0.02	0.04	9	insuff. data		
Nickel (Ni)	mg/kg wwt	0.07	0.12	0.35	1-400	110		
Selenium (Se)	mg/kg wwt	0.13	0.26	0.55	3-100	9-80	0.75-1.0	
Strontium (Sr)	mg/kg wwt	0.50	3.46	19.20	no data	no data		
Thallium (Tl)	mg/kg wwt	0.00	0.01	0.01	no data	no data		
Tin (Sn)	mg/kg wwt	0.03	0.04	0.06	no data	no data		
Uranium (U)	mg/kg wwt	0.00	0.00	0.01	2	insuff. data		
Vanadium (V)	mg/kg wwt	0.07	0.13	0.25	1-8	no data		
Zinc (Zn)	mg/kg wwt	4.10	30.12	112.00	10-1200	80-120	40-64	

* ERED (Environmental Effects Residue Database (USACE, 2008)

** Hinck et al. (2006)

Source: adapted from URS, 2008b

7.8.2.3.2 Fish Tissue Metal Concentrations for the 2008 Program

In the 2008 fisheries program by Roche, tissue samples were collected in order to evaluate total metal content (As, Pb, Se, Ni and Hg) in 20 specimens. Tissue samples were collected from four Walleyes (*Stizostedion vitreum)*, seven Northern pikes (*Esox lucius)*, three White suckers (*Catostomus commersoni)*, four Longnose suckers (*Catostomus catostomus)*, and two Yellow perch (*Perca flavescens)*. Northern pike, Walleye and perch are predators while suckers are preys. Table 7.8-15 summarizes the main characteristics of the 20 fishes selected for metal content analysis. Laboratory certified reports for the fish tissues are presented in Appendix L7.8.

Usually, Northern pike is the biggest and largest fish among the examined species followed by Walleye. One of the Northern pike specimens weighed 4.5 kg, which is more than the average for this species (1 to 2 kg) (Roche, 2008a). The smallest fish sampled weighed 0.22 kg (Yellow perch). Males represented 60% of all sampled fishes. (The sex of one Northern pike specimen was not identified.)

None of the analyzed tissue samples exceeded the 2007 Canadian Food Inspection Guidelines for Chemical Contaminants and Toxins in Fish and Fish Products criteria for arsenic and lead. In fact, metal concentrations for arsenic, selenium and lead were always below the detection limit. However, twenty-five percent (25%) of all sample fishes showed mercury concentrations above the 2007 Canadian Food Inspection Guidelines for Chemical Contaminants and Toxins in Fish and Fish Products (Roche, 2008a). Measured mercury concentrations varied from 0.06 to 1.6 mg/kg. These exceedances were essentially observed for Northern pike (40%) and Walleye (60%).

The elevated mercury concentrations may be explained by the trophic level of Northern pike and Walleye. Mercury bioaccumulation along the food chain occurs and highest contamination levels are often found in predators at the top of the food chain. It is also important to note that the highest mercury concentration (1.6 mg/kg) was observed for the Northern pike specimen weighing 4.5 kg and measuring nearly 1 m. This individual was assumed to have been older than the other sampled fishes and might therefore have accumulated more mercury over a longer period of time and also have eaten bigger and thus more contaminated fishes (Roche, 2008a).

7.8.3 Scope of Effects Assessment

For the purposes of this effects assessment, “fish” refers to all life stages of resident species known or suspected to occur within the project area. Fish habitat refers to spawning, egg incubation, rearing, overwintering areas and migratory corridors used by fish or other organisms that fish depend upon directly or indirectly in order to carry out their life processes. Habitat includes instream physical habitats (as characterized by channel gradient, width, residual pool depth, etc.), riparian habitats (that is stream bank vegetation that provides shade, cover and organic input to instream habitat), invertebrate food production, and stream water quality (dissolved oxygen, temperature, pH, turbidity, etc.). Protection of fish, fish habitats and the management of fisheries resources are regulated by the federal *Fisheries Act*; therefore, the environmental effects of the project on freshwater fish and fish habitat are considered.

Table 7.8-15 Fish Tissue Analysis Results (2008 Program)

Parameters	Units	Method detection limit	CFIG Criteria [1]	Flesh Sample Information																			
				1	2	3	4	5	6	7	8	9	1 0	1	2	13	14	15	16	17	18	19	20
Certificate of Analysis number				08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389	08-260389
Laboratory sample number				1186501	1186502	1186503	1186504	1186505	1186506	1186507	1186508	1186509	1186510	1186511	1186512	1186513	1186514	1186515	1186516	1186517	1186518	1186519	1186520
Date of sampling				2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12	2008-05-12
Date Laboratory received sample				2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22	2008-05-22
Sampling Location				Hill Lake	Hill Lake	Hill Lake	Hill Lake	Hill Lake	Hill Lake	Hill Lake	Hill Lake	Limestone Bay	Limestone Bay	Limestone Bay	Limestone Bay	Limestone Bay	Limestone Bay	Limestone Bay	Cross Lake	Cross Lake	Cross Lake	Cross Lake	Cross Lake
				Species Characteristics																			
Species	-			ESLU	ESLU	STVI	STVI	CACO	CACO	CACO	STVI	STVI	CACA	CACA	CACA	CACA	ESLU	ESLU	PEFL	PEFL	ESLU	ESLU	ESLU
Sex	-			N/D	F	M	M	F	M	M	M	M	M	M	M	F	F	M	F	F	M	F	F
Maturity	-			2	2	5	3	3	4	3	3	5	5	5	4	3	4	5	4	4	4	3	4
Length	mm			800	910	520	460	515	425	415	380	620	465	405	430	435	910	575	240	230	430	720	830
Weight	g			3 000	4 500	1 200	800	1 800	900	800	400	2 300	1 200	800	700	1 100	6 100	1 200	220	180	400	1 900	3 400
				Tissue Concentrations																			
Arsenic	mg/kg	0.5	3.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.6	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Lead	mg/kg	0.5	0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Mercury	mg/kg	0.01	0.5	**0.67**	**1.6**	0.38	**0.88**	0.16	0.16	0.09	**0.62**	**0.78**	0.17	0.06	0.06	0.08	0.29	0.13	0.17	0.22	0.27	0.42	0.38
Selenium	mg/kg	0.1	-	< 0.1	< 0.1	0.2	< 0.1	< 0.1	< 0.1	0.2	< 0.1	0.2	0.5	0.3	0.3	0.4	< 0.2	0.2	0.2	0.1	0.1	< 0.1	0.1

[1] Canadian Food Inspection Guidelines for Chemical Contaminants and Toxins in Fish and Fish Products (2007) .

(shaded) Value exceeding Canadian Food Inspection Guidelines for Chemical Contaminants and Toxins in Fish and Fish Products (2007)

ESLU = *Esox lucius (Northern pike)*
STVI = *Stizostedion vitreum (Walleye)*
CACO = *Catostomus commerson (White sucker)*
CACA = *Catostomus catostomus (Longnose sucker)*
PEFL = *Perca flavescens* (Yellow Perch)

Source: adapted from Roche, 2008a

Issues and Selection of Valued Ecosystem and Cultural Components (VECCs)

Project activities have the potential to affect a number of fish bearing and non-fish bearing streams that flow into Minago River, Cross Lake, Oakley Creek and William River. Fish species that have been documented in some of the sub-basins and that may be affected by the project development are summarized in Table 7.8-6. Of these species, Walleye (*Sander vitreus*) have been designated as a "sensitive" species by the fishers. Sensitive indicates that a "species is not believed to be at risk of immediate extirpation or extinction but may require special attention or protection to prevent them from becoming at risk."

As Walleye are relatively widespread throughout the area, they have have been identified as sentinel species for this assessment. By protecting the habitat requirements necessary to sustain this species, the habitat quality and quantity of the other fishes and the fish populations themselves will also be protected.

Project activities that have the potential to affect fish and fish habitat include the following:

- Changes in stream flows from effluent discharge affecting physical habitat capability in Oakley Creek and Minago River;
- Habitat disturbance during construction;
- Changes in water quality in Oakley Creek or Minago River due to effluent discharge, with potential direct toxic effects on fish, effects on benthic community that provide food for fish, and/or potential metal accumulation in fish tissue; and
- Erosion and runoff from disturbed areas at the mine site and along the transportation corridors with potential for sedimentation of instream habitat or stress to fish from elevated suspended solids in water.

The VECCs selected for assessment of effects on fish resources and the rationales for their selection are summarized in Table 7.8-16. Fish habitat is defined in terms of observed fish presence or physical habitat that is suitable or accessible for use by fish, in particular Walleye (a "sensitive" indicator species). Project effects on metals accumulation in fish, in particular selenium, while difficult to predict are of growing concern in relation to mining developments. Therefore, metal levels in fish tissue are identified as a VECC for this assessment and for the purpose of baseline characterization for future monitoring.

Study Area

The local and regional study areas for the assessment of effects on fish resources are the same as those used for the water and sediment quality assessment.

Table 7.8-16 Fish Resource VECCs, Selection Rationale and Baseline Data Sources

VECC	Rationale for Selection	Linkage to EAP and Other Regulatory Drivers	Baseline Data for EAP
Fish habitat	• Potential project effects on physical habitat due to facility and transportation corridor construction and maintenance potentially resulting in loss/alteration of instream and riparian habitat, siltation, barriers to fish passage). • Potential effects on productive capacity of fish habitat due to changes in water quality and associated toxic effects or effects on benthic organisms (fish food). • Habitat provides effective proxy for assessing effects on fish.	• Environmental Baseline Study (EBS) and Assessment Work Plan • Protection regulated by *Fisheries Act*	• 2006 field data • 2007 and 2008 field data
Metals in fish tissue	• Bioaccumulation of metals (e.g., Se) provides a link between project impacts and effects of fish and wildlife. • Species such as Walleye can provide human food sources.	• EBS and Assessment Work Plan	• 2006 field data • 2007 and 2008 field data

The local study area (LSA) includes all streams and associated water bodies that may be influenced by construction or operation of the mine and transportation corridors. This includes streams in the Oakley Creek and Minago River watersheds:

- Oakley Creek, which is near (> 500 m) the mine site area, will receive permitted discharges of effluent that meet discharge criteria;
- Minago River will receive permitted discharges of effluent that will meet discharge criteria;
- William River, which partly receives water from the Oakley Creek, drains to the Limestone Bay.

The regional study area (RSA) includes water bodies and watersheds beyond the LSA that reflect the general region to be considered for cumulative effects and that provide suitable reference areas for sampling:

- Hargrave River that drains to the Minago River and then to Cross Lake;
- Oakley Creek, upstream and downstream of the William River confluence;
- Minago River, upstream and downstream of the effluent discharge point;
- Little Limestone Lake; and
- Cross Lake.

Temporal Boundaries

The temporal boundaries applicable to fish and fish habitat include all phases of the project – construction, operation, decommissioning and closure. The potential direct effects on instream habitat are greatest during transportation corridors construction, in particular construction of stream crossings. The potential for introduction of silt and sediment to fish habitat will be present in all phases, but greatest during construction. The potential for introduction of metals or nitrogen to area streams will be present in all phases, but greatest during operation. The assessment of the closure phase assumes stabilization of water quality and associated effects on benthic organisms and fish. It is anticipated that this will be possible, based on operations phase monitoring and adaptive management, to ensure effective long-term management of potential project effects from tailings, waste rock and groundwater.

7.8.4 Effects Assessment Methodology

Potential effects of the project on fish resources during construction; operations; decommissioning, and closure are discussed in detail in the following sections. For each phase of the project, effects on fish resource VECCs were assessed as follows:

- Potential project interactions with fish and fish habitat are characterized and the locations of effects identified. This section describes potential project effects on physical habitat. Effects due to changes in water quality and benthic communities are assessed on the basis of effects findings detailed in Sections 7.5: Surface Water Quality and Section 7.7: Periphyton and Benthos, respectively.
- Magnitude of effect is considered based on the documented fish presence or fish bearing classification of affected areas, as described in the Environmental Baseline Study (EBS).
- Identified mitigation measures and commitments in VNI's Environmental Protection Plan (Section 9) are considered in terms of proven effectiveness to protect fish resources.
- Follow-up and monitoring plans with identified contingency measures to address unexpected effects are discussed.
- Predicted residual effects (taking into consideration mitigation and contingency measures) are characterized.
- The potential for residual project effects to contribute to cumulative effects is assessed in terms of multiple project effects on fish resources, effects in combination with existing activities, and effects with foreseeable future activities or events.

Project and cumulative effects on the fish resource VECCs are characterized in accordance with effects attributes defined in Table 7.8-17. The ecological and social contexts of effects are integrated in the attributes for effect magnitude and elaborated upon as appropriate in the text. The likelihood of occurrence of residual effects happening as predicted is stated with a supporting rationale.

Table 7.8-17 Effect Attributes for Fish Resources

Attribute	Definition
Direction	
Positive	Condition of VECC is improving
Adverse	Condition of VECC is worsening or is not acceptable
Neutral	Condition of VECC is not changing in comparison to baseline conditions and trends
Magnitude	
Low	Effect occurs that might or might not be detectable but is within the range of natural variability, does not pose a serious risk to resident fish populations, and does not compromise economic or social/cultural values.
Moderate	Clearly an effect but unlikely to pose a serious risk to resident fish populations or represent a management challenge from an ecological, economic or social/cultural standpoint.
High	Effect is likely to pose a serious risk to resident fish populations and represents a management challenge from an ecological, economic or social/cultural standpoint.
Geographic Extent	
Site- Specific	Effect on VECC confined to a single small area within the Local Study Area (LSA).
Local	Effect on VECC confined to the Local Study Area (LSA).
Regional	Effect on VECC extends into the Regional Study Area (RSA).
Duration	
Short-term	Effects on VECC are measurable for less than 1 year.
Medium term	Effects on VECC are measurable for 1 to 5 years (Ford et al. 1995).
Long-term	Effects on VECC are measurable after 5 years but do not extend more than 10 years after decommissioning and final reclamation.
Far future	Effects on VECC are measurable more than 10 years after decommissioning and abandonment.
Frequency (Short-term duration effects that occur more than once)	
Low	One time event and does not pose a serious risk to the VECC or its economic or social/cultural values.
Moderate	Occurs annually but is unlikely to pose a serious risk to the VECC or its economic or social/cultural values.
High	Occurs more than once a year and is likely to pose a serious risk to the VECC or its economic or social/cultural values.
Reversibility	
Reversible	Effect on VECC is reversible through natural processes or compensation.
Irreversible	Effect on VECC will persist during and/or after the project is complete.
Likelihood of Occurrence	
Unknown	Effect on VECC is not well understood and, based on potential risk to the VECC or its economic or social/cultural values, effects will be monitored and adaptive management measures taken, as appropriate.
High	Effect on VECC is well understood and there is a high likelihood of effect on the VECC as predicted.

Determination of Effects Significance for Fish Resources

The significance of residual project and cumulative effects are determined based on the defined effects attributes, as follows:

- a residual effect on fish habitat is considered significant, if it results in Harmful Alteration, Disruption or Destruction of fish habitat (HADD) that cannot be mitigated or compensated for;
- a residual effect on fish tissue is considered significant, if Contaminants of Concern (COC) levels are elevated above interim tissue guidelines;

otherwise, effects will be rated as not significant.

7.8.5 Project Effects

This section provides an analysis of the environmental effects of key project activities on the fish resource VECCs by phase.

7.8.5.1 Construction

Construction phase activities with the potential to affect fish resources may include the following:

- Site clearing and ground disturbance for construction of mine site facilities and the transportation corridors.
- Changes in stream flow due to pumping water from the Polishing Pond to Minago River and Oakley Creek;
- Potential introduction of contaminants from fuel spills, concrete mixing; and
- Potential increase in angling pressure from construction crews.

Further discussion of potential effects and management measures are presented in the next sections.

7.8.5.1.1 Riparian Habitat Disturbance and Sedimentation

The mine site, ancillary facilities and transportation corridors are not located in fish-bearing streams, and preparation and construction-related activities will not occur in fish-bearing streams. All these activities will occur outside fish-bearing streams/reaches and outside the riparian areas. Site preparation work for construction activities generally includes clearing, grubbing and grading of trees, brushing vegetation along the transportation corridors and mine site facility areas. Graders, bulldozers, and in some cases, excavators will be used to strip and stockpile topsoil, surface organic material and upper mineral soils. Following removal of topsoil, grading will be conducted on slopes and irregular ground surfaces to provide a safe and clean work surface. No riparian habitat will be disturbed as there are no creeks and rivers in the vicinity of the work site.

Riparian Habitat

Mine site development and access transportation corridors construction (clearing and grubbing activities) will not occur near or in fish bearing streams and therefore will not result in loss and / or alteration of riparian habitat structure (species, canopy height, etc.) through removal of mixed forest and shrub communities (i.e., area covered by road surface) beyond the life of the project (access road retention). The closest creek – Oakley Creek is located more than 500 metres from the boundaries of the property.

Sedimentation and Instream Habitat

Increased sediment loads entering a watercourse or waterbody may adversely affect fish and fish habitat. High concentrations of sediment are detrimental to benthic organisms, fish ova (eggs) and alevin (young fish) survival and habitat productive capacity. DFO Land Development Guidelines (DFO and MELP, 1992) recommend that total suspended solids (TSS) concentrations should not increase by more than 25 mg/L above background levels of the receiving waters during normal, dry weather conditions and less than 75 mg/L above background levels during storm events. The TSS concentration is set at 15 mg/L in the *Metal Mining Effluent Regulations* (MMER). However, all construction activities will not be near fish bearing streams. In addition, the area is surrounded by peat bogs and any discharges will pass through the peat bogs before it reaches the fish bearing streams. Peat bogs will assist to clean up the accidental discharges.

The extent of these potential environmental effects depends on the concentration of suspended sediment, event duration, species and life stage of fish present within the increased TSS zone of influence, and sensitivity of the habitat type affected (spawning, overwintering, wetland, etc.). Exposure of fish and habitats to low levels of suspended sediments and seasonal freshet-related instantaneous increases occurs naturally. During increased TSS events, juvenile and adult fish most frequently avoid the zone of influence and return once TSS levels subside. However, high concentrations of suspended sediments over extended durations of exposure will reduce fish feeding success (reduced prey capture and predator avoidance rates), reduce growth rates, damage gill membranes, decrease disease resistance, and/or impair ova development and embryonic development (hypoxia). Increased suspended sediments may also interfere with the production of benthic invertebrates and other aquatic fish food organisms. Behavioral, physiological and other sub-lethal and/or lethal effects may also occur depending on the concentration and duration of exposure, stream discharge, fish life stage, as well as TSS, particle hardness, size and angularity. For this project, there are no fish bearing streams within the project boundaries and VNI will not discharge effluents that will exceed the legal limits (MMER Limits), as mitigative measures will be implemented for all components of the project.

In the mine site area, part of the Site Water Management Plan will include diversion of clean water flows around construction sites and collection of drainage from disturbed areas for settlement of suspended solids in settling ponds prior to discharge (Section 2.14: Site Water Management). A comprehensive Erosion and Sediment Control Plan will be developed and implemented for all phases of the project. Key elements of the plan are listed in the Environmental Protection Plan

(Section 9). Best practices will be outlined along with conditions for application. Additional site-specific requirements will be included based on the detailed design of facilities, access road and Site Water Management Plans.

If at all, any work within 20-70 m of a watercourse will only proceed under the appropriate regulatory permits and approvals. Instream work in fish bearing watercourses will be undertaken during the approved fisheries work windows and will use identified mitigative procedures and structures. It is important to note that very little to no work will be undertaken in and around fish bearing streams.

Monitoring of total suspended solids in streams will be conducted during the construction phase in fish bearing streams, in accordance with permit requirements. If results are out of compliance with permit requirements, activities will cease and mitigative measures applied or enhanced as required to achieve compliance.

Project effects of sedimentation on instream habitat during construction are expected to be adverse, low magnitude, local in extent, short-term in duration and reversible given that:

- there will be little or no work to be conducted in and around fish bearing streams; and
- effective mitigation options exist.

The likelihood of effects as predicted is high based on observations of project effects and mitigation effectiveness at many comparable developments.

Culvert Installation

No culverts will be installed in fish-bearing streams as there are no creeks and rivers in the LSA where development will take place. Culverts will only be installed on the mining site for local drainage purposes.

All instream work (if any) will proceed only under the appropriate regulatory permits and approvals. Instream work at known fish bearing watercourses will be undertaken during the approved fisheries work windows and will use identified mitigative procedures and structures for the protection of fish and fish habitat as specified in the Environmental Protection Plan (Section 9).

Instream construction (if required/requested) timing constraints are designed to protect fish species during sensitive life-stages (i.e., alevins, eggs). To avoid potential conflict with fish spawning timings, instream construction for all fish-bearing (known and inferred) watercourses will be scheduled during the period of least risk to fish and fish habitat (mid-late summer, low or no flow, or ice-in period(s)), unless specifically permitted by regulatory authorities. As there are no streams in the vicinity of the project area, it is unlikely that access culvert placement will affect downstream fish and fish habitats during a constrained instream work.

7.8.5.1.2 Changes in Stream Flow

Project effects on surface flows during construction include the following:

- potential effects of open pit dewatering during pre-production mining on ground water regimes; and
- discharge of effluent from the Polishing Pond to the Minago River/Oakley Creek.

On the basis of work completed by Golder Associates (2008b), there is no hydraulic connection between Oakley Creek and the limestone and sandstone aquifers. Effects of flow reduction, if any, will be monitored during operations. Stage discharge relationships will be refined (Section 7.4: Surface Water Hydrology) and the potential for effects on overwintering habitat (pools) will be clarified.

Changes in stream flow due to open pit dewatering will be adverse, low in magnitude, site specific, long-term in duration and reversible. Therefore, the likelihood of this effect as predicted is low.

7.8.5.1.3 Runoff of Contaminants

A number of site construction activities may generate wastewater. Direct release of wastewaters, such as concrete wash water or storm water that has been in contact with uncured concrete, into a stream may result in degradation of water quality and subsequent fish kills. Residual hydrocarbons leaked from heavy equipment usage during construction activities or concentrations of lime in concrete wastewaters could also exceed water quality guidelines for the protection of freshwater aquatic life (CCME, 2007).

To minimize such releases, the on site concrete batch plant will be entirely self-contained with no disposal of wash water to surface waters. Refueling, equipment maintenance and inspection procedures will be implemented to minimize the risk of spills that could make their way to surface waters (Section 9: Environmental Protection Plan). Accordingly, effects of contaminant runoff affecting fish habitat are expected at worst to be low, site-specific, short-term, and infrequent. The small volumes potentially involved and the self-renewing nature of streams would make any such effects reversible. The likelihood of this effect as predicted is high.

7.8.5.1.4 Angling Pressure

Construction personnel on site may increase fish mortality in the project area due to sports fishing. A policy to protect fish stocks will be incorporated into the project's environmental education and orientation program. All project personnel living on site will be apprised of potential pressures on fish stocks from fishing. Fishing regulations will be reviewed, including requirements for licenses, use of single barbless hooks, bait bans and catch and release strategies.

Because of the low occurrence of fish in streams that may be affected by the project, any effects would likely be confined to the Oakley Creek and the Minago River. However, there are many fish bearing lakes and rivers in Minago's vicinity that require a low level of effort to catch fish. Oakley Creek and Minago River will not be the preferred options. Potential effects would be greatest during the two-year construction period when onsite personnel numbers will be highest, but would continue to a lesser extent throughout the life of the project. Effects are therefore expected to be adverse, low magnitude, regional, short-term and irreversible. The likelihood that effects will occur as predicted is high.

7.8.5.2 Operations

During operations, some of the effects identified during construction will persist. The main incremental project effect on fish and fish habitat during operations will be changes in water quality and quantity in Oakley Creek and Minago River due to effluent discharges from the Polishing Pond, with related potential for toxic effects, effects on stream productivity and potential for metals accumulation in fish tissue. The effluent quality will meet *Metal Mining Effluent Regulations* (MMER) discharge water quality objectives.

7.8.5.2.1 Riparian Habitat Disturbance and Sedimentation

As noted above, riparian vegetation is an important component of a stream's ecosystem as it provides shade, over stream fish cover, nutrients and woody debris, and maintains channel bank integrity. Operational activities will have no effect on riparian habitat as no disturbances will be experienced.

7.8.5.2.2 Changes in Stream Flow

Project effects on stream flows are discussed and assessed in Section 7.4: Surface Water Hydrology.

7.8.5.2.3 Impacts on Biological Aspects

Two main components of the receiving environment could be impacted by how the final effluent will be managed, namely wetlands and stream habitats.

Impacts on Wetlands

From May to October, the final effluent will first be discharged in a vast treed bog before being released to the receiving streams. These bogs still have the capacity to store additional water by creating ponds.

A marsh will certainly be created where the final effluent will be discharged. However, it would be quite surprising to see such a significant transformation over the entire bog's surface (creation of ponds and reduction of the tree cover) given that:

- no ponds at all have been observed within these bogs;

- they cover significant areas and are parts of a vast complex of wetlands that are hydrologically connected together and form one of the most important ecosystem in the region;
- the flow of water being discharged within the receiving bogs will not even represent what the waterways typically discharge during the summer period in this region (about 0.4 m^3/s for the Minago River compared to the Minago River flow between June and October of 1.9 m^3/s and less than 0.2 m^3/s for the Oakley Creek compared to the Oakley Creek flow between June and October of 0.5 m^3/s).

Still, if a significant transformation of the bog's surface were to occur, it is important to note that it is widely accepted that open bogs with ponds represent more attractive habitats for many wildlife species such as waterfowl and amphibians. Ducks Unlimited Canada, as well as Québec's ministère du Développement durable, de l'Environnement et des Parcs (Department of Sustainable Development, Environment and Parks), has recognized this general concept and use it to evaluate the ecological value of a bog. Poulin (2002) has also proposed a set of criteria to assess a bog's ecological value, including the area covered by ponds.

A diffuser will be installed to reduce erosion at the point where the final effluent will be released in the bog. A perforated pipe will be installed perpendicularly to where the final effluent will be released. Rocks (riprap) will also be installed at this same location.

7.8.5.2.4 Impacts on Stream Habitats

The fact that water will first be discharged in a bog before being released in the receiving streams means that the flow increases, detailed in Section 7.4, should be considered as maximum values since they represent a situation in which water is being directly discharged in the Oakley Creek or the Minago River without passing through a wetland before. Given the capacity of wetlands, such as these bogs, to slow the water flow coming to the receiving streams, the impact on stream habitats should be low, or not significant, particularly in May (See Section 7.4). However, if an increase in the amount of water flowing in those streams should occur, the impact on stream habitat quality would likely be positive, especially in winter low flow conditions.

Low flows are defined as those typical during a prolonged dry period (Smakhtin, 2001), or more precisely in the Canadian context, those that occur during periods without significant rainfall or snowmelt input. During low flows, most stream habitat types are reduced in extent and changes in water quality can occur, which can be stressful for fish and other biota (IFC, 2004).

Therefore, especially from November to April, higher water flow and thus water level would help maintain the existing stream habitat types and limit changes in water quality that can occur, therefore limiting seasonal stresses for fish and other biota. Such positive impacts of higher winter flow have been observed in northern Québec by Hydro-Québec along rivers regulated for hydroelectric power generation purposes.

Water coming out of a mine is usually not at the same temperature than water flowing in the surrounding streams. However, before being released as the final effluent, that water will have to flow through the TWRMF and the Polishing Pond, therefore will be exposed to rainfall and ambient temperatures for some days. Based on these facts, the thermal impact of the water being discharged to the receiving environment is considered to be not significant.

The effects of discharge additions on fish habitat capability in Minago are expected to be minimal, low magnitude, local in geographic extent, long-term and reversible. The likelihood of effects as predicted is high. Monitoring and mitigation measures will be established to ensure that river base flows are not exceeded significantly.

7.8.5.2.5 Angling Pressure

Effects predicted for construction are expected to continue during operations. Angler education for operations personnel, use of barbless hooks, catch-and-release strategies and compliance with the applicable regulations will reduce or eliminate project effects on the fisheries resources associated with potential increases in angler pressure. As such, projects effects associated with increased angling pressure by operations personnel are expected to be adverse, low magnitude, regional in geographic extent, long-term and irreversible. The likelihood of effects as predicted is high. It is important to note that there are other fish bearing lakes and rivers in Minago's vicinity that require a low level of effort to catch fish. Therefore, potential anglers will likely go to such lakes and rivers to do sports fishing.

7.8.5.3 Decommissioning

During decommissioning, most ancillary facilities and mine site infrastructure will be removed. However, the access road and the Tailings and Ultramafic Waste Rock Management Facility (TWRMF) will be remain at closure.

Riparian Habitat Disturbance and Sedimentation

No effects are anticipated.

Change in Stream Flows

During decommissioning, water discharge from the Polishing Pond to Oakley Creek and Minago River will cease. As discussed in Section 7.4, the impacts of increasing or decreasing the water flow in the Minago River and the Oakley Creek will be low, or not significant, in terms of hydrology since they are within the natural variation occurring in this region.

The impacts of a reduction in the water flow on stream habitats would be significant. Indeed, especially in winter low flow conditions, lower water flow and thus water level reduces stream habitat types and increases the risk of changes in water quality, increasing seasonal stresses for fish and other biota.

Therefore, mitigation measures will have to be implemented in order to limit the potential impacts of such a change in water level conditions, meaning that water will have to be stored in the PP in such a way that the final effluent flow will be gradually reduced and not drastically. This would enable a comeback to pre-mining conditions. In addition, the discharge flow will still have to change according to the seasons.

Cessation of discharges to the Minago River and Oakley Creek will be staged to recondition the streams to pre-mining conditions. The staging process is outlined in Section 7.4: Surface Water Hydrology. Site water management facilities (e.g. diversions and drainage collection ditches) will be decommissioned and natural drainage patterns restored in both drainages. Drainage from the TWRMF within the Oakley Creek basin will be discharged to Oakley Creek.

Angling Pressure

Effects predicted for mine construction and operations may continue during the decommissioning phase. Angler education for personnel, use of barbless hooks, catch-and-release strategies and compliance with applicable regulations will reduce or eliminate project effects on the fisheries resources associated with potential increases in angler pressure. Accordingly, effects are expected to be adverse, low magnitude, regional in geographic extent, long-term and irreversible. The likelihood of this effect is high.

7.8.5.4 Closure

Riparian Habitat Disturbance and Sedimentation

There will be no effects as there are no rivers and creeks within the LSA that will be disturbed.

TWRMF Decant to Oakley Creek Watershed

The TWRMF will be maintained and monitored as described in the Mine Closure Plan to ensure no elevated metals are released into the Oakley Creek watershed. Accordingly, no effects on fish and fish habitat are expected at closure.

Angling Pressure

There will be no angling pressure as there are better fish bearing lakes and rivers in the area. Accordingly, effects are expected to be adverse, low magnitude, regional in geographic extent, long-term and irreversible. The likelihood of this effect is high.

7.8.6 Residual Project Effects and Significance

7.8.6.1 Site Preparation

For this project, there will be no mine site effects as there will be no activities taking place near streams. However, established standards for mitigation measures to minimize effects on fish and fish habitat (Site Water Management Plan, Sediment and Erosion Control Plan, Fish Habitat Protection Plan) will be implemented. Inspection during construction and operation and reporting to regulators will ensure compliance. Egg mortality due to sedimentation is expected to be very low. At no time during the life of the project are effects expected to be greater than low magnitude and local in extent. In all cases, effects will be ultimately reversible. The likelihood of effects as predicted is high based on observations of effects and mitigation effectiveness at many similar projects. Based on criteria listed in Table 7.8-17, effects of the project related vegetation clearing, erosion and sedimentation are determined to be not significant. In addition, there will be no construction activities near the fish bearing streams.

7.8.6.2 Water Quality Effects on Fish Habitat and Fish Tissue

Oakley Creek

At closure, Tailings and Waste Rock Management Facility (TWRMF) decant discharges to the Oakley Creek watershed will meet discharge criteria. There is no potential for a Harmful Alteration, Disruption or Destruction of fish habitat (HADD) that cannot be mitigated; therefore effects are determined to be not significant.

Water quality effects on Oakley Creek and Minago River during operations and decommissioning have the potential to contribute to metals accumulation in fish tissue. Mitigating factors such as compliance with discharge criteria in fish bearing reaches, swift flowing conditions and probable dispersion of metal bearing sediments within the larger William River and Minago River basins indicate that the risk of this occurrence is low. Monitoring will provide an early warning of metals trends in sediments and trigger follow-up tissue monitoring as required. Adaptive management to mitigate any observed effects will be developed and implemented in consultation with regulatory bodies. Accordingly, the effect of the project on metals levels in fish tissue is determined to be not significant.

Minago River

As discharges of Polishing Pond waters into the Minago River during the closure phase are not planned, project effects of water quality on fish habitat and fish tissue are not anticipated.

7.8.6.3 Flow Changes

Discharges from the Polishing Pond will be gradually reduced in the closure phase. The proposed Water Discharge Cessation Plan is outlined in Section 7.4: Surface Water Hydrology.

Oakley Creek

There will be no discharges from the mine to Oakley Creek; therefore, there will be no effect on the Oakley Creek flow regime.

Minago River

There will be no discharge from the mine to Minago River. Therefore, there will be no effect on the Minago River flow regime.

7.8.6.4 Summary of Residual Effects

Residual project effects on fish, fish habitat and fish tissue metals levels are expected to be not significant. Residual low level effects may include:

- potential metals accumulation in fish tissue; and
- potential increased mortality due to angling pressure.

All of these effects are expected to be of low magnitude and localized in extent, as discharges will meet legal discharge criteria.

7.8.7 Cumulative Effects and Significance

It is not expected that multiple localized project impacts on fish habitat will result in a measurable cumulative effect on fish populations or habitat in the regional receiving drainages (Minago River, Cross Lake, William Lake and Limestone Bay).

Other activities within the mine site that may combine with project effects to influence fish resources include:

- increased traffic on the PTH6 due to the project with potential for introduction of contaminated runoff (due to potential spills, accidents, and road maintenance) to fish habitat in William River and Minago River;
- effects of future mining projects in the same drainages (there are currently no mining projects under review that would incur cumulative effects on fish habitat in the area);
- increased risk of forest fires due to mining activity with the potential for sedimentation of instream habitat.

The effects of a contaminant introduction to fish habitat from the PTH6 are variable depending on the amount and toxicity of the contaminant and habitat use of the affected reach at the time (potential concentrations in fish or ova). The magnitude of effects could range from low to high and a HADD could result. In any instance, the contribution of the project to cumulative effects from this source will be low and not significant.

Increased angler effort associated with the Minago Project and various other development activities within the LSA may increase fish mortality through retention fisheries. Implementation of an angler education program and signage postings along the access road or at the PTH6 intersection encouraging the use of single barbless hooks, bait bans and catch-and-release strategies will reduce the contribution of the project to cumulative effects.

A forest fire could destroy vegetation and alter water quality within the assessment area, resulting in environmental effects on fish resources, including fish mortality. Fire within the LSA could occur during any phase of the project due to natural or anthropogenic activities. Factors influencing the severity and duration of environmental effects caused by a forest fire include time of year, weather conditions (wind, ground moisture, etc.), extent of fire damage and type of fire.

A fire during the late summer or early fall could affect fish migrations, and timing and success of spawning depending on duration, size and intensity. If a forest fire were to affect a large proportion of a watershed (i.e., Oakley Creek/Minago River/William River) and were to occur during the late fall, the magnitude of the environmental effect would be moderate to severe. Reversibility of physical environmental effects is high, but would occur over a long duration (five to ten years), particularly due to the high latitude. Increased bed load transport and sedimentation would result in substrate aggradations in some reaches and infilling of critical habitats (spawning gravels and overwintering pools) downstream and bank degradation in other reaches during subsequent spring freshets/snow melts until substantial revegetation occurs. Changes to groundwater patterns, base flows and instantaneous discharge rates in the stream may also be altered during this period due to changes in evaporation and infiltration rates. Although individual fish and ova mortality may occur as a result of a forest fire, the environmental effects on the population of resident and migratory fish are likely to be reversible as individuals from other reaches/sub basins would eventually re-colonize the affected areas.

While project activities and increased traffic in the area could increase the risk of fire, the presence of people in the area can also support earlier detection and suppression. VNI will establish procedures to prevent and respond to fires in the project area. All personnel and contractors will be provided with an orientation in these procedures and key personnel will have appropriate training to implement emergency response procedures. Project mitigation measures will minimize the risk of project related fires and support effective management of natural fires. Moreover, major roads, such as PTH6, and power lines usually act as fire barriers slowing down fire progression.

Nevertheless fires can and have occurred in the past, as the charred remains of past fire(s) were observed during the 2007 fisheries assessment. Associated effects on fish habitat could range in magnitude from low to high, local to regional in extent and could result in a HADD. The contribution of predicted project related effects on fish habitat to cumulative effects due to fire would be low and not significant.

7.8.8 Mitigation Measures

Mitigation measures for protection of fish and fish resources during all project phases are summarized in Table 7.8-18.

7.8.9 Monitoring and Follow-up

Follow-up Studies

No further follow-up studies are planned for the Fish Resource VECCs based on sufficient fish species assemblage data obtained during previous studies (the 2006-2008 programs), confirmation of fish distribution limits and generally low fish densities or absence. However, to confirm the accuracy of the effects predications on metals bioaccumulations in fish tissue, follow-up sampling consisting of annual, single season collection and metal analyses of fish samples will be initiated.

Monitoring Programs

All construction activities will require inspection and monitoring of sediment input to local streams and receiving waters, to ensure that erosion and sediment control structures are appropriately installed, maintained and removed in accordance with regulatory requirements, the Site Water Management Plan, and commitments stated in the Environmental Protection Plan (Section 9). An on-site monitor (environmental inspector) will be present during all mine site and ancillary facilities development and access road construction to conduct monitoring and ensure compliance with all requirements.

Project-related HADD is unlikely. VNI will develop an Environmental Protection Plan (EPP), and sediment control, revegetation, mitigation and monitoring programs. As such, the project is expected to achieve DFO's no net loss principle (NNL; DFO, 1986) and it is expected that the productive capacity of fish habitats will be maintained.

Water levels in Oakley Creek and the Minago River will continue to be monitored to check impact predictions and ensure protection of fish habitat, as required.

Table 7.8-18 Mitigation Measures for Effects on the Fish Resources

Potential Project Effect	Mitigation Measures
Effects of site clearing, grubbing, grading and sedimentation of instream fish habitat	**NOTE: NO WORK WILL BE DONE NEAR RIPARIAN MANAGEMENT AREAS.** • Locate buildings, TWRMF and facilities outside of Riparian Management Areas. There will be no infrastructure near of in the vicinity of the riparian zone. • Implement a Sediment Control Plan (Section 9: Environmental Protection Plan). • Implement a Fish Habitat Protection Plan (Section 9: Environmental Protection Plan). • Implement a Site Water Management Plan (Section 2.14: Site Water Management). • Revegetate stream banks with native plants, grasses, shrubs and trees. • Obtain required DFO and MB Gov.'t Authorizations for instream and riparian works, if any such works were to be needed.
Effects of construction works on fish and fish egg mortality and instream fish habitat	**NOTE: THERE ARE NO CULVERT OR STREAM CROSSINGS CONTEMPLATED FOR THE PROJECT.** • Adhere to *Standards and Best Practices for Instream Works,* if any such works were to be needed. • If any crossing construction will be needed, it will be completed in the dry during the summer low flow period or in winter when streams are frozen solid (surface to substrate), i.e. during the period of least risk to fish and fish habitat. • Implement a Sediment and Erosion Control Plan (Section 9: Environmental Management Plan). • Implement a Fish Habitat Protection Plan (Section 9: Environmental Protection Plan). • Where applicable, conduct blasting in accordance with *Guidelines for Use of Explosives in Canadian Fisheries Waters.* • Maintain all culverts in good working order; replace dysfunctional culverts as required in association with sedimentation control measures.
Changes instream flow due to mine dewatering, stream diversions and drainage collection and diversion with potential effects on instream habitat in Oakley Creek and Minago River	• Implement the Site Water Management Plan (Section 2.14: Site Water Management and Section 7.4: Surface Water Hydrology)

Table 7.8-18 (Cont.'d) Mitigation Measures for Effects on the Fish Resources

Potential Project Effect	Mitigation Measures
Potential introduction of contaminants to fish habitat from fuel spills, concrete mixing	• Discharge all wastewater in accordance with MB Gov.'t regulations and more than 100 m from fish habitat. • Implement a Site Water Management Plan (Section 2.14: Site Water Management). • Implement a Sediment Control Plan. • Adhere to protocols for refueling and equipment inspection and maintenance. • Implement the Mine Closure Plan. • Ensure stabilization of water quality prior to closure. • Maintain a water cover on the TWRMF as designed. • Conduct regular/routine monitoring of the TWRMF water quality and for potential leaks.
Potential increase in angling pressure from project personnel	• Implement personnel environmental awareness training and environmental protection policy (Section 9: Environmental Management Plan). • All personnel will abide by applicable MB Gov.'t fishing regulations. • Signage will be posted along access road / PTH6 intersection describing responsible angling techniques.

Monitoring of project facilities, effluents and receiving water quality will occur as required by provincial and federal permits and regulations. If Environmental Effects Monitoring (EEM) suggests increasing metals levels in water and sediments, monitoring of fish tissue metals levels will be initiated to check for potential bioaccumulation. Based on monitoring results, requirements and approaches for adaptive management of project effects will be developed and implemented in consultation with the responsible provincial and federal agencies.

Proposed monitoring programs for fish resources are summarized in Table 7.8-19 and will be implemented by the proponent.

7.8.10 Summary of Effects

Project and cumulative effects on fish resources are summarized in Tables 7.8-20, 7.8-21, 7.8-22 and 7.8-23 for the construction, operations, decommissioning, and closure phases of the project, respectively.

Table 7.8-19 Monitoring Programs for the Fish Resource VECCs

Potential Project Effect	Program Objectives	General Methods	Reporting	Implementation
Alteration of instream habitat quality due to sedimentation from clearing, ground disturbance and culvert installation during construction	• To monitor effectiveness and best management practices for sediment control and fish habitat protection and ensure compliance with permit regulations	• Turbidity and TSS monitoring during construction as required by permit	• MB Gov.'t and other regulatory Agencies (ORA) as required	Proponent
Alteration of instream habitat quality due to culvert installation (if it happens)	• To confirm effectiveness of sediment control and fish habitat protection measures, and to address compliance issues immediately	• Post-construction evaluation of instream habitat in the vicinity of culvert installations (sedimentation, fish passage, bank erosion, culvert effectiveness) • Complete remedial action for any failed culvert, bank protection measures, etc.	• MB Gov.'t and other regulatory agencies (ORA) as required	Proponent
Metals bioaccumulation in fish tissues	• To confirm effects predictions • To initiate contingency plans to address unexpected effects, as required	• Conduct EEM Monitoring (Section 7.5: Surface Water Quality). • Set aside contingency to initiate fish tissue sampling & analysis. • Collect fish samples at identified monitoring sites, and analyze for metals levels.	• MB Gov.'t as required • Reporting schedule according to *Metal Mining Effluent Regulations* (MMER)	Proponent

Table 7.8-20 Summary of Effects on Fish Resources during Construction

Potential Effect	Level of Effect [1]						Effect Rating [2]	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Construction								
Effects of site clearing, grubbing, grading and sedimentation of instream fish habitat	Adverse	Low	Local	Long-term for mine site	Reversible	High	Not significant	Not significant
Effects of culvert placement on fish and fish egg mortality and sedimentation of instream fish habitat. No culverts will be installed.	Neutral	Low	Local	Short-term Low frequency	Reversible for sedimentation Irreversible for mortality	High	Not significant	Not significant
Changes in stream flow (Minago River and Oakley Creek) due to discharges from the Polishing Pond with potential effects on instream habitat	Adverse	Low	Site-specific	Long-term	Reversible	High	Not significant	Not significant
Potential introduction of contaminants to fish habitat from fuel spills and concrete mixing	Adverse	Low	Site-specific	Short-term Low frequency	Reversible	High	Not significant	Not significant
Potential increase in angling pressure from construction crews	Adverse	Low	Regional	Short-term	Irreversible	High	Not significant	Not significant

Notes:

1 Based on effects attributes in Table 7.8-17.

2 Based on significance criteria.

Table 7.8-21 Summary of Effects on Fish Resources during Operations

Potential Effect	Level of Effect [1]						Effect Rating [2]	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Operations								
Effects of vegetation management on the mine site and transportation corridors right-of-way on sedimentation of instream fish habitat **NOTE:** There are no fish bearing streams within the project area.	Adverse	Low	Local	Local Long-term for mine site Far future for access road	Reversible	High	Not significant	Not significant
Changes in stream flow and habitat capability due to pit dewatering in Oakley Creek and from the TWRMF	Adverse	Low	Local	Long-term	Reversible	High for TWRMF Unknown for Oakley Creek	Not significant	Not significant
Potential increase in angling pressure from project personnel	Adverse	Low	Regional	Long-term	Irreversible	High	Not significant	Not significant

Notes:

1 Based on effects attributes in Table 7.8-17.

2 Based on significance criteria.

Table 7.8-22 Summary of Effects on Fish Resources during Decommissioning

Potential Effect	Level of Effect [1]						Effect Rating [2]	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Decommisioning								
Effects of mine infrastructure removal on riparian and instream fish habitat in Oakley Creek (sedimentation) **NOTE:** There are no fish bearing streams within the project area.	Adverse	Low	Local	Medium term for mine site Far future for access road	Reversible	High	Not significant	Not significant
Effects of Polishing Pond decant on instream fish habitat (water quality) and fish tissue metals levels in Oakley Creek and Minago River	Adverse	Low	Local	Medium term	Reversible	Unknown	Not significant	Not significant
Changes in stream flow and habitat capability due to the recovery of the groundwater table in the Oakley Creek basin	Adverse	Low	Site specific	Long-term	Reversible	Unknown	Not significant	Not significant
Potential increase in angling pressure from project personnel	Adverse	Low	Regional	Short-term	Irreversible	High	Not significant	Not significant

Notes:

1 Based on effects attributes in Table 7.8-17.

2 Based on significance criteria.

Table 7.8-23 Summary of Effects on Fish Resources during Closure

Potential Effect	Level of Effect [1]						Effect Rating [2]	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
Closure								
Effects of Polishing Pond decant on instream fish habitat (water quality) and fish tissue metals levels in Oakley Creek and Minago River	Adverse	Low	Local	Medium term	Reversible	Unknown	Not significant	Not significant
Potential increase in angling pressure from public access	Adverse	Low	Regional	Long-term	Irreversible	High	Not significant	Not significant

Notes:

1 Based on effects attributes in Table 7.8-17.

2 Based on significance criteria.

7.9 Vegetation

This subsection summarizes the 2007 and 2008 vegetation survey programs completed at and surrounding the Minago Project site. URS Canada Inc. (URS, 2008d) conducted a detailed vegetation survey on the Minago Project site in 2007 and Roche Consulting Group (Roche, 2008a) conducted a vegetation survey along a 24.4 km stretch on Highway 6, just south of the site's main entrance and along a potential railway siding near Ponton, Manitoba.

Prior to a detailed description of the vegetation survey methodology and results, characteristics of regional and local settings are summarized below in terms of ecozone and ecoregion.

7.9.1 Regional Setting – Ecozone

Regionally, the Minago Project Site is located within the Boreal Plains ecozone (URS, 2008d). This ecozone is a wide band that extends from the Peace River area of northeast British Columbia to the southeast corner of Manitoba. This zone is located immediately south of and is distinctly different from the Boreal Shield ecozone, which is bedrock controlled. The Boreal Plains ecozone is not bedrock controlled and contains fewer lakes. The dominant coniferous species in this ecozone are white and black spruce, jack pine and tamarack. Deciduous species consist predominantly of white birch, trembling aspen and balsam poplar, particularly in transition zones to the prairie grasslands to the south. Black spruce and tamarack are more abundant along the northern transition zone to the Boreal Shield ecozone.

7.9.2 Local Setting – Ecoregion

The Minago Project Area including the Site occupies approximately 2,428 hectares, west of Highway 6, and is located within the Mid-Boreal Lowland ecoregion of the northern section of the Manitoba Plain (URS, 2008d). The ecoregion is defined as having a sub-humid mid-boreal climate. It is part of a mixed deciduous and coniferous forest, which extends from northwest Ontario to the Rocky Mountain foothills. This mixed deciduous and coniferous forest is comprised of medium to tall, closed stands of balsam poplar and trembling aspen, white and black spruce, and balsam fir occurring in later successional stages.

The topography in the Minago Project Area is relatively flat with extensive low-lying areas containing wetlands covering approximately one-half of the ecoregion. Fens and bogs are poorly drained and frequently covered with tamarack and black spruce. Sites that are well drained consist mostly of plateaus above 265 m a.s.l. covered by limestone, tills and fluvio-glacial sands. These plateaus are usually colonized by an open conifer forest (Roche, 2008a).

Surficial materials of the Minago Project site consist essentially of three types: fine grained glaciolacustrine, till blanket and organic deposits. Glaciolacustrine deposits are sediments deposited in glacial lakes, which formed when meltwater was trapped between the front of a glacier and a moraine or rock wall that prevented drainage. Glaciolacustrine deposits consist primarily of well-stratified fine sand, silt and clay. Till is any sediment that was transported and deposited by a glacier without being sorted by meltwater. It consists of clay, sand and large rock fragments that are deposited in irregular sheets or in ridges called moraines. Organic deposits are rich in partially decomposed plant matter. They usually form and accumulate in poorly drained environments such as swamps and peat bogs (Roche, 2008a).

7.9.3 Scope/Objectives of Vegetation Assessments

The objectives of the 2007 vegetation survey program were to (URS, 2008d):

- establish pre-mining baseline vegetation species, spatial distribution and metal content for the Minago Project Area;
- provide baseline vegetation data required to complete an Environmental Impact Assessment of the Minago Project under the Manitoba *Environmental Assessment Act*;
- provide baseline surface vegetation data required to complete bankable Feasibility Study on the Minago Project; and
- provide baseline vegetation data for determining potential impacts to terrestrial resources during the future development, operation and post-closure phases of the Minago Project Site/Mine.

Upon completing the vegetation survey in the vicinity of Highway 6, established transportation corridors (i.e., Minago Project Site roads and trails) were also surveyed to assess the degree to which invasive/exotic species may have spread and established (URS, 2008d).

The objectives of the August 2008 vegetation survey program were to establish pre-mining baseline vegetation species, spatial distribution for the Highway 6 corridor that might be impacted by mining activities at the Minago Project and a potential railway siding near Ponton, MB. Roche (2008a) assessed vegetation along Highway 6 from the existing power station, located nearby the Minago Camp, to the main Minago entrance (54°06.031' N, 99°09.567'W). Roche (2008a) also recorded the main vegetation species on the Minago Property and at the potential railway siding.

7.9.4 Vegetation Survey Methodology

7.9.4.1 Existing Data Collection and Review

To assist in the identification and delineation of vegetation communities, URS (2008d) and Roche (2008a) reviewed existing data for background information prior to the vegetation field surveys. Data reviewed included:

- Existing GIS data layers including: 1) Forest Resources Management-Forest Inventory Maps (Manitoba Conservation, 2000a); 2) Land Use/Land Cover Maps, (Manitoba Conservation, 1989); and 3) Ecological Areas (Government of Canada, 1996);

- The Canadian Vegetation Classification System: First Approximation (National Vegetation Working Group, 1990);
- Plants of the Western Boreal Forest and Aspen Parkland (Johnson *et al.,* 1995);
- The Canadian Wetlands Classification (National Wetlands Working Group, 1997); and
- Resource specialists at the Manitoba Department of Conservation (Manitoba Conservation 2007d,e).

7.9.4.2 Field Data Collection

Existing vegetation community data and aerial photos were used to determine where field surveys should occur. Transportation in the Project Area was by vehicle (truck), an ARGO off-road vehicle, and foot. Vegetation field data was collected between September 5 and 9, 2007 and May 6 and 10, 2008. The 2007 vegetation field study was led by Eric Klein (Biologist, URS) and assisted by Chris Brown (Environmental Scientist, URS) and Trevor Wilson (Field Assistant, Norway House First Nations). The 2008 vegetation field study was led by Simon Thibault (Biologist) and assisted by Brigitte Dutil (Technician) and Ken Budd (Norway House Cree Nation, Technician).

7.9.4.3 Vegetation Communities

At each field location, the plant community was characterized in terms of species composition, structure, and density of cover (URS, 2008d). Photographs were also taken at each location. Data collected in the field were used to create a map showing the vegetation classifications in the Project Area according to ‘The Canadian Vegetation Classification System: First Approximation’ (National Vegetation Working Group, 1990).

7.9.4.4 Invasive/Exotic Communities

Non-native plant species have potential to cause significant impacts to native ecosystems. Invasive plant species aggressively compete for moisture, nutrients (primarily nitrogen and phosphorus), space, and light. This competition can lead to reduced numbers of native species and potentially, extinction (Royer and Dickinson, 1999).

Highway 6 runs parallel to the Minago Project Site and has wide clearings on both sides (~5 m on the western side and greater than 5 m on the eastern side) that have already been invaded by some exotic species. Subsequently, the area around the shoulders of Highway 6 would be the most likely source for non-native species that could impact the Project Area. Vehicles, as well as individual’s shoes and clothing, could disperse the seeds of these species and allow them to germinate and propagate within the Project Area. For this reason, the shoulder area of Highway 6 was surveyed for invasive species that could pose a threat to native species within the Project Area.

Upon completing a vegetation survey in the vicinity of Highway 6, established transportation corridors (i.e., Minago Project Site roads and trails) were surveyed in order to assess the degree to which some of these species may have already spread (URS, 2008d).

7.9.4.5 Plant Tissue Samples

In 2007, vegetation sampling for metals uptake was conducted within the Minago Property surrounding the Minago Project Site. Vegetation sample sites were located where vegetation could be impacted by effluent discharge and/or fugitive dust and where it could be sampled again during development, operation and post-closure.

Vegetation samples were taken from forty (40) locations and analyzed for total metals. To help assess local chemical variability, five (5) duplicate samples were also collected, for a total of forty-five (45) vegetation samples. Vegetation samples consisted of the living material (leaves, branches and stems).

The vegetation samples collected depended on the species present at each site, but focused on vegetation both commonly used by wildlife (i.e., diamond leaf willow-*Salix planifolia*) as forage and potentially used by local communities as traditional foods (i.e., bog cranberry-*Vaccinium oxycoccos*). Since lichen (i.e, *Cladina* spp.) are an important food source to woodland caribou, especially in the winter time, they were also a focus of the vegetation sampling.

The vegetation material was clipped with stainless steel shears, put in sample bags, labeled, and placed in a cooler with ice packs. At the conclusion of each workday, samples were placed in a refrigeration unit (for a maximum of five days for the samples collected earliest) to prevent decay or moisture loss prior to arriving at the lab. All samples were shipped in a cooler to the ALS Laboratory Group in Vancouver, BC for analysis. To help prevent contamination between samples, the shears were cleaned with alcohol after each sample collection.

7.9.5 2007 Vegetation Survey Results

7.9.5.1 Vegetation Communities near Minago Property

Eleven different vegetation communities were found within and adjacent to the Minago Property, which are described below in a general manner. Each vegetation classification is based on a seven level heirarchy, per 'The Canadian Vegetation Classification System' (National Vegetation Working Group, 1990). The seven levels of this classification system are as follows:

- Level I: distinguishes broad physiognomic types (i.e., tree or shrub);
- Level II: subdivides the physiognomic types on the basis of different growth-forms of plant communities (i.e., deciduous or graminoid);
- Level III: subdivides the growth-forms of Level II on the basis of total stand ground cover (i.e., closed or sparse);

Level IV: subdivides the physiognomic classes within Level III on the basis of height (i.e., tall or low);

Level V: subdivides Level IV on the basis of dominant (a species having the greatest cover and/or biomass within a community) and co-dominant (two or more dominant species that occur in approximately equal abundance and have similar physiognomy) species (i.e., black spruce);

Level VI: subdivides Level V on the basis of major understory vegetation, if present (i.e., willow/reed grass); and

Level VII: subdivides Level VI classes on the basis of one or more major understory species using scientific names (i.e., *Picea glauca*, *Salix bebbiana, Hylocomium splendens* Community type (National Vegetation Working Group, 1990).

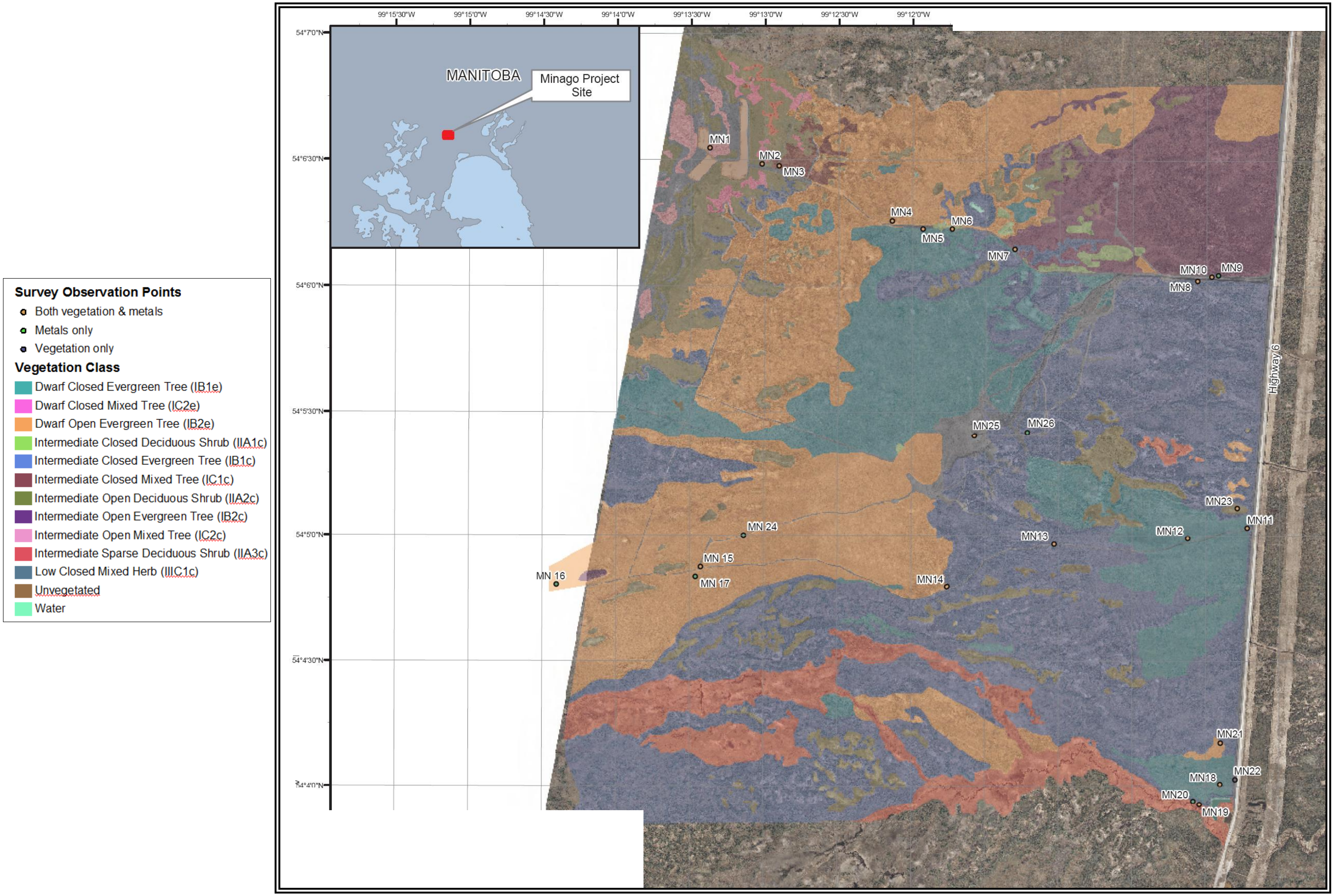
Figure 7.9-1 illustrates the distribution of various vegetation communities within the Minago Project Area. Based on the first four levels of the Canadian Vegetation Classification System, an abbreviated naming convention was devised to facilitate both the textual and visual representation of vegetation classification information (Table 7.9-1). Each heading in italics below the main unit is a Level IV classification and is followed by the naming convention devised from the Canadian Vegetation Classification System. Species that compose the bulk of the biomass are listed in descending order based on absolute cover percentage. Identification down to the species level was not possible in some cases and in these instances, only the genus was listed.

Table 7.9-2 provides an estimate of the area per vegetation classification in the Project Area. Representative photographs of vegetation communities occurring at the Minago site are provided in Appendix 7.9.

7.9.5.1.1 Tree Units

<u>Intermediate Closed Evergreen Tree (IB1c)</u>

The intermediate height, closed evergreen forests in the Project Area were found on poorly-drained soils and dominated by primarily black spruce (*Picea mariana*), but also had some tamarack (*Larix laricina*) in the tree stratum (URS, 2008d). The shrub stratum was composed of diamond leaf willow (*Salix planifolia*), green alder (*Alnus crispa*), and small paper birch (*Betula papyrifera*) found primarily atop the hummocks. The herb stratum was fairly diverse, but was dominated by sedges (*Carex* sp.), bluejoint reedgrass (*Calamagrostis canadensis*), and arrow-leaved coltsfoot (*Petasites sagittatus*). The nonvascular stratum was dominated by stair step moss (*Hylocomnium splendens*), spruce moss (*Evernia mesomorpha*), which was primarily hanging from the branches of black spruce, and hooded tube lichen (*Hypogymnia physodes*). Observation point MN 8, shown in Appendix 7.9, was within this vegetation classification. This vegetation is usually referred to as black spruce moss stand.



Source: adpated from URS, 2008d

Figure 7.9-1 2007 Vegetation Classification at the Minago Project

Table 7.9-1 Canadian Vegetation Classification Level IV Abbreviations

Level I	Level II	Level III	Level IV
I. Tree (≥10% cover of trees)	A. Deciduous (all broadleaf species, including the genus *Arbutus*)	(1) Closed (>60% cover)	a. Very tall (>25m) b. Tall (>15-25m) c. Intermediate (>3-15m) d. Low (< 3m due to age) e. Dwarf (≤3m due to environment)
		(2) Open (>25-60% cover)	a. Very tall (>25m) b. Tall (>15-25m) c. Intermediate (>3-15m) d. Low (< 3m due to age) e. Dwarf (≤3m due to environment)
		(3) Sparse (10-25% cover)	a. Very tall (>25m) b. Tall (>15-25m) c. Intermediate (>3-15m) d. Low (< 3m due to age) e. Dwarf (≤3m due to environment)
	B. Evergreen (all conifers, including the genus *Larix*)	(1) Closed (>60% cover)	a. Very tall (>25m) b. Tall (>15-25m) c. Intermediate (>3-15m) d. Low (< 3m due to age) e. Dwarf (≤3m due to environment)
		(2) Open (>25-60% cover)	a. Very tall (>25m) b. Tall (>15-25m) c. Intermediate (>3-15m) d. Low (< 3m due to age) e. Dwarf (≤3m due to environment)
		(3) Sparse (10-25% cover)	a. Very tall (>25m) b. Tall (>15-25m) c. Intermediate (>3-15m) d. Low (< 3m due to age) e. Dwarf (≤3m due to environment)
	C. Mixed	(1) Closed (>60% cover)	a. Very tall (>25m) b. Tall (>15-25m) c. Intermediate (>3-15m) d. Low (< 3m due to age) e. Dwarf (≤3m due to environment)
		(2) Open (>25-60% cover)	a. Very tall (>25m) b. Tall (>15-25m) c. Intermediate (>3-15m) d. Low (<3m due to age) e. Dwarf (≤3m due to environment)
			a. Very tall (>25m) b. Tall (<15-25m)

Table 7.9-1 (Cont.'d) Canadian Vegetation Classification Level IV Abbreviations

Level I	Level II	Level III	Level IV
		(3) Sparse (10-25% cover)	c. Intermediate (>3-15m) d. Low (< 3m due to age) e. Dwarf (≤3m due to environment)
	A. Deciduous	(1) Closed (>60% cover)	a. Very tall (>5m) b. Tall (>3-5m) c. Intermediate (>1-3m) d. Low (>0.2m-1m) e. Very low (≤0.2m)
		(2) Open (>25-60% cover)	a. Very tall (>5m) b. Tall (>3-5m) c. Intermediate (>1-3m) d. Low (>0.2m-1m) e. Very low (≤0.2m)
		(3) Sparse (2-25% cover)	a. Very tall (>5m) b. Tall (>3-5m) c. Intermediate (>1-3m) d. Low (>0.2m-1m) e. Very low (≤0.2m)
II. Shrub (≥10% cover if tallest stratum, or composes ≥50% of total vegetation if of a similar height as other species in stand)	B. Evergreen	(1) Closed (>60% cover)	a. Very tall (>5m) b. Tall (>3-5m) c. Intermediate (>1-3m) d. Low (>0.2m-1m) e. Very low (≤0.2m)
		(2) Open (>25-60% cover)	a. Very tall (>5m) b. Tall (>3-5m) c. Intermediate (>1-3m) d. Low (>0.2m-1m) e. Very low (≤0.2m)
		(3) Sparse (2-25% cover)	a. Very tall (>5m) b. Tall (>3-5m) c. Intermediate (>1-3m) d. Low (>0.2m-1m) e. Very low (≤0.2m)
	C. Mixed	(1) Closed (>60% cover)	a. Very tall (>5m) b. Tall (>3-5m) c. Intermediate (>1-3m) d. Low (>0.2m-1m) e. Very low (≤0.2m)
		(2) Open (>25-60% cover)	a. Very tall (>5m) b. Tall (>3-5m) c. Intermediate (>1-3m) d. Low (>0.2m-1m) e. Very low (≤0.2m)
		(3) Sparse (2-25% cover)	a. Very tall (>5m) b. Tall (>3-5m) c. Intermediate (>1-3m) d. Low (>0.2m-1m) e. Very low (≤0.2m)
		(1) Closed (>60% cover)	a. Tall (>3-5m) b. Intermediate (>1-3m) c. Low (>0.2m-1m) d. Very low (≤0.2m)

Table 7.9-1 (Cont.'d) Canadian Vegetation Classification Level IV Abbreviations

Level I	Level II	Level III	Level IV
III. Herb (Incl. ferns and their allies; ≥2% herb cover; nonvascular: herb cover ratio ≤2.0 i.e., 0-2)	A. Forb (incl. ferns and their allies)	(2) Open (>25-60% cover)	b. Intermediate (>1-3m) c. Low (>0.2m-1m) d. Very low (≤0.2m)
		(3) Sparse (2-25% cover)	a. Tall (>3-5m) b. Intermediate (>1-3m) c. Low (>0.2m-1m) d. Very low (≤0.2m)
	B. Graminoid	(1) Closed (>60% cover)	a. Tall (>3-5m) b. Intermediate (>1-3m) c. Low (>0.2m-1m) d. Very low (≤0.2m)
		(2) Open (>25-60% cover)	a. Tall (>3-5m) b. Intermediate (>1-3m) c. Low (>0.2m-1m) d. Very low (≤0.2m)
		(3) Sparse (2-25% cover)	a. Tall (>3-5m) b. Intermediate (>1-3m) c. Low (>0.2m-1m) d. Very low (≤0.2m)
	C. Mixed	(1) Closed (>60% cover)	a. Tall (>3-5m) b. Intermediate (>1-3m) c. Low (>0.2m-1m) d. Very low (≤0.2m)
		(2) Open (>25-60% cover)	a. Tall (>3-5m) b. Intermediate (>1-3m) c. Low (>0.2m-1m) d. Very low (≤0.2m)
		(3) Sparse (2-25% cover)	a. Tall (>3-5m) b. Intermediate (>1-3m) c. Low (>0.2m-1m) d. Very low (≤0.2m)
IV. Nonvascular (≥2% cover of nonvasculars, >2 times the cover of herbs)	A. Lichen	(1) Closed (>60% cover) (2) Open (>25-60% cover) (3) Sparse (2-25% cover)	
	B. Bryophyte	(1) Closed (>60% cover) (2) Open (>25-60% cover) (3) Sparse (2-25% cover)	
	C. Mixed	(1) Closed (>60% cover) (2) Open (>25-60% cover) (3) Sparse (2-25% cover)	

Source: URS, 2008d (Secondary source: National Vegetation Working Group, 1990)

Note: For example, the abbreviation IB1c translates to intermediate closed evergreen tree; IIIB2c translates to low open graminoid herb, etc.

Table 7.9-2 Area per Vegetation Classification in the Minago Project Area

Vegetation Classification	Hectares	Percent of Total
Intermediate Closed Evergreen Tree (IB1c)	894	34
Dwarf Closed Evergreen (IB1e)	362	14
Intermediate Open Evergreen (IB2c)	177	7
Dwarf Open Evergreen Tree (IB2e)	638	25
Intermediate Closed Mixed Tree (IC1c)	11	<0.01
Intermediate Open Mixed Tree (IC2c)	14	<0.01
Dwarf Closed Mixed Tree (IC2e)	9	<0.01
Intermediate Closed Deciduous Shrub (IIA1c)	10	<0.01
Intermediate Open Deciduous Shrub (IIA2c)	211	8
Intermediate Sparse Deciduous Shrub (IIA3c)	165	6
Low Closed Mixed Herb (IIIC1c)	112	4
Water	2	<0.01
Unvegetated	8	<0.01
TOTAL	**2613**	**100**

Source: URS, 2008d

Dwarf Closed Evergreen Tree (IB1e)

The dwarf height, closed evergreen forests in the Project Area were located on poorly-drained soils. The tree stratum was entirely composed of tamarack (*Larix laricina*). The shrub stratum was dominated by shrub birch (*Betula glandulosa*), bog rosemary (*Andromeda polifolia*), and small bog cranberry (*Vaccinium oxycoccos*). Sedges (*Carex* sp.) made up most of the herb layer, but buckbean (*Menyanthes trifoliata*) and bog violet (*Viola nephrophylla*) were also present to a lesser degree. The nonvascular stratum was dominated by large hummocks primarily composed of golden fuzzy fen moss (*Tomenthypnum nitens*). Observation point MN 12, shown in Appendix 7.9, was within this vegetation classification. This vegetation is usually referred to as treed bog or bog.

Intermediate Open Evergreen Tree (IB2c)

The intermediate height, open evergreen forests in the Project Area were found on poorly-drained soils and dominated by black spruce (*Picea mariana*). The shrub stratum was dominated by shrub birch (*Betula glandulosa*), Labrador tea (*Ledum groenlandicum*), and diamond leaf willow (*Salix planifolia*). The herb stratum was dominated by sedges (*Carex* sp.) and buckbean (*Menyanthes trifoliata*), while poor fen peat moss (*Sphagnum angustifolium*) was the dominant nonvascular. Observation point MN 5, shown in Appendix 7.9, was within this vegetation classification. This vegetation is usually referred to as treed bog or bog.

Dwarf Open Evergreen Tree (IB2e)

The dwarf height, evergreen open forests in the Project Area were on poorly-drained soils. The tree stratum was dominated by tamarack (*Larix laricina*). The shrub stratum was dominated by shrub birch (*Betula glandulosa*) and bog rosemary (*Andromeda polifolia*). Bog sedge (*Carex magellanica*) and swamp horsetail (*Equisetum fluviatile*) were the dominant herbs. The nonvascular stratum was dominated by midway peat moss (*Sphagnum magellanicum*) and Blandow's feather moss (*Helodium blandowii*). Observation point MN 4, shown in Appendix 7.9, was within this vegetation classification. This vegetation is usually referred to as treed bog or bog.

Intermediate Closed Mixed Tree (IC1c)

The intermediate height, mixed closed forests in the Project Area were found on moderately well-drained soils. The tree stratum was dominated by black spruce (*Picea mariana*), while Labrador tea (*Ledum groenlandicum*) and diamond leaf willow (*Salix planifolia*) were dominant in the shrub layer. The herb stratum was dominated by bluejoint reedgrass (*Calamagrostis canadensis*) and bishop's cap (*Mitella nuda*). *Sphagnum* moss was dominant in the nonvascular stratum. Observation point MN 3, shown in Appendix 7.9, was within this vegetation classification. This vegetation is usually referred to as black spruce moss stand.

Intermediate Open Mixed Tree (IC2c)

The intermediate height, open mixed forests in the Project Area were located on well-drained soils. The tree stratum was dominated by jack pine (*Pinus banksiana*), with lesser amounts of paper birch (*Betula papyrifera*) also present. The shrub stratum was dominated by diamond leaf willow (*Salix planifolia*), bog cranberry (*Vaccinium vitis- idaea*) and shrubby cinquefoil (*Potentilla futicosa*). Wild strawberry (*Fragaria virginiana*) dominated the herb stratum, while grey reindeer lichen (*Cladina rangiferina*) and dog pelt (*Peltigera mitis*) were dominant in the nonvascular layer. Observation point MN 1, shown in Appendix 7.9, was within this vegetation classification. This vegetation is usually referred to as open conifer forest.

Dwarf Closed Mixed Tree (IC2e)

The dwarf height, closed mixed forests in the Project Area were located on moderately well-drained soils. The tree stratum was dominated by black spruce (*Picea mariana*), with about half as much tamarack (*Larix laricina*). The shrub stratum was dominated by Labrador tea (*Ledum groenlandicum*), while meadow horsetail (*Equistem pratense*) dominated the herb layer. Green reindeer lichen (*Cladina mitis*) dominated the nonvascular stratum. Observation point MN 2, shown in Appendix 7.9, was within this vegetation classification. This vegetation is usually referred to as black spruce stand.

7.9.5.1.2 Shrub Units

Intermediate Closed Deciduous Shrub (IIA1c)

The intermediate height, closed deciduous shrub vegetation units in the Project Area were located in poorly-drained soils. The shrub stratum was dominated by shrub birch (*Betula glandulosa*) and diamond leaf willow (*Salix planifolia*) (URS, 2008d). Swamp horsetail (*Equistem fluviatile*) was dominant in the herb stratum, while *Sphagnum* moss dominated the nonvascular layer.

Intermediate Open Deciduous Shrub (IIA2c)

The intermediate height, open deciduous shrub vegetation units in the Project Area were located on poorly-drained soils. The dominant shrubs were shrub birch (*Betula glandulosa*) and tall blueberry willow (*Salix myrtillifolia* var. *cordata*). The herb stratum was dominated by swamp horsetail (*Equisetum fluviatile*) and bog sedge (*Carex magellanica*). Common tree moss (*Climacium dendroides*) dominated the nonvascular stratum. Observation point MN 23, shown in Appendix 7.9, was within this vegetation classification.

Intermediate Sparse Deciduous Shrub (IIA3c)

The intermediate height, sparse deciduous shrub vegetation units in the Project Area were located on very poorly-drained soils. The dominant plant in the shrub stratum was myrtle-leaved willow (*Salix myrtillfolia*). The herb stratum was dominated by beaked sedge (*Carex utriculata*) and water sedge (*Carex aquatilis*). Common tree moss (*Climacium dendroides*) was the dominant nonvascular. Observation point MN 19, shown in Appendix 7.9, was within this vegetation classification and is representative of the riparian zone within the Project Area.

7.9.5.1.3 Herb Units

Low Closed Mixed Herb (IIIC1c)

Low height, closed mixed herb vegetation units in the Project Area were located on moderately poorly-drained soils. The herb stratum was dominated by wild mint (*Mentha arvensis*) and nodding beggarticks (*Bidens cernua*) (URS, 2008d). Stiff club-moss (*Lycopodium annotinum*) was dominant in the nonvascular stratum. Observation point MN 10, shown in Appendix 7.9, was within this vegetation classification.

7.9.5.1.4 Other Units

Water

A portion of the Minago Project Area is covered by small ponds (URS, 2008d). These isolated water bodies are likely kettle ponds and make up a very small percentage (<0.01%) of the total Project Area.

Unvegetated

The northwest portion of the Minago Project area contains a small amount of unvegetated ground. This unvegetated area, which trends in a linear, mostly north-south direction, has a very small amount of herbaceous vegetation at various locations, but is primarily composed of rock-sized mineral cover (URS, 2008d).

7.9.6 2008 Vegetation Survey Results

Table 7.9-3 summarizes the main vegetation species observed by Roche (2008a) on the Minago Property. Roche (2008a) found that black spruce was by far the most abundant vascular species due to the badly drained soil conditions. On better drained soils, black spruce and jack pine were abundant. Jack pine was frequently dominating the more xeric environments. Well drained locations typically had limestone, tills and fluvio-glacial sands as substrate and were located above 265 m a.s.l. The well drained locations were usually colonized by an open conifer forest and sphagnum-spruce forest and treed bogs were colonizing depressions filled with marine clay and silt. These depressions were typically covered by peat, which was up to 4 m thick (Roche, 2008a).

7.9.6.1 Highway 6 Corridor

7.9.6.1.1 Terrestrial Habitats

Roche (2008a) found that the 24.4 km long Highway 6 corridor north of the power station (located near the Minago camp) up to the main entrance to the Minago Project (NAD 83 5994719, 489575 or 54°06.031' N, 99°09.567' W) was dominated by open conifer forests (Figure 7.9-2), black spruce moss stands and treed bogs. There were also some sparse mixed stands in the Highway 6 corridor, which were characterized by medium to tall, closed stands of trembling aspen and balsam poplar with white birch and willows. Roche (2008a) did not identify vegetation on rock outcrops near Highway 6 because of repeated disturbance due to human activities (recent construction works).

Black spruce moss stands constitute a transitional environment between wetlands (especially bogs) and drier stands such as open conifer forests. This is why this plant community is usually observed on a topographical gradient between the lowest depressions filled with clay and higher plateaus.

Black spruce moss stands (Figure 7.9-3) were the most abundant plant community at the margin of depressions filled with clay and silt. The moss layer was dominated by Schreber’s feathermoss and, within the wetter stands, by Sphagnum mosses such as *Sphagnum fuscum*, *S. girgensohnii* and *S. capillifolium* (Roche, 2008a). The most abundant shrubs were Labrador tea, leatherleaf, blueberry and sheep laurel. Lichens such as *Cladina stellaris*, *C. mitis*, *C. rangiferina* and *C. stygia* often appeared as patches within the moss carpet. Some brown mosses also grew

Table 7.9-3 Main Species Observed Within the Study Area

Common name	Latin name
Ligneous	
Black spruce	*Picea mariana*
Larch	*Larix laricina*
Jack pine	*Pinus banksiana*
Alder	*Alnus rugosa*
Labrador tea	*Rhododendron groenlandicum*
Leatherleaf	*Chamaedaphne calyculata*
Sheep laurel	*Kalmia angustifolia*
Blueberry	*Vaccinium angustifolium*
Cranberry	*Vaccinium oxycoccos*
Herbaceous	
Three-leaf false lily	*Maianthemum trifolium*
Cloudberry	*Rubus chamaemorus*
Tussock cottongrass	*Eriophorum vaginatum* var *spissum*
Few-seed sedge	*Carex oligosperma*
Thallophyta	
Schreber's feathermoss	*Pleurozium schreberi*
Lichens	*Cladina stellaris, C. mitis, C. stygia*
Sphagnum	*Sphagnum fuscum, S. capillifolium*
Brown mosses	*Mylia anomala, Dicranum* spp.

Source: Roche, 2008a

within this carpet, mainly *Mylia anomala* and *Dicranum* spp. Other than black spruce, alders and larches (*Larix laricina*) were the main tree species growing within this plant community. This plant community was also colonized by many herbaceous like few-seed sedge, three-leaf false lily (*Maianthemum trifolium*), cloudberry (*Rubus chamaemorus*) and tussock cottongrass. Horsetail (*Equisetum arvense*) was also growing within the moss carpet (Roche, 2008a).

Wetter stands, located nearby small creeks and at the border of bogs, showed more acidic soil conditions and were dominated by Sphagnum mosses rather than by Schreber's feathermoss. However, the abundance of trees in these stands was indicative of better drainage conditions than in the bogs. Thus, species associated with wetlands were cohabitating with more xeric species.

Open conifer forests were the most abundant plant community on plateaus and had a far more open tree cover than black spruce moss stands. Main tree species were black spruce and jack

Source: Roche, 2008a

Figure 7.9-2 Open Conifer Forest

Source: Roche, 2008a

Figure 7.9-3 Black Spruce Moss Stand

pine, their relative abundance essentially depending on drainage conditions since jack pine is a more xeric species. At elevations above 274 m (a.s.l.), jack pine was the most abundant species since soils, at that elevation, essentially consisted of localized limestone bedrock outcrops. Again, the main shrubs were Labrador tea, sheep laurel and blueberry. However, what characterized these forests most was that their moss layer was dominated by lichens. In fact, in some areas, 90% of the moss layer consisted of lichens. Dominant species were *Cladina stellaris*, *C. mitis*, *C. rangiferina* and other *Cladonia* spp. Only some brown mosses such as hair-cap mosses, Schreber's feathermoss and *Dicranum* spp. are able to colonize the lichen carpet (often under shrubs, taking advantage of wetter conditions generated by their shade). Herbaceous species are rare in this plant community; only some willows are able to compete with the dominant ericaceous shrubs.

7.9.6.1.2 Wetlands

The 24.4 km long Highway 6 corridor studied was relatively flat and had extensive wetlands covering approximately one-third of the area. The poorly drained bogs located within the study area consisted essentially of treed bogs (Figure 7.9-4), which were largely dominated by Sphagnum mosses and were colonized by trees such as black spruce and larch. These ecosystems were colonized by the same species which were growing within the wetter black spruce moss stands. Schreber's feathermoss and lichens were also observed in treed bogs, especially under trees.

7.9.6.2 Railway Siding

Following is a description of vegetation that is growing in the area surrounding the proposed railway siding. The proposed railway siding is about 60 km north of the Minago Property and 5 km south of Ponton, Manitoba (where Highway 6 connects with Highway 39). The central geographical coordinates (UTM; NAD83) of that location are: 493 669 mE and 6 056 470 mN (Roche, 2008c).

The proposed railway siding is located along the existing Hudson Bay Railway, which is operating over 1,300 km in Northern Manitoba. It includes an existing gravel pit (Figure 7.9-5), which covers approximately half of the area (Figure 7.9-6), and a pond (Figure 7.9-7). The pond is located in the south-western corner of the proposed location. There is also a bog close by, but outside the proposed location of the railway siding.

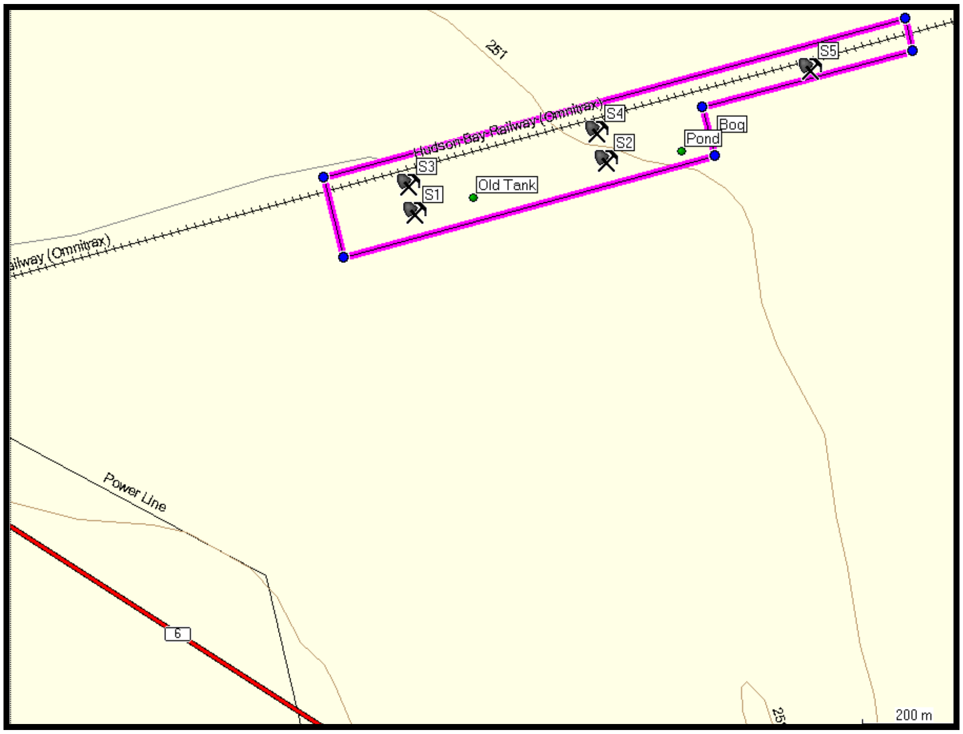
The pond is located within the proposed railway siding and will likely be destroyed, if the railway siding were to be built. Vegetation colonizing its margins does not differ from what was observed within black spruce moss stands, with exception of some sedges and grasses. These sedges and grasses are common in the surroundings of the study area where ponds and swamps tend to occur (poorly drained substrate) and are not listed as species of environmental concern or as special-status species. The pond is not connected with any streams or creeks, but appears to receive some runoff water from the nearby bog. Therefore, the pond is not a fish habitat.

Source: Roche, 2008a

Figure 7.9-4 Treed Bog

Source: Roche, 2008c

Figure 7.9-5 Existing Gravel Pit Located along the Hudson Bay Railway



Source: Roche, 2008c

Figure 7.9-6 Location Map of the Proposed Railway Siding

The treed bog is located at the margin of the study area and expands south and west from that corner (Figure 7.9-6). Species composition in that bog was similar to what was observed in the wetter stands of black spruce moss stands and is typical of the regional plant composition.

Vegetation in the other areas of the proposed railway siding include black spruce stands and wetter stands already described above.

7.9.7 Special Status Plant Species

At the federal level, the *Species at Risk Act* (SARA) does not list any species that occur in this region of Manitoba. All the SARA listed plant species in Manitoba are south of Lake Winnipeg. In addition, there are no plant species listed under the Manitoba *Endangered Species Act* known in or near the Project Area (Manitoba Conservation, 2007d).

The Manitoba Conservation Data Centre (MBCDC) was contacted to gather any existing information on rare plants or communities in the Project Area. In correspondence dated June 15, 2007, URS (2008d) received a response that there are no known rare plants or communities in the Project Area (Manitoba Conservation, 2007e). However, one species, the few-flowered sedge

Source: Roche, 2008c

Figure 7.9-7 Pond in the Area of the Proposed Railway Siding

(*Carex pauciflora*) is listed as a species of conservation concern for the Mid-Boreal Lowland ecoregion (Roche, 2008a). The term "species of conservation concern" includes species that are rare, disjunct, or at risk throughout their range or in Manitoba and in need of further research. The few-flowered sedge (*Carex pauciflora*) is not listed under the Manitoba *Endangered Species Act* (MBESA) and has not been designated as 'special' by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC). Throughout its range, *C. pauciflora* grows in Sphagnum bogs and acidic peat, usually on open mats and is identifiable from late May to early September. Within the Minago area, it would be more likely to observe this species in partial conifer shade, within the black spruce moss stand. Associated species include *Sphagnum fuscum*, *S. capillifolium*, Labrador tea, black spruce, blueberry, leatherleaf, cloudberry and other sedges such as *Carex oligosperma* and *Eriophorum vaginatum* var *spissum*.

The vegetation field studies included surveys for any rare or endangered species as well as the few-flowered sedge (*Carex pauciflora*) at each vegetation sampling site. No rare or endangered species were observed (URS, 2008d, Roche, 2008a).

7.9.8 Invasive/Exotic Species

Invasive species observed in the area of Highway 6 include (URS, 2008d):

1) western willow aster (*Aster hesperius*),

2) milk-vetch (*Astragalus* sp.),
3) marsh ragwort (*Senecia congestus*),
4) Canada goldenrod (*Solidago canadensis*),
5) common dandelion (*Taraxacum officinale*),
6) alsike clover (*Trifolium hybridum*),
7) tufted vetch (*Vicia cracca*),
8) narrow-leaved hawkweed (*Hieracium umbellatum*),
9) ox-eye daisy (*Chrysanthemum leucanthemum*),
10) nodding beggarticks (*Bidens cernua*),
11) wild mint (*Mentha arvensis*), and
12) horsetail (*Equisetum* sp.).

Some of these species have already been dispersed to the transportation corridors within the Project Area and are thriving. The most abundant invasive species that have already colonized vast sections of trails at Minago include (URS, 2008d): horsetail, nodding beggarticks, wild mint, and western willow aster (refer to Photos in Appendix 7.9). All of these species are aggressive growers and can be detrimental to native plants. In the case of horsetail, various species (i.e., swamp and marsh horsetail) are naturally present in some locations beyond the trails and highway sides, but given the opportunity, would likely propagate into other areas. Therefore, the potential exists for these species, as well as others previously listed, to propagate further within the Project Area and impact native plants.

7.9.9 Traditional-Use Plants

The various benefits that Cree and other populations may be getting from plants have been compiled as part of numerous impact assessment studies that were conducted in the James Bay area in Northern Québec based on meetings, discussions and interviews with members of different native communities in 2002 and 2003.

Based on this information and the literature, there are about 50 vascular plants for which a traditional use (medicine, food or other) is known (Table 7.9-4) (Roche, 2008a). These plants were divided in three groups (trees, shrubs and herbaceous). Globally, plants are used for many things, particularly for feeding, tool production, lodging and traditional medicine. There seems to be a good correlation between the importance of a plant's use and its abundance in the environment. Most of the 50 vascular plants are abundant and located within the Minago Project area. However, none of these species is of conservation concern neither at the regional level nor at the provincial level and they are almost all very abundant in the region.

Table 7.9-4 List of Traditional-Use Plant Species Possibly Located in the Area

TREE SPECIES	SHRUB SPECIES
White birch (*Betula papyrifera*)	Sweet blueberry (*Vaccinium angustifolium*)
White spruce (*Picea glauca*)	Alpine bilberry (*Vaccinium uliginosum*)
Black spruce (*Picea mariana*)	Bog rosemary (*Andromeda glaucophylla*)
Larch (*Larix laricina*)	Green alder (*Alnus crispa*)
Balsam poplar (*Populus balsamifera*)	Leatherleaf (*Chamaedaphne calyculata*)
Trembling aspen (*Populus tremuloides*)	Pin cherry (*Prunus pensylvanica*)
Jack pine (*Pinus banksiana*)	Choke cherry (*Prunus virginiana*)
Eastern white cedar (*Thuja occidentalis*)	Creeping snowberry (*Gaultheria hispidula*)
HERBACEOUS SPECIES	Redosier dogwood (*Cornus stolonifera*)
Wild chives (*Allium schoenoprasum*)	Skunk currant (*Ribes glandulosum*)
Wild sarsaparilla (*Aralia nudicaulis*)	Swamp black currant (*Ribes lacustris*)
Purple avens (*Geum rivale*)	Canada gooseberry (*Ribes hirtellum*)
Cow parsnip (*Heracleum lanatum*)	Swamp laurel (*Kalmia polifolia*)
Bunchberry (*Cornus canadensis*)	Lambkill (*Kalmia angustifolia*)
Strawberry (*Fragaria virginiana*)	Labrador tea (*Ledum groenlandicum*)
Stiff club moss (*Lycopodium annotium*)	Cranberry (*Vaccinium oxycoccos*)
Common mint (*Mentha arvensis*)	Long-beaked willow (*Salix bebbina*)
Buckbean (*Menyanthes trifoliata*)	Shining willow (*Salix lucida*)
Meadow rue (*Thalictrum pubescens*)	Balsam willow (*Salix pyrifolia*)
Pitcher plant (*Sarracenia purpurea*)	Bush willow (*Salix humilis*)
Cattail (*Typha latifolia*)	Bog willow (*Salix pedicellaris*)
	Red raspberry (*Rubus idaeus*)
	Dwarf raspberry (*Rubus pubescens*)

Source: Roche, 2008a

7.9.10 Baseline Metals Analysis

Table 7.9-5 provides a statistical summary of metal analyses across all 45 vegetation samples (including the five duplicate samples), both wet and dry weights, for the mean, minimum, median, maximum, 75th percentile, and 95th percentile. For example, the values (in mg/kg) for the wet weight of mercury are: mean (0.011), minimum (0.002), median (0.006), maximum (0.109), 75th

(0.014), and 95th percentile (0.024) (URS, 2008d). As there is no guidelines for metal concentrations in plant tissue samples, this data provides background information (URS, 2008d).

Statistical summaries of some of the elements (Barium, Chromium, Cobalt, Copper, Nickel, and Strontium) in vegetation tissue samples are given in Appendix 2.9. Complete laboratory certified reports for metal analyses on plant samples are presented in Appendix L7.9. Information in Appendix L7.9 includes results for baseline metal analyses conducted on plants with potential for forage and/or subsistence use (i.e., bog cranberry-*Vaccinium oxycoccos* or green reindeer lichen-*Cladina mitis*) (URS, 2008d).

Overall, there was not a large degree of difference between each duplicate sample and the original. A Student's t-test was run for each duplicate pair and the average t-value was 0.41, which indicates that the values are not vastly different from one another.

7.9.11 Conclusions – Baseline Vegetation Survey

Most of the Project Area contains saturated soils, varying degrees of standing water during non-winter months, and hydrophytic vegetation. Subsequently, most of the vegetation in the Project Area is suited to survival in anoxic conditions. The majority of the Project Area would likely be classified as wetland, either treed or not. The driest part of the Project Area, which is also the highest point, is in the northwest corner. The relatively dry nature of this small area is manifested through the presence of slightly different species from the rest of the area (i.e., jack pine and pin cherry) (URS, 2008h).

The Project Area has a relatively uniform composition and does not have a substantial amount of vegetative diversity. No rare, threatened, endangered, or special-status plant species were found. However, due to the presence of invasive/exotic species along Highway 6, as well as some of the trails within the Project Area, the potential exists for dispersal of some of these species further within the Project Area.

Overall, the Project Area contains vegetation consisting of mostly evergreen trees (primarily black spruce and tamarack) of intermediate (>3-15 m) to dwarf (3 m) heights. Intermediate closed evergreen tree was the most dominant (34%) vegetation classification, followed by dwarf open evergreen tree (25%) (Table 7.9-2). Combined, these two classifications make up nearly two-thirds of the entire Project Area and can be referred to as black spruce moss stands and treed bogs or bogs, respectively. There is a relatively low level of vegetative biodiversity and there are not any vegetation types unique to the area or region. A small loss of vegetation would likely have a negligible influence on area wide vegetation functions and values.

Table 7.9-5 Statistical Summary of Metal Analyses in Vegetation

Average across all 45 samples	Moisture	Aluminum (Al)-Total*	Aluminum (Al)-Total*	Antimony (Sb)-Total*	Antimony (Sb)-Total*	Arsenic (As)-Total*	Arsenic (As)-Total*	Barium (Ba)-Total	Barium (Ba)-Total	Beryllium (Be)-Total*	Beryllium (Be)-Total*
Mean	54.95	51.93	26.60	0.063	0.013	0.215	0.067	45.519	19.939	0.380	0.127
Min	7.10	10.00	2.80	0.050	0.010	0.052	0.013	4.730	1.290	0.300	0.100
Median	53.60	32.00	14.95	0.050	0.010	0.080	0.030	30.300	14.900	0.300	0.100
Max	82.00	187.00	143.00	0.350	0.070	3.070	0.713	276.000	82.500	2.100	0.700
75th Percentile	62.6	69	23.925	0.050	0.010	0.167	0.041	58.500	26.900	0.300	0.100
95th Percentile	76.78	172	100.56	0.140	0.028	0.482	0.203	116.200	57.200	0.840	0.280

Bismuth (Bi)-Total*	Bismuth (Bi)-Total*	Cadmium (Cd)-Total*	Cadmium (Cd)-Total*	Calcium (Ca)-Total	Calcium (Ca)-Total	Chromium (Cr)-Total*	Chromium (Cr)-Total*	Cobalt (Co)-Total*	Cobalt (Co)-Total*	Copper (Cu)-Total	Copper (Cu)-Total	Lead (Pb)-Total*
0.380	0.035	0.238	0.110	8788.889	3604.644	0.666	0.176	0.256	0.072	2.417	1.136	0.346
0.300	0.030	0.030	0.005	790.000	272.000	0.500	0.100	0.100	0.020	0.457	0.106	0.100
0.300	0.030	0.077	0.034	7430.000	3330.000	0.500	0.130	0.100	0.020	2.290	0.959	0.200
2.100	0.210	4.060	1.850	33600.000	9830.000	3.500	0.700	5.190	1.210	5.620	2.620	2.510
0.300	0.030	0.133	0.061	9840.000	4250.000	0.500	0.190	0.120	0.052	3.450	1.640	0.300
0.840	0.054	0.551	0.458	21320.000	7086.000	1.500	0.308	0.320	0.147	4.376	2.412	1.102

Lead (Pb)-Total*	Lithium (Li)-Total*	Lithium (Li)-Total*	Magnesium (Mg)-Total	Magnesium (Mg)-Total	Manganese (Mn)-Total	Manganese (Mn)-Total	Mercury (Hg)-Total*	Mercury (Hg)-Total	Molybdenum (Mo)-Total*	Molybdenum (Mo)-Total*	Nickel (Ni)-Total*	Nickel (Ni)-Total*
0.184	0.669	0.138	2321.956	888.289	823.549	291.789	0.023	0.011	0.439	0.146	0.660	0.168
0.020	0.500	0.100	321.000	106.000	38.100	14.200	0.005	0.002	0.050	0.010	0.500	0.100
0.092	0.500	0.100	1750.000	803.000	290.000	132.000	0.014	0.006	0.121	0.047	0.500	0.100
2.330	3.500	0.700	8250.000	1990.000	14800.000	3450.000	0.118	0.109	5.030	1.840	3.500	0.860
0.132	0.500	0.100	3040.000	1080.000	818.000	233.000	0.036	0.014	0.243	0.102	0.500	0.150
0.617	1.500	0.300	5852.000	1794.000	1806.000	879.000	0.057	0.024	2.849	0.669	1.400	0.362

Selenium (Se)-Total*	Selenium (Se)-Total*	Strontium (Sr)-Total	Strontium (Sr)-Total	Thallium (Tl)-Total*	Thallium (Tl)-Total*	Tin (Sn)-Total*	Tin (Sn)-Total*	Uranium (U)-Total*	Uranium (U)-Total*	Vanadium (V)-Total*	Vanadium (V)-Total*	Zinc (Zn)-Total
1.267	0.255	25.175	10.851	0.038	0.014	0.253	0.064	0.013	0.003	0.633	0.140	85.947
1.000	0.200	1.040	0.342	0.030	0.010	0.200	0.050	0.010	0.002	0.500	0.100	8.450
1.000	0.200	15.800	7.380	0.030	0.010	0.200	0.050	0.010	0.002	0.500	0.100	48.900
7.000	1.400	104.000	53.500	0.210	0.070	1.400	0.350	0.070	0.014	3.500	0.700	290.000
1.000	0.200	31.700	12.900	0.030	0.010	0.200	0.050	0.010	0.002	0.500	0.100	113.000
2.800	0.560	73.920	41.560	0.084	0.030	0.560	0.140	0.030	0.008	1.400	0.324	255.600

Zinc (Zn)-Total
40.161
2.790
22.000
154.000
52.400
126.800

Note: Moisture is measured as a percent of total weight. All total metals values are listed twice: first is mg/kg dry weight and second is mg/kg wet weight.

*Represents a total metals estimated average value negligibly higher than the actual average value. This is because at least one of the samples for a given metal analysis had a value below a detectable limit (i.e., <0.20). For calculation purposes, these ordinal level data were given the same value as what they were less than (i.e., <0.20 became 0.20). Therefore, the true average sample value is negligibly less than what is presented. This table is for summary reference only, please refer to the lab report for original values.

Source: URS, 2008d

7.9.12 Effects Assessment Methodology

The objective of this assessment is to predict project and cumulative effects of the Minago Project on vegetation; to identify mitigation measures to both minimize adverse effects and associated impacts to vegetation and wildlife habitat; and to support sound project design.

7.9.13 Project Related Effects

Development of the project will involve the following new clearing or other vegetation disturbance, summarized in Table 7.9-6.

Table 7.9-6 Summary of Vegetation Disturbance

Designated Area	Area (ha)
Industrial Complex (Buildings)	4.2
Transportation Corridors and Access roads	40.0
Waste rock dumps	
Dolomite Waste Rock Dump	191.0
Country Rock Waste Rock Dump	301.4
Overburden Disposal Facility (ODF)	300.0
Pit Area	190.0
Tailings and Ultramafic Waste Rock Management Facility (TWRMF)	219.7
Polishing Pond	75.0
300-Person Camp	2.4
TOTAL	**1323.7**

At Minago, the types of disturbed sites will include flat sites in or to close to the natural muskeg (poorly drained/saturated and organic); flat sites that are poorly drained/saturated but have a lower organic matter and plant nutrient content than the muskeg sites (laydown areas), and which also may be compacted; rocky, well-drained sites with little or no organic matter, little or no plant nutrients, and low water holding capacity such as the waste rock dumps; and side slopes of waste rock dumps and the TWRMF with little or no organic matter, little or no plant nutrients, and low water holding capacity.

The affected vegetation areas do not involve species at risk. Any useful timber will be harvested or will be salvaged during clearing, and will be made available to the nearby communities for use as firewood. The forested areas will also be prepared to facilitate natural revegetation at mine closure.

The only permanent vegetation losses will be the areas occupied by the waste rock and overburden dumps, TWRMF and the pit area. The company will exercise reasonable efforts to revegetate the industrial area, once all buildings have been decommissioned, the waste rock dumps, and all access roads not required during the post closure period. After mine operations cease, the pit area will be flooded, tailings contained in the TWRMF will be submerged under 0.5 m of water, and the Polishing Pond will be left as wetland.

7.9.13.1 Impacts on Wetlands

From May to October, the final effluent will first be discharged in a vast treed bog before being released to the receiving streams as detailed in Sections 2.14 (Site Water Management) and 7.4 (Surface Water Hydrology). These bogs still have the capacity to store additional water by creating ponds.

A marsh will certainly be created where the final effluent will be discharged. However, it would be quite surprising to see such a significant transformation over the entire bog's surface (creation of ponds and reduction of the tree cover) given that:

- no ponds at all have been observed within these bogs;
- they cover significant areas and are parts of a vast complex of wetlands that are hydrologically connected together and form one of the most important ecosystem in the region.

Still, if a significant transformation of the bog's surface were to occur, it is important to note that it is widely accepted that open bogs with ponds represent more attractive habitats for many wildlife species such as waterfowl and amphibians. Ducks Unlimited Canada, as well as Québec's ministère du Développement durable, de l'Environnement et des Parcs (Department of Sustainable Development, Environment and Parks), has recognized this general concept and use it to evaluate the ecological value of a bog. Poulin (2002) has also proposed a set of criteria to assess a bog's ecological value, including the area covered by ponds.

A diffuser will be installed to reduce erosion at the point where the final effluent will be released in the bog. A perforated pipe will be installed perpendicularly to where the final effluent will be released. Rocks (riprap) will also be installed at this same location.

7.9.14 Cumulative Effects

Currently, there are no other projects in the vicinity of the Minago Nickel Property.

7.9.15 Mitigation Measures

Erosion and sedimentation caused by work related activities will be minimized by managing off and onsite runoff. Erosion and sedimentation control will involve:

- minimizing the disturbance to vegetation and limiting the area of clearing;
- installation of sediment control measures (silt fences, sediment traps, etc.) before starting work;
- regular inspection and maintenance of sediment control measures;
- minimizing the length of time that unstable erodible soils are exposed;
- conveying sediment-laden or turbid runoff into settling ponds or vegetated areas; and
- stabilizing erodible soils as soon as practical by seeding, revegetation or installing erosion control blankets.

The primary mitigation measures regarding vegetation involve land reclamation and revegetation of the Minago property to provide short- and long-term erosion control, to ensure that land use is compatible with surrounding lands, and to leave the area as a self-supporting ecosystem. The overall goal will be to prepare the site so that the vegetation returns to a state as near as possible to that in existence prior to mining activities by modifying site features where necessary and by facilitating ‘natural’ reestablishment of indigeneous vegetation and productive habitat for wildlife.

VNI will develop a Reclamation Plan during the operational phase for the Minago Project site to specify appropriate reclamation techniques for the different types of conditions identified. Reclamation techniques will include site preparation (such as scarification), planting or seeding techniques and best periods for planting/seeding, specification of suitable planting stock or seed mix(es) for revegetation, and specifications for fertilization, if required. The Reclamation Plan will also detail stockpiling techniques for muskeg and surface soils that will be removed during the construction and operation of site facilities to ensure their viability as top soils.

The identification and amelioration of physical environmental impediments to restoration will be part of Minago’s reclamation plan. This includes ensuring low side slope angles for waste rock dumps (2.5H:1V); ripping/scarifying compacted surfaces prior to replanting/revegetating; recontouring and scarifying decommissioned roads and borrow pits, if necessary, to facilitate the reestablishment of native vegetation; and where possible, applying organic matter such as peat stockpiled in the initial construction phase to nutrient and organic matter deficient sites. Stockpiled top soil/peat will be spread, where available, to facilitate revegetation and to increase the organic matter content and water holding capacity of disturbed sites.

The revegetation program at Minago will include a research component to identify the most suitable local species and reclamation techniques for the range of disturbed sites that will need to be reclaimed and revegetated, including the reclamation of waste rock dumps. The research component will include field test plots established on representative disturbed site conditions to evaluate the vegetation's rate of establishment, growth, and nutrient and metal status as well as its suitability as wildlife habitat. Minago's Reclamation Plan will be based on the results of the research component and will incorporate a progressive reclamation strategy for disturbed areas that will no longer be used for site operations.

Whenever possible, local, native planting stock and seed mixes will be used at Minago to ensure a high success rate of the revegetation program and compatibility with surrounding lands. Freshly revegetated or reseeded sites will also be protected from further disturbance by humans by posting signs and/or restricting access where possible for example with soil or rock roadblocks. Restricted access will allow seedlings to become established.

7.9.15.1 Currently Established and Potential Revegation Species

To identify potential, local and native revegetation species, the currently established shrub and vascular herb strata were reviewed in light of succession studies. Succession studies reported in the literature have identified pioneer vegetation species and their seed dispersal capability, reproductive capabilities, and timeframes for establishment. The currently established shrubs and herbs in the dominant tree and shrub units are summarized in the next Section.

7.9.15.1.1 Currently Established Shrubs and Herbs in the Tree and Shrub Units

The currently established shrubs and herbs in the domitant tree and shrub units are summarized below based on the vegetation baseline studies conducted at Minago.

In the Intermediate Closed Evergreen Tree (IB1c) unit (Table 7.9-7), encountered on 34% of the Minago Project site, the shrub stratum was composed of diamond leaf willow (*Salix planifolia*), green alder (*Alnus crispa*), and small paper birch (*Betula papyrifera*) found primarily atop the hummocks. The herb stratum was fairly diverse, but was dominated by sedges (*Carex* sp.), bluejoint reedgrass (*Calamagrostis canadensis*), and arrow-leaved coltsfoot (*Petasites sagittatus*) (URS, 2008d).

In the Dwarf Open Evergreen Tree (IB2e) unit (Table 7.9-7), encountered on 25% of the site, the shrub stratum was dominated by shrub birch (*Betula glandulosa*), bog rosemary (*Andromeda polifolia*), and small bog cranberry (*Vaccinium oxycoccos*). The herb stratum was dominated by sedges (*Carex* sp.) and buckbean (*Menyanthes trifoliata*) (URS, 2008d).

In the Dwarf Closed Evergreen Tree (IB1e) unit (Table 7.9-7), encountered on 14% of the site and located on poorly-drained soils, the shrub stratum was dominated by shrub birch (*Betula glandulosa*), bog rosemary (*Andromeda polifolia*), and small bog cranberry (*Vaccinium oxycoccos*). Sedges (*Carex* sp.) made up most of the herb layer (URS, 2008d).

In the Intermediate Open Evergreen Tree (IB2c) unit (Table 7.9-7), encountered on 7% of the site, the shrub stratum was dominated by shrub birch (*Betula glandulosa*), Labrador tea (*Ledum groenlandicum*), and diamond leaf willow (*Salix planifolia*). The herb stratum was dominated by sedges (*Carex* sp.) and buckbean (*Menyanthes trifoliata*) (URS, 2008d).

In the Intermediate Open Deciduous Shrub (IIA2c) unit (Table 7.9-7), encountered on 8% of the site and located on poorly-drained soils, the dominant shrubs were shrub birch (*Betula glandulosa*) and tall blueberry willow (*Salix myrtillifolia* var. *cordata*). The herb stratum was dominated by swamp horsetail (*Equisetum fluviatile*) and bog sedge (*Carex magellanica*) (URS, 2008d).

In the Intermediate Sparse Deciduous Shrub (IIA3c) (Table 7.9-7), encountered on 6% of the site and located on very poorly-drained soils, the dominant plant in the shrub stratum was myrtle-leaved willow (*Salix myrtillfolia*). The herb stratum was dominated by beaked sedge (*Carex utriculata*) and water sedge (*Carex aquatilis*) (URS, 2008d).

7.9.15.1.2 Potential Revegetation Species

Based on the review of currently established shrub species in the previous Section, green alder (*Alnus crispa*), willows (*Salix* spp.), and potentially paper birch (*Betula papyrifera*) and/or shrub birch (*Betula glandulosa*) appear to be good candidates for successful revegetation at Minago (Table 7.9-7). All of these species have been successfully used or recommended at other sites for the purposes of reclamation and revegetation (Densmore et al., 2000; Smyth and Butler, 2004; Geographic Dynamics Corp., 2002; Strathcona County, 2008).

Out of these potential revegetation species, green alder and willows will be used for the reclamation program at Minago. Green alder and willows are described in more detail in the next sections due to their extensive and successful use.

It is planned to plant green alder seedlings throughout the Minago site to result in an approximate density of 0.5 alder per m^2 and willows in islands amongst the alders to facilitate their establishment and seed dispersal as soon as possible (progressive revegetation). It is anticipated that there will be approximately one willow island per hectare consisting of 50 stems. A custom seed mix will also be developed or obtained for Minago to seed small areas prone to erosion or areas for which revegetation with shrubs is not suitable (e.g. shoulders of access roads that will remain trafficable).

*Alnus crispa (*Green Alder*)*

Alnus crispa (= *Alnus viridis* ssp. *crispa*), a common alder species at Minago, is useful for revegetation projects. Vigorous growth on harsh sites, their ability to fix nitrogen, easy seed collection, and simple propagation make alder the species of choice for many revegetation projects (Densmore et al., 2000).

Table 7.9-7 Potential Revegetation Species based on Currently Established Vegetation

VEGETATION CLASSIFICATION	CURRENT SITE COVERAGE AT MINAGO	CURRENTLY DOMINANT SHRUBS	CURRENTLY DOMINANT HERBS
Intermediate Closed Evergreen Tree (IB1c)	34%	green alder (*Alnus crispa*), paper birch (*Betula papyrifera*)	bluejoint reedgrass (*Calamagrostis canadensis*)
Dwarf Open Evergreen Tree (IB2e)	25%	shrub birch (*Betula glandulosa*)	sedges (*Carex* sp.)
Dwarf Closed Evergreen Tree (IB1e)	14%	shrub birch (*Betula glandulosa*)	sedges (*Carex* sp.)
Intermediate Open Deciduous Shrub (IIA2c)	8%	shrub birch (*Betula glandulosa*)	swamp horsetail (*Equisetum fluviatile*)
Intermediate Open Evergreen Tree (IB2c)	7%	shrub birch (*Betula glandulosa*)	sedges (*Carex* sp.)
Intermediate Closed Evergreen Tree (IB1c)	34%	diamond leaf willow (*Salix planifolia*)	sedges (*Carex* sp.)
Intermediate Open Evergreen Tree (IB2c)	7%	diamond leaf willow (*Salix planifolia*)	sedges (*Carex* sp.)
Intermediate Open Deciduous Shrub (IIA2c)	8%	tall blueberry willow (*Salix myrtillifolia* var. *cordata*)	bog sedge (*Carex magellanica*)
Intermediate Sparse Deciduous Shrub (IIA3c)	6%	myrtle-leaved willow (*Salix myrtillfolia)*	beaked sedge (Carex utriculata) and water sedge (Carex aquatilis)

Planting container grown seedlings is typically the most efficient, because on disturbed sites with very poor soils, alders tend to have trouble getting started from seed, but will grow well once they are established (Densmore et al., 2000).

To obtain green alder planting stock for Minago, potential nurseries in Manitoba, Saskatechwan, and Alberta will be contacted. VNI will collect green alder cones, if no suitable planting stock is available for the Minago site from potential suppliers. The collected cones will be kept dry and warm to ensure complete drying of the seeds. Seeds will then be collected from the dried cones, kept in sealed plastic bags and stored in a freezer until use. Alders form root nodules that contain the mircoorganism *Frankia* sp., which fix nitrogen, and convert it to a form of nitrogen usable by plants.

If treated and planted appropriately, survival rates of alders are usually very high (> 95%) after 5 years for container grown alder seedlings, with a growth of 1 m in 3 years (Densmore et al., 2000).

Salix spp. (Willows)

Willows typically produce numerous seeds, which are dispersed over kilometres by wind, and they will establish naturally from seed on all disturbed sites suitable for willow growth (Densmore et al., 2000).

Willows (*Salix* spp.), when grown alongside alders, will use some of the nitrogen fixed by the alders, which promotes good growth of willows on soils where soil nitrogen is low.

To speed up the restoration process at Minago, willows will be planted alongside green alders in clumps (vegetation islands) on the disturbed sites. To protect the genetic integrity of the Minago Project site, willow cuttings will be collected from the site and its vicinity.

Most willows are adapted to root rapidly after stems are buried by flooding and have dormant root buds all along the stems. These buds, called preformed root initials, are formed in each year’s new shoot growth and are covered by wood in subsequent years. As not all willows root readily from root initials, only willows will be selected for the reclamation at Minago that will grow readily from root initials and are acclimatized to the site conditions. Cuttings will be 1.0-2.5 cm in diameter at the base and 25-45 cm in length. Each cutting will at least have one leaf node or bud. The node is the place where shoots originate, and without a node, the cutting will not grow.

The revegetation program at Minago will mainly rely on dormant willow cuttings. Dormant willow cuttings are typically preferred for revegetation because they have higher carbohydrate reserves and can be stored frozen for long periods of time. Cuttings can be stored in a freezer or under snow and sawdust (Densmore et al., 2000). Once the air temperature rises above freezing in the spring, the cuttings will be planted as soon as possible. If not planted, the quality of the cuttings will deteriorate as melting snow will thaw the cuttings after which the cuttings will start using the stored carbohydrates, which they will also need for establishing themselves on a disturbed site.

It is anticipated that willow cuttings will be planted in shallow holes at an approximate angle of 45°. The planting holes will be deep enough to bury the cuttings and allow 5-8 cm of the cuttings to protrude above the soil surface. Willow cuttings will be fertilized with a slow release fertilizer or fertilizer tablets designed for trees and shrubs. The fertilizer will be placed at the bottom of the hole, but will not touch the cutting. Each planted cutting will be watered, if possible.

Typically, willow cuttings root in 1-3 weeks. Growth rates of 0.5 m per year are considered good. Moose and snowshoe hares often browse planted willows (Densmore et al., 2000).

Custom Seed Mix

A custom seed mix will be developed or obtained for the Minago site to seed small areas prone to erosion or areas for which revegetation with shrubs is not suitable (e.g. shoulders of access roads that will remain trafficable). An effort will be made to source local and native seed mixes. Due to the remoteness of the site, suitable seed mixes for the climatic and soil conditions at the Minago site may not be commercially available. In case that suitable seed mixes cannot be easily sourced by VNI, the company may to resort to an 'autumn seed blitz technique' (Densmore et al., 2000) to collect local native seeds for cultivation and propagation.

The autumn blitz technique involves harvesting a variety of seeds near the disturbed area and may also involve sowing them immediately on the disturbed areas. In the autumn seed blitz technique, seeds are collected from a variety of plants that are ripe. Seeds must be dry on the plant. Whole seed heads may be collected for later separation of individual seeds from the seed heads.

By swamping a disturbed site with seeds from a variety of native species, prevailing site conditions will determine which species will survive. This technique usually provides good cover and high species diversity, especially if sown seeds are raked into the soil and fertilized to enhance seed germination (Densmore et al., 2000).

7.9.16 Monitoring and Follow-up

The revegetated areas will be subject to scheduled periodic inspections for the first five years in order to track the revegetation success and to make adjustments to the program as required. Success of the revegetation program will be determined by measuring a number of aspects including growth, survival, density and diversity of perennial species, metal uptake in vegetation, and the inspection of native plant invasion. Monitoring locations will include randomly located plots within areas representative of the reclaimed lands. A number of transects will also be established permanently across selected disturbed sites to assess native species ingress. The monitoring will be continued until the ecosystem has been self-regulating for some period of time.

Monitoring reports will be submitted to the regulatory agencies and communities of interest as required to obtain feedback on the success of the reclamation program.

7.9.17 Summary of Effects

Since plant communities and species in the Project Area are quite abundant and common both at the regional and local levels, they are not of conservation concern. Moreover, no special status plant species were observed in the vicinity of the Project Area. Therefore, the effects of site clearing are considered to be adverse, low magnitude, site-specific and long-term. The likelihood of that effect to occur as predicted is high given the baseline data that has been gathered as part of this project. These effects are considereed to be reversible since a Reclamation Plan will be implemented and disturbed surfaces will be revegetated with indigenous species (green alder and willows). The only permanent losses will be the areas occupied by the TWRMF as well as the pit area, totaling about 410 ha and representing about 30% of all cleared surfaces. These will be left as flooded areas or lakes. The Polishing Pond will be left as wetland.

The impact of seasonally discharging the final effluent in a bog before it reaches the Oakley Creek or the Minago River are considered to be neutral, low magnitude, site-specific and long-term. Indeed, even if the bog's water inflow is increased and thus it was to modify the surface vegetation, such effects are considered to be positive for wildlife since ponds are considered as high quality habitat.

7.10 Wildlife

This subsection summarizes the 2007 and 2008 wildlife survey programs completed at and surrounding the Minago Property. URS Canada Inc. (URS, 2008e) conducted a spring survey in 2007 and a winter survey in 2008 and Roche Consulting Group (Roche, 2008a) conducted a wildlife opportunistic observation program from May 6-9, 2008.

These wildlife surveys, excluding assessments of fish habitat and related results are presented and discussed in this Section. Fish habitat and abundance in watercourses surrounding the Minago Property are presented and discussed separately in Section 7.8.

The spring 2007 wildlife survey consisted of a qualitative presence/absence terrestrial survey at the Minago Project site and surrounding areas and opportunistic observations made throughout an eight-day fisheries and wildlife field survey. The 2008 winter wildlife survey consisted of an aerial survey of a 16 by 18 km^2 area surrounding the Minago Project site, terrestrial transects, and helicopter transects along winter roads. The main objective of August 2008 wildlife assessment program was to document the presence of large and small mammal species as well as of bird species.

A photographic record of the 2007 and 2008 wildlife surveys (URS, 2008e) is presented in Appendix 7.10.

7.10.1 Preliminary Data Collection

To assist in the identification of wildlife habitat, distribution, and seasonal presence/absence, and the potential presence of special status wildlife species, existing documents and data were reviewed for background information on the project area prior to the spring 2007 and winter 2008 wildlife field investigations. Documentation of wildlife in the project vicinity is limited due to its distance from population centres and limited use by hunters or trappers. Data reviewed included the following:

➢ **Map and Aerial Photo Documentation:**

- 1:50,000 Topographic Maps (Limestone Bay, Gladish Lake, Hill Lake, William Lake, and Hargrave River) (Manitoba Conservation, 2007a);
- Topoweb Canada: Manitoba (Softmap, 2007);
- Minago Region Orthorectified Aerial Photograph (ER, 2007);
- Google Earth Pro Satellite Photograph (Google Earth Pro, 2008);
- Forest Resources Management-Forest Inventory Maps (Manitoba Conservation, 2000a);
- Land Use/Land Cover Maps (Manitoba Conservation, 1989); and
- Ecological Areas (Government of Canada, 1996).

- **Documented Habitat Utilization:**
  - Plants of the Western Boreal Forest and Aspen Parkland (Johnson Et Al., 1995);
  - The Atlas of Canada (Natural Resources Of Canada, 2007);
  - Functional Profile of Black Spruce Wetlands in Alaska (Post, 1996);
  - Ecology of Eastern Forests (Kricher and Morrison, 1988); and
  - Eastern Trees (Petrides, 1988).

- **Special Status Wildlife Species:**
  - MBCDC Species of Conservation Concern (Manitoba Conservation, 2007b);
  - Phone Conversation with Cam Elliot (Elliot, 2008);
  - Environmental Assessment Best Practice Guide for Wildlife at Risk in Canada (Canadian Wildlife Service, 2004);
  - Species at Risk in Manitoba (Environment Canada, 2007b); and
  - Species listed under the Manitoba *Endangered Species Act* (Manitoba Conservation, 2007).

- **Documented Wildlife Distribution and Field Guides:**
  - Mammals of North America (Reid, 2006);
  - Mammal Tracks and Signs (Elbroch, 2003);
  - The Sibley Guide to Birds (Sibley, 2000);
  - The Sibley Guide to Bird Life and Behavior (Sibley, 2001);
  - Warblers (Dunn And Garett, 1997);
  - Birds of North America (Kaufman, 2000);
  - Birds of North America, Eastern Region (Alsop, 2001);
  - Guide to Birds of North America (Thayer, 2006);
  - Bird Tracks and Sign (Elbroch And Marks, 2001); and
  - The Amphibians and Reptiles of Manitoba (Preston, 1982).

7.10.2 2007 Spring Wildlife Survey – Data Collection

The wildlife habitat and opportunistic wildlife species survey was conducted by URS over a six-day period between May 31 and June 5, 2007 in conjunction with a survey of fisheries resources. This initial survey was followed by a two-day qualitative presence/absence terrestrial species survey. The 2007 spring wildlife field study was led by Bill Kidder (Wetland and Wildlife Scientist, URS) and assisted by Dr. Rob Nielsen (Fish and Wildlife Scientist, URS) and Ken Budd (Field Assistant, Norway House Cree First Nations).

Most of the wildlife habitat and opportunistic wildlife species survey occurred in the immediate vicinity of the Minago Property, including the riparian habitat of Oakley Creek. However, habitat and wildlife observations were also made during fisheries surveys of the Minago and William Rivers.

Existing habitat and fish distribution reports, aerial photographs, and topographic maps were used to create maps, which helped determine where field surveys should occur. Topographic maps of the area were downloaded from Topoweb Canada: Manitoba (Softmap 2007), converted to a PathAway 4.0 (Muskoka Tech 2007) file format and loaded onto a Palm Treo 680 PDA. The PathAway mapping application on the Treo 680 was used in conjunction with an EMTAC mini Bluetooth GPS unit to locate positions in the field and record their coordinates.

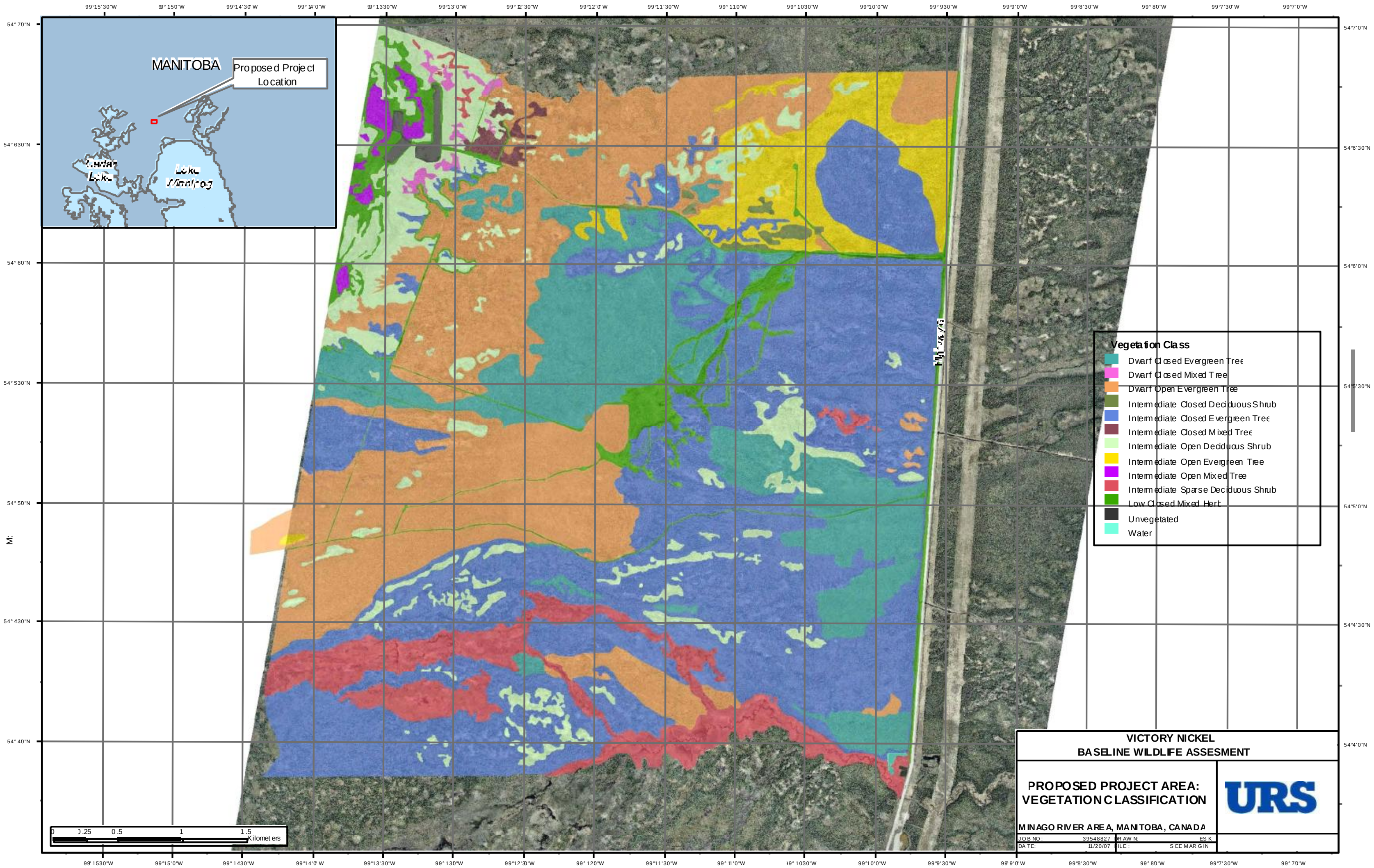
The wildlife survey began with a preliminary general helicopter over-flight of the Minago Project area and the Minago and William River watersheds in the vicinity of the project site. Oakley Creek was over-flown to its confluence with William River and Minago River was over-flown for approximately 10 kilometres east and west of Highway 6. During the aerial survey, notes were taken on aerial photographs of the project area and the coordinates of specific types of habitat and sightings of wildlife were marked as points with the PDA/GPS combination.

Wildlife Habitat Assessment

The field crew attempted to reach each habitat type observed during the preliminary aerial survey and make general observations of the plant communities for later incorporation into vegetation mapping.

Vegetation in the wildlife habitat surrounding the Minago Project site is shown in Figure 7.10-1. It should be noted that the vegetation mapping in Figure 7.10-1 displays two types of unvegetated areas. The labelled unvegetated area in the northwest corner of the figure represents landing strips of exposed limestone and mineral soil. A light olive-green was used to mark the more heavily used winter roads in the project area, the Highway 6 roadside ditch and a sinuous road/firebreak south of the landing strips. Most of the winter roads were vegetated with herbaceous vegetation or emergent marsh vegetation. The roadside ditch was vegetated primarily with shrubs, grasses, and herbaceous vegetation, and the areas surrounding the project access road and roads to drill sites on the property were primarily composed of unvegetated peat muck formed by tracked vehicles driving over the roads in the spring.

The intermediate open deciduous shrub vegetation shown in Figure 7.10-1 actually represents two types of wildlife habitat. Most of the intermediate open deciduous shrub habitat in the northwest corner of the Figure, west of the firebreak/road and in the vicinity of the landing strips is early seral bogs or fens. The many patches of intermediate open deciduous shrub habitat distributed over



Source: URS (2008e)

Figure 7.10-1 Vegetation Classification in the Vicinity of the Minago Project

the remainder of the project area are located in areas of muskeg, bogs, or fens. Often the centre of these patches is an open bog containing large areas of standing water during the spring. Many of these contain clumps of dead spruce trees that provide snag habitat. Also, many of these areas are surrounded by rings of taller black spruce and tamarack, with the tamarack (*Larix laricina*) closest to the open area. There were also a number of thaw lakes (small cave-in ponds) located in dwarf open evergreen tree habitat just north of the winter road running west from the end of the west-east access road to the landing strips. These shallow ponds were surrounded by taller black spruce and tamarack, similar to those surrounding the bog habitats. They also had a yellowish layer of precipitates suspended over their substrates.

A final habitat feature (not shown in Figure 7.10-1) is a series of narrow east-west ridges located south of the access road, west of Highway 6, east of UTM Easting 0488325, and north of UTM Northing 5993597. These ridges were elevated a few metres above the surrounding terrain and are slightly drier. They contained the tallest conifers present at the Minago Property. Generally, the north sides of the ridges were dominated by tamarack and the south sides dominated by black spruce. The color differences between the two tree species and greater heights of the trees give the ridges a three dimensional effect in aerial photographs that does not accurately reflect the slight elevation difference.

<u>2007 Wildlife Survey</u>

The spring 2007 wildlife survey focused on migratory birds, amphibians, and other species best observed in late spring and early summer. The field crew recorded incidental observations of wildlife during terrestrial surveys, during a canoe survey of Oakley Creek and its riparian habitat south of the project area, fish collection stations on the William and Minago Rivers in the vicinity of Highway 6 and William River above and below its confluence with Oakley Creek.

Wildlife surveys were restricted by access problems throughout the project area and vicinity due to swampy conditions. Hence, surveys in terrestrial habitat within the project area were primarily confined to the project area access roads traversable by ARGO, the areas immediately accessible by foot near Highway 6, winter roads that were not churned up by tracked vehicles, and short traverses on foot from locations along the access roads where it was possible to travel on foot.

Survey crews were able to travel by ARGO and truck along several fire roads and transmission line corridors in the vicinity of the Minago River for short distances and along a road paralleling the William River upstream of Highway 6 to its confluence with the outlet stream of Little Limestone Lake. An attempt was made to access the lower William River by an ARGO east along a transmission line access road, but it was only possible to travel a few kilometres before reaching impassable areas of bog and fen habitat. Crews found the presence of northern pitcher plants (*Sarracenia purpurea*) a reliable indicator of wetlands as such the ARGO could not successfully cross. The pitcher plant is a carnivorous plant that prefers highly acidic and poorly drained bogs, a sure indication of the deep peat deposits.

The qualitative presence/absence terrestrial species survey was conducted by the URS field crew on June 6 and 7, 2007. On the first day, morning and mid-day surveys were conducted, and on the second day a survey was conducted from mid-day to late evening. The survey was conducted by driving project area accessible by ARGO and stopping at random sampling points to make observations in as many habitat types as possible. The locations of visual or auditory observations of wildlife and tracks while driving were recorded. Thirty (30) minutes were spent listening to bird, amphibian, and other wildlife calls and using binoculars to scan vegetation in the vicinity for birds and other wildlife. This was followed by short transects on foot away from the ARGO to look for tracks, nests, scats, and other signs while stopping frequently to listen and scan the area with binoculars to observe any wildlife present. Transects on foot varied between 100 and approximately 400 metres away from the ARGO. In most cases, a slightly different route was used to walk back to the access road and the ARGO to maximize the area observed. In every case, the two URS wildlife biologists and field assistants walked separate transects to maximize opportunistic sightings. All observations were noted and locations placed on either an aerial photograph or their coordinates were recorded on a PDA.

7.10.3 2008 Winter Wildlife Survey

Collection of wildlife field data for the winter survey took place between January 15 and 18, 2008. The winter wildlife field study was led by Dr. Rob Nielsen (Fish and Wildlife Scientist, URS) and assisted by Jonathan Anderson (Field Assistant, Victory Nickel).

The winter wildlife survey consisted of an aerial transect wildlife survey and a terrestrial transect wildlife survey. The aerial survey included the Minago Project area and extended out to encompass an 18 km by 16 km (288 square kilometres) block of land on both sides of Highway 6 that surrounded the project area. The terrestrial transect survey consisted of transects of winter roads by truck as far as the roads were drivable. Roads were generally drivable by truck to active drill sites. Beyond areas of activity, several feet of wind blown snow covered the winter roads. These sections of winter roads were traversed by ski and snowshoe. A few transects of wider winter roads were completed from a helicopter by flying low enough to observe tracks.

<u>2008 Aerial Wildlife Survey</u>

On January 15 and 18, 2008 a Robinson 44 helicopter was used to conduct an aerial survey of the Minago Project area. Surveys began each day at approximately 10 AM (CST). Observations of animals on the left side and front were made by the pilot and Jonathan Anderson, while observations of animals on the right side and front were made by Rob Nielsen. Dr. Nielsen recorded all sightings and marked their locations with the PDA/GPS. Aerial surveys were modeled after literature winter survey aerial transect methodologies for moose and caribou in semi-open canopy (Gasaway et al., 1986, Parker 1973, Thompson and Fisher, 1979). Both surveys were conducted on clear days with good visibility, with snowfall the previous evening covering tracks and signs from the day before.

The helicopter was flown at a speed and height above the ground that allowed opportunity to observe all eastern moose (*Alces alces americana*) and woodland caribou present within approximately 0.5 km to each side. Survey time was approximately 1.7 minutes per km^2. North-south transects began at the north end of the survey area and proceeded south in a grid pattern with a spacing of 0.8 km between transects. Transects were flown at approximately 100 km per hour and 100 metres above ground level. Flight speed was increased or decreased depending upon how open the canopy was and flight speed was greatly reduced over the few regions where the canopy became close enough to interfere with observations. Observations of wildlife from the winter aerial surveys are presented in Figure 7.10-2.

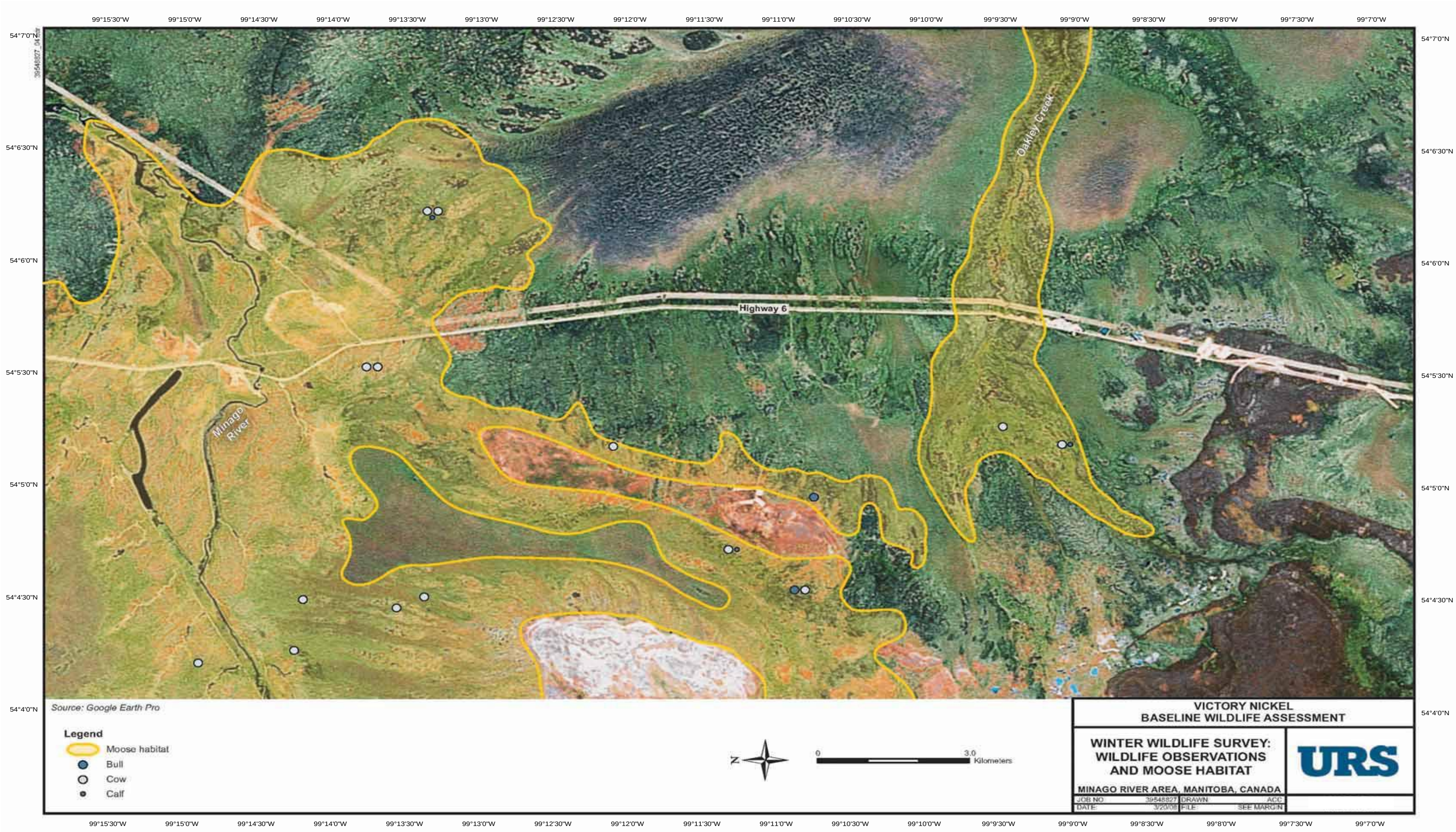
2008 Terrestrial Transect Wildlife Survey

Terrestrial transects of the Minago Project area were conducted from January 15 to 17, 2008. Initial transects on January 15 were made by slowly driving a truck on the project area access road and winter roads in active use by drillers in the evening after completing the initial helicopter aerial survey. The snow on these roads was tightly packed to avoid any danger of becoming stuck in freezing weather by deep snowdrifts that crossed un-traveled winter roads. The initial road transects were made to determine what areas could be reached to begin transects by cross country ski and snowshoe. The sides of the roads were closely observed while driving to determine the habitats and areas of the project area most heavily used by wildlife. Since the winter roads had to be travelled on January 16 and 17, 2008 to reach starting points for ski/snowshoe transects, the truck transects were repeated on these days.

Transects surveyed by means of ski/snowshoe (ski/snowshoe transects) were selected to travel quietly through as many different habitat types as possible and to access regions of the project area away from drilling activity. During these transects, tracks, beds, and scat were identified, photographed next to an object for size reference, and recorded. Any visual or auditory observations of wildlife were also recorded. Several areas originally intended for traverses could not be skied during the time available, so these areas were over-flown by helicopter on January 18, 2008. It was possible to fly relatively close to the ground because the traverses were on wide winter roads. All transects are presented with letter designations in Figure 7.10-3 by type (truck, ski, helicopter). The distances of the traverses in km were:

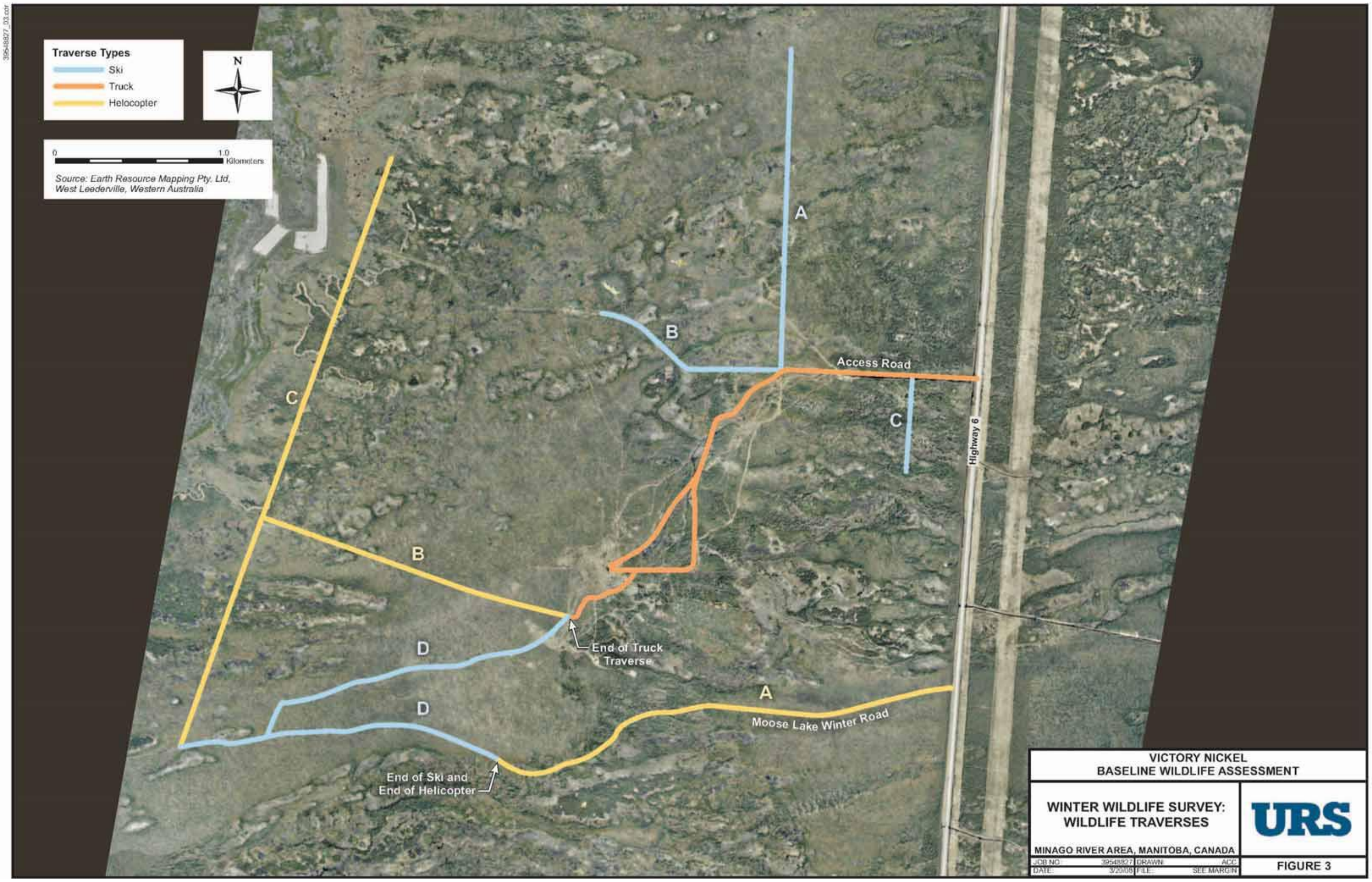
Truck:

• Access Road	1.2 km
• Roads to Drill Sites	4.0 km
• Total Distance	5.2 km



Source: URS (2008e)

Figure 7.10-2 2008 Winter Wildlife Survey Observations



SOURCE: URS (2008E)

FIGURE 7.10-3 WILDLIFE TRAVERSES IN 2007 WINTER WILDLIFE SURVEY

Ski:

- Ski Traverse A 2.0 km
- Ski Traverse B 2.0 km
- Ski Traverse C 0.7 km
- Ski Traverse D 5.1 km
- Total Distance 9.8 km

Helicopter:

- Helicopter Traverse A 3.5 km
- Helicopter Traverse B 2.0 km
- Helicopter Traverse C 4.0 km
- Total Distance 9.5 km

7.10.4 May 2008 Wildlife Survey

The May 2008 wildlife survey by Roche was purely opportunistic. No specific survey was carried out to document the presence of wildlife.

7.10.5 Wildlife Survey Results

7.10.5.1 Birds

A list of birds with a potential to occur in the vicinity of the Minago Project area is presented in Table 7.10-1 along with residence timing (Winter (W), Summer (S), or Resident (R) throughout the year). Species that were observed by URS (2008e) and Roche (2008a) to occur in the project area are noted in this table. Few birds were observed during the winter wildlife survey. The most commonly observed species during the winter survey was sharp-tailed grouse (*Tympanuchus phasianellus*), with some observations of ravens (*Corvus corax*) along Highway 6 and gray jays (*Perisoreus canadensis*) in intermediate closed canopy black spruce forest at the project site survey area. During helicopter over-flights of the project area, flocks of sharp-tailed grouse frequently took off when disturbed by the helicopter. These flocks of grouse were almost always sighted in areas of dwarf open evergreen habitat (tamarack and black spruce) with widely spaced trees and abundant low growing deciduous shrubs. Although sharp-tailed grouse were not observed during truck and ski traverses (Figure 7.10-3), their distinctive tracks were observed throughout Ski Traverse D, which crossed similar habitat, but with more closely spaced trees, and along portions of Ski Traverses A and B, which crossed patches of intermediate closed deciduous shrub habitat. These are also the habitats that sharp-tailed grouse were found to be abundant in during spring surveys.

Other than sharp-tailed grouse, most birds observed within the Minago Project area during 2007 spring surveys were shorebirds (Table 7.10-1) foraging in the deeply churned trails of muck in-

Table 7.10-1 Birds Occurring in the Vicinity of the Minago Project Area

Scientific Name	Common Name	Occurrence (R/S/W)	Observed by	
			URS (2008e)	Roche (2008a)
Gaviidae: Loons				
Gavia immer	Common Loon	S		X
Podicipedidae: Grebes				
Podiceps auritus	Horned Grebe	S		
Podilymbus podiceps	Pied-billed Grebe	S		
Ardeidae: Herons				
Ardea herodias	Great Blue Heron	S		
Botaurus lentiginosus	American Bittern	S		X
Anatidae: Waterfowl				
Aix sponsa	Wood Duck	S		
Anas acuta	Northern Pintail	S		X
Anas americana	American Wigeon	R		
Anas clypeata	Northern Shoveler	S		
Anas crecca	Green-winged Teal	S		
Anas discors	Blue-winged Teal	S		
Anas platyrhynchos	Mallard	S		X
Anas strepera	Gadwall	S		
Aythya affinis	Lesser Scaup	S		X
Aythya collaris	Ring-necked Duck	S		X
Aythya valisineria	Canvasback	S		X
Branta canadensis	Canada Goose	S		X
Bucephala albeola	Bufflehead	S		
Bucephala clangula	Common Goldeneye	S		X
Cygnus columbianus	Tundra Swan	S		X
Lophodytes cucullatus	Hooded Merganser	S		
Mergus merganser	Common Merganser	S		X
Mergus serrator	Red-breasted Mergans	S		X
Oxyura jamaicensis	Ruddy Duck	S		
Accipitridae: Hawks and Eagles				
Accipiter gentilis	Northern Goshawk	R		
Accipiter striatus	Sharp-shinned Hawk	S		
Buteo jamaicensis	Red-tailed Hawk	S		X
Buteo platypterus	Broad-winged Hawk	S		
Circus cyaneus	Northern Harrier	S	X	
Haliaeetus leucocephalus	Bald Eagle	S		X
Pandion haliaetus	Osprey	S		X
Falconidae: Falcons				
Falco columbarius	Merlin	S		
Falco rusticolus	Gyrfalcon	W		
Falco sparverius	American Kestrel	S	X	
Phasianidae: Grouse				
Bonasa umbellus	Ruffed Grouse	R		X
Falcipennis canadensis	Spruce Grouse	R		X
Tympanuchus phasianellus	Sharp-tailed Grouse	R	X	
Rallidae: Rails				
Fulica americana	American Coot	S		
Porzana carolina	Sora	S		
Gruidae: Cranes				
Grus canadensis	Sandhill Crane	S	X	
Scolpacidae: Shorebirds				
Actitis macularius	Spotted Sandpiper	S		X
Bartramia longicauda	Upland Sandpiper	S		
Gallinago gallinago	Common Snipe	S	X	

Table 7.10-1 (Cont.'d) Birds Occurring in the Vicinity of the Minago Project Area

Scientific Name	Common Name	Occurrence (R/S/W)	Observed by URS (2008e)	Observed by Roche (2008a)
Limosa fedoa	Marble Godwit			
Numenius americanus	Long-billed Curlew	S		
Tringa flavipes	Lesser Yellowlegs	S	X	
Tringa melanoleuca	Greater Yellowlegs	S	X	
Tringa solitaria	Solitary Sandpiper	S	X	
Charadriidae: Plovers				
Charadrius vociferus	Killdeer	S	X	
Laridae: Gulls				
Larus delawarensis	Ring-billed Gull	S	X	
Larus philadelphia	Bonaparte's Gull	S	X	
Larus pipixcan	Franklin's Gull	S		
Strigidae: Owls				
Aegolius acadicus	Northern Saw-whet Owl	R	X	
Asio flammeus	Short-eared Owl	S		
Asio otus	Long-eared Owl	R		
Bubo scandiacus	Snowy Owl	W		
Bubo virginianus	Great Horned Owl	R		
Strix varia	Barred Owl	R		
Strix nebulosa	Great Gray Owl	R		
Surnia ulula	Northern Hawk Owl	R	X	
Caprimulgidae: Swifts and Nighthawks				
Chordeiles minor	Common Nighthawk	S		
Alcedinidae: Kingfishers				
Ceryle alcyon	Belted Kingfisher	S	X	
Picidae: Woodpeckers				
Colaptes auratus	Northern Flicker	S	X	
Dryocopus pileatus	Pileated Woodpecker	R		X
Picoides arcticus	Black-backed Woodpecker	R		
Picoides dorsalis	American Three-toed Woodpecker	R		
Picoides pubescens	Downy Woodpecker	R		
Picoides villosus	Hairy Woodpecker	R		
Sphyrapicus varius	Yellow-bellied Sapsucker	S		
Tyrannidae: Flycatchers				
Contopus cooperi	Olive-sided Flycatcher	S		
Empidonax alnorum	Alder Flycatcher	S		
Empidonax flaviventris	Yellow-bellied Flycatcher	S		
Empidonax minimus	Least Flycatcher	S	X	
Sayornis phoebe	Eastern Phoebe	S	X	
Tyrannus tyrannus	Eastern Kingbird	S		
Vireonidae: Vireos				
Vireo gilvus	Warbling Vireo	S		
Vireo olivaceus	Red-eyed Vireo	S	X	
Vireo philadelphicus	Philadelphia Vireo	S		
Vireo solitarius	Blue-headed Vireo	S		
Corvidae: Jays				
Corvus brachyrhynchos	American Crow	S		X
Corvus corax	Common Raven	R	X	
Cyanocitta cristata	Blue Jay	R		
Perisoreus canadensis	Gray Jay	R	X	
Pica hudsonia	Black-billed Magpie	R		X

Table 7.10-1 (Cont.'d) Birds Occurring in the Vicinity of the Minago Project Area

Scientific Name	Common Name	Occurrence (R/S/W)	Observed by URS (2008e)	Observed by Roche (2008a)
Hirundinidae: Swallows				
Hirundo rustica	Barn Swallow	S		X
Petrochelidon pyrrhonota	Cliff Swallow	S		X
Tachycineta bicolor	Tree Swallow	S		
Paridae: Chickadees				
Poecile atricapillus	Black-capped Chickadee	R	X	
Poecile hudsonica	Boreal Chickadee	R		
Sittidae: Nuthatches				
Sitta canadensis	Red-breasted Nuthatch	R		
Certhiidae: Creepers				
Certhia americana	Brown Creeper	S		
Troglodytidae: Wrens				
Cistothorus platensis	Sedge Wren	S		
Troglodytes troglodytes	Winter Wren	S		
Regulidae: Kinglets				
Regulus calendula	Ruby-crowned Kinglet	S		
Turdidae: Thrushes				
Catharus guttatus	Hermit Thrush	S		
Catharus ustulatus	Swainson's Thrush	S		
Sialia sialis	Eastern Bluebird	S		
Turdus migratorius	American Robin	S		X
Motacillidae: Pipits				
Anthus spragueii	Sprague's Pipit	S		
Bombycillidae: Waxwings				
Bombycilla cedrorum	Cedar Waxwing	S		
Bombycilla garrulus	Bohemian Waxwing			
Parulidae: Wood-Warblers				
Dendroica castanea	Bay-breasted Warbler	S		
Dendroica coronata	Yellow-rumped Warbler	S		
Dendroica magnolia	Magnolia Warbler	S		
Dendroica palmarum	Palm Warbler	S		
Dendroica petechia	Yellow Warbler	S		
Dendroica tigrina	Cape May Warbler	S		
Dendroica virens	Black-throated Green Warbler	S		
Geothlypis trichas	Common Yellowthroat	S		
Mniotilta varia	Black-and-white Warbler	S		
Oporornis agilis	Connecticut Warbler	S		
Oporornis philadelphia	Mourning Warbler	S		
Seiurus aurocapilla	Ovenbird	S		
Seiurus noveboracensi	Northern Waterthrush	S		
Setophaga ruticilla	American Redstart	S		
Vermivora celata	Orange-crowned Warbler	S		
Vermivora peregrina	Tennessee Warbler	S		
Wilsonia canadensis	Canada Warbler	S		
Cardinalidae: Cardinals and Grosbeaks				
Pheucticus ludovicianus	Rose-breasted Grosbeak	R		
Emberizidae: Sparrows				
Ammodramus leconteii	Le Conte's Sparrow	S		
Ammodramus nelsoni	Nelson's Sharp-tailed Sparrow	S	X	
Calcarius ornatus	Chestnut-collared Longspur	S		
Junco hyemalis	Dark-eyed Junco	S		

Table 7.10-1 (Cont.'d) Birds Occurring in the Vicinity of the Minago Project

Scientific Name	Common Name	Occurrence (R/S/W)	Observed by URS (2008e)	Observed by Roche (2008a)
Melospiza georgiana	Swamp Sparrow	S		
Melospiza lincolnii	Lincoln's Sparrow	S		
Melospiza melodia	Song Sparrow	S		
Passerculus sandwichensis	Savannah Sparrow	S		
Plectrophenax nivalis	Snow Bunting	W		X
Pooecetes gramineus	Vesper Sparrow	S		
Spizella pallida	Clay-colored Sparrow	S		
Spizella passerina	Chipping Sparrow	S		
Zonotrichia albicollis	White-throated Sparrow	S		
Icteridae: Icterids				
Agelaius phoeniceus	Red-winged Blackbird	S	X	
Euphagus carolinus	Rusty Blackbird	S		
Quiscalus quiscula	Common Grackle	S		
Fringillidae: Finches				
Carduelis pinus	Pine Siskin	S		
Carduelis tristis	American Goldfinch	S		
Carpodacus purpureus	Purple Finch	S		
Coccothraustes vespertinus	Evening Grosbeak	R		
Loxia curvirostra	Red Crossbill	R		
Loxia leucoptera	White-winged Crossbill	R		

Source: URS (2008e)

Notes: Ocurrence data from Sibley (2000 & 2001), Thayer (2001), Ebroch and Marks (2001)
Timing: S = Summer Resident
W = Winter Resident
R = Resident throughout the year
Observed: Birds and tracks observed or birds heard calling within the Minago Project Area.

and-along the many access roads to drilling sites. Much of this area actually traversed through intermediate and dwarf closed evergreen forest habitat dominated by black spruce and tamarack, but the wide swaths of muck left by tracked vehicles provided a feast for shorebirds. Killdeer (*Charadrius vociferus*), common snipe (*Gallinago gallinago*), solitary sandpiper (*Tringa solitaria*), lesser yellowlegs (*Tringa flavipes*), and greater yellowlegs (*Tringa melanoleuca*) were quite common in these areas and were almost completely undisturbed by the noise generated by the ARGO. Yellowlegs of both species were common enough to almost be referred to as an "incontinence of yellowlegs," the old English term for flocks of yellowlegs. Although no attempt was made to find the nests, on two occasions, solitary sandpipers appeared to be defending their nests. This occurred near ponds and bogs that were surrounded by rings of taller black spruce trees. Shorebirds were most frequently encountered along the drill roads, but were also observed near ponds and bogs. Killdeer were also observed frequently when traversing areas of dwarf open evergreen tree habitat with widely spaced trees and abundant herbaceous groundcover. Sandhill crane (*Grus canadensis*) tracks were observed in the muck along one of the drill site access roads. On one occasion, a group of Bonaparte's gulls (*Larus philadelphia*) was observed mobbing a raven while flying across the project site. This may not indicate actual use of the project site, but it is highly likely that they are using habitat within a few kilometres of the project site. A northern harrier (*Circus cyaneus*) was also observed hunting over open habitat in the vicinity of the drilling sites.

Very few forest interior birds typical of boreal forest were heard or seen at the Minago Project site. Most birds were heard calling in the strip of deciduous forest that bordered the roadside ditch along Highway 6 or in similar habitat that bordered the access road. Whenever URS field crews traversed closed canopy habitat, few birds were seen or heard. Other than observations of shorebirds and sharp-tailed grouse this lack of bird observations also held true for dwarf open evergreen tree and intermediate open deciduous shrub and bog habitats within the project area. A few northern saw-whet owls (*Aegolius acadicus*), northern hawk owls (*Surnia ulula*), black-capped chickadees (*Poecile atricapilla*), and red-eyed vireos (*Vireo flavoviridis*) were heard calling, but mostly in the vicinity of mixed or deciduous forest habitat.

A wider variety of birds was observed and heard during surveys of the riparian habitat of the William River, Minago River, and Oakley Creek. Oakley Creek was surrounded by a floodplain dominated by intermediate sparse deciduous shrub. Along the creek, this habitat actually could be more accurately described as dense willow (*Salix* spp.) and red osier dogwood (*Cornus sericea*) thickets with occasional open areas of herbaceous vegetation and emergent wetlands. Birds associated with shrub and wetland vegetation were common along the creek, including eastern phoebe (*Sayornis phoebe*), least flycatcher (*Empidonax minimus*), Nelson's sharp-tailed sparrow (*Ammodramus nelsoni*), and white throated sparrow (*Zonothrichia albicollis*).

Aquatic, shore, and wetland birds that were observed along the Oakley Creek beaver ponds and the William and Minago Rivers include the Common loon (*Gavia immer*), spotted sandpiper (*Actitis macularius*), American bittern (*Botaurus lentiginosus*), Canada goose (*Branta canadensis*), mallard (*Anas platyrhynchos*), canvasback (*Aythya valisineria*), lesser scaup (*Aythya affinis*), common merganser (*Mergus merganser*), Red-winged blackbird (*Agelaius phoeniceus*), belted kingfisher (*Ceryle alyon*), barn swallows (*Hirundo rustica*), and, in the vicinity of the Minago River Bridge on Highway 6, cliff swallows (*Petrochelidon pyrrhonota*) were commonly observed flying over the water feeding on hatches of aquatic insects.

Bald eagles (*Haliaeetus leucocephalu*s) were observed during spring helicopter over-flights of Oakley Creek and the William River east of Highway 6. American kestrel (*Falco sparverius*), common raven (*Corvus corax*), American crow (*Corvus brachyrhynchos*), American robin (*Turdus migratorius*), and black-billed magpie (*Pica hudsonia*) were observed along Highway 6 between the William and the Minago Rivers.

Spruce grouse (*Falcipennis canadensis*), ruffed grouse (*Bonasa umbellus*), and pileated woodpecker (*Dryocopus pileatus*) were observed in forested habitat along the Williams and Minago Rivers.

7.10.5.2 Mammals

A list of mammals with a potential to occur in the vicinity of the Minago Project area is presented in Table 7.10-2. Species that were observed by URS (2008e) and/or Roche (2008a) to occur in the project area are noted in this Table.

7.10.5.2.1 Small Mammals

The only small mammals observed during wildlife surveys at the Minago Project site were muskrat (*Ondatra zibethicus*) in the roadside ditch and in the beaver ponds of Oakley Creek and snowshoe hare tracks recorded during winter survey transects. Although technically not considered small mammals (which are usually lagomorphs, rodents, and Insectivores) a few little brown myotis (*Myotis lucifugus*) bats were observed flying overhead along the roadside ditches at twilight. Beavers and beaver dams were also observed in ditches and streams.

The closest documented bat hibernacula to the Minago Project site are ten limestone caves in the Grand Rapids uplands, with the closest cave (Dale's Cave) approximately 16 km from the project area (Bilecki, 2003). These caves provide hibernacula for little brown myotis, northern long-eared myotis (*Myotis septentrionalis*), and possibly big brown bat (*Eptesicus fuscus*). Three other species of bats that may be summer visitors to the project area are listed in Table 7.10-2. No caves were observed in the Minago Project Area.

In addition to fifteen beaver ponds observed during a survey of Oakley Creek, beaver activity was observed in the roadside ditch along Highway 6 and in short surface drainages that did not have surface connections to any streams draining the project area or that drained into the Highway 6 roadside ditch. One such drainage that flows into the Highway 6 roadside ditch near the entrance of Minago's main access road was dammed approximately 100 m from Highway 6.

Other than the tunnels of voles and lemmings observed in sedges during the spring and in the snow during the winter, no other signs of small mammals were observed. This includes red squirrels and chipmunks. Through the entire eight days of spring surveys and four days of winter surveys there was no visual or auditory evidence of squirrels and chipmunks at the Minago Project site. No small mammals or their tracks were observed during the 2008 winter survey (URS, 2008e). It is highly unusual to not observe red squirrels in black spruce forests (URS, 2008e). There is no readily available answer for the absence of red squirrels from the project site. Perhaps the black spruce trees in the project area produced poor seed crops or arboreal fungi and lichens were relatively scarce in the black spruce wetlands of the project area.

A few small mammals were observed outside of the project area during fisheries surveys of the Minago and William Rivers. The small mammals observed during these surveys were least chipmunk (*Tamias minimus*), snowshoe hare (*Lepus americanus*), and red squirrel (*Tamiasciurus hudsonicus*).

Table 7.10-2 Mammals Occurring in the Vicinity of the Minago Project Area

Scientific Name	Common Name	Observed by URS (2008e)	Observed by Roche (2008a)
Soricimorpha: Shrews and Moles			
Sorex arcticus	Arctic Shrew		
Sorex cinereus	Masked Shrew		
Sorex hoyi	Pygmy Shrew		
Sorex palustris	American Water Shrew		
Chiroptera: Bats			
Eptesicus fuscus	Big Brown Bat		
Lasionycteris noctivagans	Silver-haired Bat		
Lasiurus borealis	Eastern Red Bat		
Lasiurus cinereus	Hoary Bat		
Myotis lucifugus	Little Brown Myotis	X	
Myotis septentrionalis	Northern Long-eared Myotis		
Lagomorpha: Rabbits and Hares			
Lepus americanus	Snowshoe Hare	T	X
Rodentia: Rodents			
Castor canadensis	American Beaver	X	
Clethrionomys gapperi	Southern Red-backed Vole		
Phenacomys ungava	Eastern Heather Vole		
Microtus pennsylvanicus	Meadow Vole		
Synaptomys borealis	Northern Bog Lemming		
Peromyscus maniculatus	Deer Mouse		
Zapus hudsonius	Meadow Jumping Mouse		
Ondatra zibethicus	Muskrat	X	
Glaucomys sabrinus	Northern Flying Squirrel		
Tamias minimus	Least Chipmunk		X
Tamiasciurus hudsonicus	Red Squirrel		X
Erethizon dorsatum	North American Porcupine		
Carnivora: Carnivores			
Lynx canadensis	Canada Lynx	T	
Canis latrans	Coyote	T	
Canis lupus	Gray Wolf		
Vulpes vulpes	Red Fox		X
Ursus americanus	American Black Bear	T	
Gulo gulo	Wolverine		
Lontra canadensis	Northern River Otter	T	
Martes americana	American Marten	T	
Martes pennanti	Fisher	T	
Mephitis mephitis	Striped Skunk		
Mustela erminea	Ermine	T	
Mustela nivalis	Least Weasel		
Mustela vison	American Mink	T	
Artiodactyla: Even-toed Ungulates			
Alces alces americana	Eastern Moose	XT	
Odocoileus virginianus	White-tailed Deer		X
Rangifer tarandus caribou	Woodland Caribou		

Source: URS (2008e)

Notes: Occurrrence data from Reid (2006) and Elbroch and Marks (2003)
Observed: X=Mammals visually observed within project site
T=Tracks observed within project site

7.10.5.2.2 Carnivores

Tracks of river otter (*Lontra canadensis*) and mink (*Mustela vison*) were observed along Oakley Creek during 2007 spring surveys (URS, 2008e). In addition, during spring surveys the carcass of a young river otter was observed near one of the Oakley Creek beaver ponds. Tracks and scat of black bear (*Ursus americanus*) were also observed during spring surveys throughout much of the Minago Project area and vicinity. This is not surprising considering the fact that black bear are habitat generalists. A red fox was observed crossing Highway 6 between Oakley Creek and the William River. No other carnivores were observed during spring wildlife surveys.

No carnivore tracks were observed during winter aerial surveys of the project site and a 288 square kilometres block of wildland with the proposed project approximately in the middle of the survey area. However, a set of fisher (*Martes pennanti*) tracks was observed on Ski Traverse A, a set of coyote (*Canis latrans*) tracks was observed on Ski Traverse D of Moose Lake Winter Road, and a set of Lynx (*Lynx canadensis*) tracks was observed along the road traverse of the main drilling access road, just before it forked into two well traveled roads. Two sets of American marten (*Martes americana*) tracks were observed during the Ski Traverse A, along with three sets of ermine (*Mustela erminea*) tracks. A set of marten tracks and a set of ermine tracks were also observed on Ski Traverse C. Four sets of ermine tracks and two sets of marten tracks were observed along Ski Traverse D and a single set of marten tracks was observed on Ski Traverse B. Lynx tracks were found along a closed evergreen forest, while the marten and ermine tracks were found in forests of all seral stages and closure. The fisher tracks were in an area of intermediate open evergreen forest habitat. It seems likely that marten and ermine are found throughout all forested habitats of the project area. The lynx tracks were found in close proximity to the highest density of snowshoe hare tracks, so it is possible that the lynx may have been attracted to the area of highest hare population.

The generalist nature of marten in the project area may be due to the almost total lack of red squirrels observed at the project site. Where red squirrels are scarce, American marten have been documented to forage on voles (often red-backed), lemmings, and snowshoe hares (Post, 1996). There appears to be moderate numbers of marten and ermine within the project area and other carnivores occur in the project area. Apparently there are enough carnivore furbearers present in the project area to provide a reasonable level of income for a trapper when fur prices are high.

7.10.5.2.3 Ungulates

Moose were the only ungulate documented to occur within the project area during the 2007 spring and 2008 winter surveys conducted by URS biologists (URS, 2008e). During 2007 spring surveys, three sets of ungulate tracks were observed along the roads to the drilling sites. On two occasions, these tracks were tentatively identified as being those of a woodland caribou and the other set was considered to be from a moose. However, it was difficult to make a positive identification because the tracks were in deep muck. Measurements of the track pattern and stride were taken and later compared to information in Elbroch (2003). The tracks were then positively identified as moose tracks, rather than caribou tracks. No scat from ungulates was observed during any surveys of the project area (URS, 2008e). A single moose was observed at the edge of a small bog surrounded by dwarf closed evergreen tree (black spruce) habitat during a spring survey helicopter over-flight of the area. The bog where the moose was sighted is located approximately 0.8 km southwest of the four-way junction of the access road that is located about 1.9 km west of Highway 6.

Several moose were observed during spring helicopter over-flights of Oakley Creek and the William River east of Highway 6. Moose tracks were also common along the riverbanks of the William River during fisheries surveys. Several sets of white-tailed deer (*Odocoileus virginianus*) tracks were also observed along the William River near the confluence of Oakley Creek. This was the only survey location where white-tailed deer signs were found. No caribou or their tracks or signs were observed during any of the spring or winter wildlife surveys.

Figure 7.10-2 presents the results of the 2008 winter aerial wildlife survey. Two cow moose and one calf moose were observed along Oakley creek upstream of a tributary coming entering from the north at the border between riparian intermediate deciduous shrub floodplain habitat, dominated by willows and red osier dogwood, and intermediate closed black spruce forest.

Five moose were sighted along the western edge of the Minago Project area, with at least one bull within the area. These sightings consisted of a cow with calf, a single bull, and a cow and bull together. All of these sightings were at the border of an old wildfire and open-to-closed intermediate coniferous forest. The burned over habitat consisted primarily of intermediate open deciduous shrub (willows) at an appropriate seral stage for moose browse. An additional 10 cow moose and a calf were observed in a burned over area primarily located north of the Minago Project area and south of the Minago River. This included 2 cows and a calf that were east of Highway 6 approximately 2.1 km from where the transmission line corridor turns northeast and away from Highway 6. These moose were all observed near the border between post-fire regenerating intermediate open deciduous shrub habitat and black spruce trees. The black spruce trees were either patches of close intermediate black spruce forest or, in the more open part of the old burn, were rings of surviving black spruce trees that surrounded thaw lakes and beaver ponds.

A total of 14 cows, 3 calves, and 2 bull moose were observed during the 2008 winter aerial survey. All of the moose were observed at the border between dense stands of shrub forage habitat and tree cover. Although no moose were observed, there were a fair number of moose tracks and at least one bed observed along the borders of the open areas of bog and intermediate open deciduous shrub habitat and intermediate closed evergreen tree habitat between the Moose Lake Winter Road and Oakley Creek to the south. Although the later seral stage of the shrubs in this habitat apparently is not as preferred a forage source as shrub habitat in the burned-over areas or riparian areas along Oakley Creek, it apparently forms a secondary winter habitat for moose in the project vicinity.

No moose tracks were observed along Helicopter Traverse A of the Moose Lake Road, the truck traverses or Ski Traverses A, B, and C. Moose tracks were observed west of the junction of the Y in Ski Traverse D and then along the entire length of Helicopter Traverse C. Moose tracks were also observed along the western 300 m of Helicopter traverse B.

7.10.5.2.4 Reptiles and Amphibians

Lists of amphibians and reptiles with a potential to occur in the vicinity of the Minago Project area are presented in Tables 7.10-3 and 7.10-4. Species that were observed by URS (2008e) to occur in the project area are noted in this table.

Table 7.10-3 Amphibians Potentially Occurring in the Vicinity of the Minago Project

Scientific Name	Common Name	Observed by URS (2008e)
Bufonidae: Toads		
Bufo americanus americanus	Eastern American Toad	
Bufo americanus hemiophrys	Canadian Toad	
Hylidae: Tree and Chorus Frogs		
Hyla crucifer crucifer	Northern Spring Peeper	X
Pseudacris triseriata maculata	Boreal Chorus Frog	X
Ranidae: True Frogs		
Rana sylvatica	Wood Frog	X
Rana pipiens	Leopard Frog	X

Source: URS (2008e)

Notes: Occurrence data from Preston (1982).
Observed: Adult wood frogs were observed and the calls of the other species were recorded.

Table 7.10-4 Reptiles Potentially Occurring in the Vicinity of the Minago Project Area

Scientific Name	Common Name	Observed by URS (2008e)
Columbridae: Snakes		
Thamnophis sirtalis parietalis	red-sided garter snake	X

Source: URS (2008e)

Note: Occurrence data from Preston (1982)

The project vicinity is near the extreme northern range of reptiles and most amphibians. The only reptile that occurs in the project area is the red-sided garter snake (*Thamnophis sirtalis parietalis*), documented by a single individual observed on beaver dam 10 (Table 7.8-3) along Oakley Creek when it was surveyed for the Fisheries Resource Inventory Report. The garter snake primarily feeds on fish and amphibians, so it is likely that it primarily occurs in close proximity to those forage species. Considering the fact that the project area consists of a forested black spruce wetland, it probably includes all but the most closed canopy forest habitats (URS, 2008e). The closest reported instance of any other reptile species is a single documented occurrence of a western painted turtle (*Chrysemys picta belli*) at Grand Rapids, Manitoba.

Northern spring peepers (*Hyla crucifer crucifer*) and boreal chorus frogs (*Pseudacris triseriata maculata*) were often heard calling from muskeg ponds and wetlands throughout the Minago Project area and a leopard frog (*Rana pipiens*) was observed in the roadside ditch along Highway 6. Several wood frogs (*Rana sylvatica*) were observed in the riparian habitat of Oakley Creek and along the banks of the William River. No toads were observed during wildlife or fisheries surveys (URS 2008b, 2008e), but the project area and vicinity are located at the interface between the distributions of the eastern American toad (*Bufo americanus americanus*) and the Canadian toad (*Bufo americanus hemiophrys*). The Canadian toad is primarily a resident of prairie ponds, so it is likely that most toads occurring in the project area are either American toads or hybrids between the two subspecies.

7.10.5.2.5 Anecdotal Observations

Telephone conversations with biologists and conservation agents at both the Northeastern and Northwestern Regional Offices of Manitoba Conservation indicated that the vicinity of the Minago Project area is not heavily utilized by sportsmen, due to difficult access and poor hunting/fishing success. Agency biologists and conservation agents mentioned driving past it on a regular basis on Highway 6, but concentrating their wildlife monitoring activities in other areas of their regions that have larger populations of game animals. Their description of the site was primarily based on observations they made while driving on Highway 6. The descriptions varied, depending upon where they thought the project was located from descriptions of the project location given over the phone. The most frequent description was jack pine (*Pinus banksiana*) forest that experiences frequent fires because it is so dry. The proposed project is named after the Minago River, located to the north of mine, a region of limestone highlands that are indeed dry and experience frequent wildfires. However, jack pines are completely absent from the area of proposed mine activity at the Minago Project location and the entire project area in the immediate vicinity of the proposed mine activity was composed of black spruce (*Picea mariana*) wetlands, bogs, fens, and shrub wetlands (URS, 2008e).

Mr. Jonathan Anderson (2008), who operates a winter trap line within the project area, primarily traps American marten (*Martes americana*) and other species along winter roads. Mr. Anderson stated that he does not trap beaver (*Castor canadensis*) on Oakley Creek because the value of their pelts is currently depressed and the creek no longer freezes solid enough to be safe to use as a winter travel route.

7.10.6 May 2008 Opportunistic Wildlife Observations

Roche (2008a) compiled data about when and where wildlife was encountered as part of its May 6-9, 2008 activities. Roche (2008a) observed a total of 3 mammals and 19 birds (Table 7.10-5).

Table 7.10-5 Opportunistic Wildlife Observations – May 2008

Common Name	Latin Name	Habitat
Mammals		
American Beaver	*Castor canadensis*	Creeks, lakes, marshes and calm rivers. Prefers aspen stands but can adapt to young balsam fir and alder stands. Inhabits woodlands and prairies. Covers an area of 2,6 to 5,2 km^2
Moose	*Alces alces*	Mixed stands, especially balsam fir stands with yellow or white birches. Openings, burns, logged areas, alder stands, swamps and ponds. Covers an area of 5 to 10 km^2
River Otter	*Lutra canadensis*	Lakes, rivers, marshes and bay as well as tundra lakes and streams, at the northern tree limit.
Birds		
Bald Eagle	*Haliaeetus leucocephalus*	Nearby water bodies; large rivers, lakes, sea coasts and surrounding areas. During the migration, in the mountains.
Canada Goose	*Branta canadensis*	Large areas such as prairies, Arctic plains and rocky areas. Nearby lakes, ponds, bay and major streams. Feed in the tundra and in fields colonized by herbs.
Common Goldeneye	*Bucephala clangula*	Nest on lakes in wooded areas and on ponds in bogs. Sea coast, estuaries, lakes and freshwater rivers.
Common Merganser	*Mergus merganser*	Forested lakes, rivers and ponds. During the winter, lakes and rivers, rarely in salt water.
Common Raven	*Corvus corax*	Boreal forest, mountains, Arctic coasts and woodlands. Nest along cliffs of within trees. Lakes, rivers and sea coast. Along roads and in dumps.
Greater Yellowlegs	*Tringa melanoleuca*	During migration, ponds, swamps, shallow lakes, calm streams. Along coasts, salt marshes, barrier ponds, mud flat, bay. Nest in bogs, ponds, lakes, open forests.
Mallard	*Anas platyrhynchos*	Varied habitats; marshes swamps, ponds, small and large lakes, calm rivers. Sometimes along the coast. Can feed in crop fields.
Northern Pintail	*Anas acuta*	Shallow freshwater water bodies, small and large marshes, ponds, lakes, steppe. While not nesting, may also frequent salt water areas.
Osprey	*Pandion haliaetus*	Rivers, lakes, estuaries, coasts, bay.
Piper sp.	--	Riverbanks, beaches, mud flat, marshes, ponds.
Red-breasted Merganser	*Mergus serrator*	Freshwater and salt water. During winter, prefer salt water. While nesting, bay, lagoons, estuaries, lakes and rivers.
Red-tailed Hawk	*Buteo jamaicensis*	Woodlands, open areas, groves, mountains, plains. While nesting, areas where trees were planted and rock outcrops.
Ring-billed Gull	*Larus delawarensis*	Shores, islands, lakes, rivers, ponds, dumps, fields, crops.
Ring-necked Duck	*Aythya collaris*	Shallow freshwater, forested lakes, marshes, Sedge prairies, bogs, estuaries influences by tides. While migrating, rivers, large lakes, swampy shores. Rarely in salt water.
Sandhill Crane	*Grus canadensis*	While nesting, marshes, bogs, large Arctic river valleys, swampy tundra, and steppe. While migrating, fields, marshes, shallow lakes.
Seagull	--	Lakes, coasts, estuaries.
Snow bunting	*Plectrophenax nivalis*	In the Arctic, rocky areas such as shores, outcrops, cliffs and tundra. While migrating, fields, shores and along roads.
Swan sp.	--	Ponds, lagoons and lakes.
Tundra Swan	*Cygnus columbianus*	Tundra, lakes, large rivers, swamps, bay, estuaries, flooded fields.

Source: Roche (2008a)

7.10.7 Effects Assessment Methodology

The scope of the environmental effects assessment includes:

- identification of key wildlife issues within the Project Study Area;
- identification of valued ecological and cultural components (VECCs) to focus the assessment;
- an analysis of potential environmental effects including cumulative effects;
- identification of mitigation measures; and
- determination regarding the significance and likelihood of potential residual effects.

Each of these topics is discussed in more detail in the following sections.

Key Issues

Based on the proposed project facilities and design, consultation with regulators and other deemed experts and the local land users, a number of key issues were defined to focus the wildlife assessment on relevant project effects, and to assess the project's contribution to cumulative effects in the area. The potential project effects on wildlife may include the following key issues:

- **Habitat availability** — impacted either directly by habitat loss or alteration, or indirectly by sensory disturbance (such as noise and human activity) and reduced patch size (e.g., increased habitat fragmentation). Potential project effects are related to clearing and removal of habitat in the mine site area, clearing and construction of transportation corridors, and human use activities associated with both facilities (open pit blasting, ore crushing and road transport).

- **Disruption to movement patterns** — resulting from increased habitat/landscape fragmentation (e.g., increased density of access corridors) or higher road use levels limiting daily or seasonal wildlife travel. The mine transportation corridors and PTH 6 will be used to haul concentrate and Frac Sand on a regular basis.

- **Mortality risk** — increased mortality resulting directly from site development, vehicle collisions (i.e., mine traffic), increased hunting/poaching, or lethal control of problem wildlife.

Of these key issues, the potential for increased wildlife mortality rates due to increased road access and human use is of particular concern.

Biodiversity Approach

Consideration of potential effects on biodiversity has only recently been integrated into the environmental impact assessment process. Biological diversity, or biodiversity, is defined as the variety and variability of life, and it includes the diversity of genes, species, ecosystems and landscapes. Effects on biodiversity may be assessed at various levels of biological organization. For purposes of most impact assessments, effects can be investigated at three levels, including:

- **Species level** – refers to the number and variety of animal species and their abundance.
- **Community/ecosystem level** – refers to the interrelationships between species and their habitats, focusing on the ecological units that sustain species.
- **Landscape level -** refers to the ability of the landscape to operate as a sustainable, integrated ecological unit, and is affected by regional processes such as habitat fragmentation.

For this assessment, potential project effects on wildlife biodiversity at the species level are evaluated in the context of habitat availability and mortality risk. Additionally, the assessment of potential project effects on selected vegetation VECCs (i.e., ecosystem communities of conservation concern, wetlands) (Section 7.9: Vegetation) addresses biodiversity at the community and ecosystem level, and can be indirectly related back to wildlife biodiversity considerations. At the landscape level, potential effects on biodiversity were assessed by considering regional habitat fragmentation and possible disruptions to wildlife movement patterns for wide-ranging species.

7.10.7.1 Study Area

For the purposes of this assessment, two study areas are identified — a Local Study Area (LSA), and a Regional Study Area (RSA).

Local Study Area

The LSA encompasses all of the proposed project components where activities associated with construction and commissioning, operation, decommissioning as well as accidents and malfunctions could result in environmental effects on wildlife and wildlife habitat.

Delineation of the LSA is specifically intended to assess the direct impacts of the proposed project on habitat availability (i.e., through habitat alteration or removal). In addition, the LSA will be the focus of qualitative discussion on other potential direct or indirect impacts of the proposed development (e.g., sensory disturbance, mortality risk, contaminants). The LSA is defined by a potential disturbance footprint for direct effects on wildlife and habitat, buffered by zones of influence for indirect effects on wildlife and habitat due to noise and human disturbance. The disturbance footprint is conservatively defined as the total areas of VNI claims that will be directly affected by project facilities.

The actual disturbance footprint will comprise areas of clearing and development within these claim boundaries. However, the area as defined allows for potential movement or expansion of project components within that area, without changing the conclusions of the effects assessment.

Wildlife field assessments were conducted in detail within the LSA.

Regional Study Area

The RSA provides context for effects findings in the LSA by describing wildlife and wildlife habitat availability over a larger area surrounding the LSA. In addition, the RSA sets the spatial boundaries for the review of existing local knowledge in the area. Within the RSA, wildlife and wildlife habitat are tabulated using existing knowledge for the area by both URS and Roche Ltd. The RSA boundary is defined by the existing watershed boundaries, and provides an appropriate spatial scale to assess natural processes including potential constraints to animal movement.

For the purposes of this assessment, eight wildlife VECCs have been selected to represent the larger assemblage of wildlife species known to occur within the LSA and RSA. Wildlife VECCs have been defined for the project environmental assessment based on the following criteria:

- conservation status (e.g., *Species at Risk Act*), known presence and relative abundance in the area;
- ability of a species to be used as an indicator species for a broader number of species (keystone species);
- socio-economic and regional importance;
- review of the Biophysical Assessment Workplan submitted to regulators;
- findings of field investigations; and
- review and input from the project Technical Committee meetings.

Based on these criteria, the seven selected VECCs (Table 7.10-6) include:

- William Caribou Herd (*Rangifer tarandus caribou*);
- Moose (*Alces alces*);
- Black bear (*Ursus americanus*);
- Lynx (*Felis lynx*);
- Beaver (*Castor canadensis*);
- American marten (*Martes americana*); and
- Song bird community.

These VECCs were used to direct the impact assessment of habitat availability for the project and to focus the review of existing knowledge in the area.

Table 7.10-6 Selected Wildlife VECCs

Selected VECC	Rationale for Selection	Linkage to EAP Report Guidelines or other regulatory drivers	Baseline Data
Moose	• Identified in a regional context as a territorial significant moose population in Manitoba • Species of social and economic significance • Potential to sustain project impacts	• Requirements to integrate traditional knowledge and to address social and economic issues • EIS Workplan	• Field Data • MB Key Wildlife Habitat
Caribou	• The William Caribou herd is of social and economic importance • Sensitive to disturbance	• Baseline Assessment Workplan • Listed as a species of special concern	• Field Data • Terrestrial lichen model • Telemetry and survey point location data
Black bear	• Species of social and economic significance • Sensitive to disturbance • Potential to sustain project impacts	• Requirements to integrate traditional knowledge and to address social and economic issues	• Project ecosystem mapping • Field Data
Lynx	• Species of social and economic significance • Potential to sustain project impacts	• Requirements to integrate traditional knowledge and to address social and economic issues	• Field Data • Project ecosystem mapping
American marten	• Species of social and economic significance • Potential to sustain project impacts	• Requirements to integrate traditional knowledge and to address social and economic issues	• Field Data • Project ecosystem mapping
Song bird community	• Sensitive to disturbance • Potential to sustain project impacts	• Includes species listed by COSEWIC (2005) and in the *Migratory Birds Convention Act*	• Project ecosystem mapping • Bird habitat indices provided from applicable studies
Beaver	• Occurrences in the LSA • Potential to sustain project impacts • Representative of other mammal species that utilize wetland habitats • Species of social and cultural significance	• Requirements to integrate traditional knowledge address social and economic issues	• Project ecosystem mapping • Aerial survey to detect presence of beaver lodges and dam locations in the LSA

7.10.7.2 Temporal Boundaries

Based on the range of potential effects on wildlife, three assessment scenarios were used:

- **Baseline:** Represents conditions for wildlife species prior to any development activities under the proposed project. Seasonal habitat use for baseline conditions was characterized based on habitat conditions in 2006, 2007 and 2008.
- **Full Build-out:** Represents conditions during construction activities, operations, and decommissioning, assuming the worst-case land disturbances expected for this period (i.e., disturbance of the total area of all claim areas touched upon by project facilities).
- **Closure:** Represents conditions forecasted into the future following complete decommissioning and reclamation of the mine site. This scenario assumes implementation of all mitigation recommendations to achieve optimal wildlife habitat conditions at closure.

Decommissioning will be phased over a number of years. Reclamation will be completed five years following the end of production. All disturbed surfaces will be re-contoured, natural drainages reinstated and re-vegetated where practicable. The Tailings and Ultramafic Waste Rock Management Facility (TWRMF) will be reclaimed as a permanent pond. The access road will remain in place. Reclamation goals are a stabilized surface and a native plant community to provide wildlife habitat. Green Alder will be used for re-vegetation. It is assumed that successional processes will move post-mine vegetation communities towards the local vegetation type, ideally within a 10-year period following decommissioning and final reclamation.

7.10.7.3 Baseline Conditions

7.10.7.3.1 Methods

- **Information Sources** - Information sources used to describe baseline conditions and complete the assessment of wildlife and wildlife habitat included:
  - a literature review;
  - consultation with regulators;
  - field surveys; and
  - consultation with local traplines owners.

  Overall, the data that is currently available to describe baseline conditions and assess potential environmental effects of the project on wildlife and wildlife habitat are judged by the study team to be sufficient. The following sections describe the methods used to characterize baseline conditions, focusing on the seven selected VECCs.

- **Literature Review** - Existing wildlife information was reviewed including wildlife inventory and habitat use information for the project area and the Province of Manitoba, and from applicable studies conducted elsewhere within a similar ecological context. The review focused on the seven selected VECCs. Literature sources (including government reports and regulations, technical reports, unpublished documents, and peer-reviewed publications) are cited throughout the document.

- **Consultation -** Consultation was undertaken to gather knowledge regarding wildlife from individuals who are most familiar with the project area (traplines owners) and/or who have expertise with respect to specific VECCs. Specifically, consultation included:

  - discussions on VECC selection;
  - impact assessment approach;
  - baseline habitat assessment methods at the VECC level;
  - issues and management concerns surrounding the project and selected VECCs; and
  - available baseline knowledge and knowledge gaps for the selected VECCs in the study area.

  Through consultation, several additional baseline data and information sources were obtained for use in this assessment. These sources include, but are not limited to, the following:

  - key wildlife habitat areas delineated within the project area;
  - survey and technical reports from extensive studies;
  - a list of bird species known to occur near the Project Area, in northern Manitoba and across the Province of Manitoba;
  - a list of wildlife species of concern in Manitoba;
  - fur harvest data and current traplines within a regional context to the study area; and
  - numerous reports for wildlife surveys and for wildlife-habitat studies conducted in the project area and within similar ecological units in Manitoba.

- **Field Surveys -** Three wildlife field surveys were conducted and/or coordinated by URS and Roche Group during 2007 and 2008, respectively. These surveys included:

  - wildlife habitat assessment as part of the ecosystem mapping program;
  - aerial surveys; and
  - incidental wildlife observations within the Project Study Area.

Incidental wildlife observations were recorded during the ecosystem mapping program and the aerial wetland survey (above), referenced by a GPS location, and a digital picture was taken when possible.

7.10.7.3.2 Results

The Minago Project area is underutilized by all wildlife species but shorebirds, sharp-tailed grouse, small forest carnivores and black bear, beaver, and amphibians (and likely the red-sided garter snake) (URS, 2008e). None of the project area habitat is particularly critical to the survival of these species in the project vicinity.

With the exception of the long-tailed weasel (*Mustela frenata*), northern raccoon (*Procyon lotor*), Arctic fox (*Alopex lagopus*), American badger (*Taxidea taxus*), and bobcat (*Lynx rufus*), the range of all species of furbearers native to Manitoba generally encompass the Minago Project area (URS, 2008e).

Small forest carnivores, such as marten and ermine, were observed in moderate abundance. Other carnivores, such as lynx and fisher, utilize Minago Project area as habitat. However, prey species typically utilized by these species, such as showshoe hare and red squirrel are either limited in distribution or rare within the Minago Project area, requiring these species to utilize alternative prey species, such as voles, sharp-tailed grouse, and lemmings. Although shorebirds are probably a normal resident of the Minago Project area bog and fen habitat, their numbers are probably elevated due to the presence of the peat soil that has been converted into muck along the drilling access roads (URS, 2008e).

With rare exceptions, such as grouse, all of the birds that occur in the Minago Project vicinity are migratory and most occur at the Minago Project site only during their nesting seasons (URS, 2008e). None of the birds occurring in the Minago Project area have special status other than that conferred by the various treaties and conventions between Canada, the U.S., Japan, Mexico, and the former Soviet Union for the protection of migratory birds and by hunting seasons established by federal, provincial, and First Nations resource management agencies. These treaties and conventions prohibit take, possession, transportation, import, export, and commerce of any migratory birds, part, nest, egg, or product, manufactured or not. Exceptions are made to assure the taking of migratory birds and their eggs by the First Nations and the establishment of legal hunting seasons and regulations for migratory game birds (URS, 2008e).

As timber harvest operations in central Manitoba create suitable early seral stage habitat, white-tail deer are likely to occur occasionally in the Minago Project area as they continue to invade more northern habitats in the boreal forest of Manitoba. This may eventually lead to the spread of Meningeal worm through the moose and caribou populations, causing declines (Anderson, 1972; Elliott, 2008).

Moose populations in the Minago Project's vicinity are concentrated north, south, and west of the Minago Project area. There is currently some summer and winter utilization of riparian habitat along Oakley Creek, bog habitat between the Moose Lake winter road and Oakley Creek, and bog and post-fire shrub habitat along the western edge of the Minago Project area. Although moose do enter the Minago Project area, they do not seem to make much use of it or utilize it as a migration route. Moose have been documented to forage most heavily on riparian willow, particularly where wildfire has stimulated willow production in burned black spruce stands (Post, 1996). Moose have been documented to prefer open black spruce wetlands with willows that surround ponds with aquatic vegetation. Moose winter habitat selection appears to be more influenced by food availability than by snow cover and the probability of moose presence increases with shrub height, levelling off when shrubs reach a height of 4 m (Keystone, 2006). Moose eat forbs and aquatic vegetation during the summer months which supply the sodium needed in their diet (Post, 1996). Black spruce need to be tall enough to provide cover next to sources of forage. Suitable shrub seral communities for moose forage mostly occur from fire or alluviation (deposition of alluvial soils) (Post, 1996).

However, one wildlife species of concern has been documented to occur in the vicinity of the project area. The boreal population of woodland caribou (*Rangifer tarandus caribou*) is listed as “threatened” by the Committee on the Status of endangered Wildlife in Canada (COSEWIC) in the *Species at Risk Act* and Manitoba’s boreal woodland caribou populations were listed as “threatened” in the Manitoba *Endangered Species Act* in June, 2006. It is important to note that woodland caribou was not observed by URS or Roche. Trappers in the area also have not observed the woodland caribou.

<u>Woodland Caribou</u>

The boreal woodland caribou, listed as threatened, was not documented in the project area or vicinity during any of the 2007 and 2008 wildlife surveys conducted for this project. This does not mean they do not ever enter the project area, it simply is not preferred habitat and most of the individuals from the two nearest herds have been documented a considerable distance north and south of the project area. Moreover, trappers in the area also have not observed Woodland caribou. The two nearest woodland caribou herds are the Wabowden and William Lake herds. There are approximately 25-40 individuals in the William Lake herd and 200-225 individuals in the Wabowden herd (Manitoba Conservation, 2005). The William Lake herd has a low conservation concern rating, while the Wabowden herd has been assigned a medium conservation concern (Manitoba conservation, 2005), based on the presence of industrial forestry in the Wabowden region north of the project vicinity (Manitoba Conservation, 2000a; Hirai, 1998). The province of Manitoba is still in the process of identifying critical habitat for the boreal woodland caribou population (Elliott, 2008). A genetic analysis of scat collected from the William Lake and North Interlake herds, located north and south of Grand Rapids, indicated that the two populations are genetically distinct with Cedar Lake and the Saskatchewan River creating a natural barrier that has significantly reduced interbreeding between the two populations (Elliott, 2008).

Studies of the Wabowden herd have concentrated on tracking the movements of radio collared cows (Elliott, 2008; Hirai, 1998). The farthest south these animals have been tracked is about 30 km north of the project area (between the Hargrave and Minago Rivers), with most individuals occurring in the vicinity of Wabowden and Ponton, north of the Hargrave River. Field data suggests that these caribou are strongly associated with lowland black spruce stands scattered across open muskeg (Hirai,1998). This type of habitat is referred to in the study as treed muskeg and is the equivalent of forested islands within a lake or open wetland. In most of the treed muskeg islands, overstory was typically dominated by black spruce (>70%) with a crown closure greater than 70% (Harai, 1998). The treed islands normally have higher elevation (about 1-3 m) and higher tree density than surrounding bogs, thus maintaining relatively well drained soil conditions. These conditions resemble those of the ridges of the project area that are slightly elevated with taller trees than the surrounding forest. However, the project area's elevated forest habitat is surrounded by slightly smaller trees, rather than open muskeg. Suitable forage is present in the project area black spruce forest habitat, but there is no protection from predators. Habitat use analysis indicates that the Wabowden herd avoids deciduous stands, early seral stages, and non-black spruce conifer stands (Hirai, 1998; Brown *et al*., 2007). Caribou have been documented to avoid marshes, treed rock, beaver ponds, aspen, and heavily forested wetlands (Schindler, 2005). In central Manitoba, caribou show fidelity to areas used for calving in summer, but not for winter locations.

Factors associated with decreases or extirpations of caribou are industrial development and agriculture, increased predation and disease caused by the removal of forest cover, which facilitates habitat for species adapted to young seral stages (moose and white-tailed deer), increased access for hunting, and reduction in food supply associated with habitat disturbances (Hirai, 1998). However, to date, the project area has not been affected by these factors.

Increases in moose and deer populations associated with early seral stage, shrub habitat maintains high wolf densities and increased opportunistic wolf predation on caribou mortalities (Hirai, 1998; Bergerud, 1988; Brown *et al*., 2000). The removal of mature forests generally causes a reduction in the production of lichen, the primary forage of caribou. Regions where lichen are the primary browse, allow caribou to occupy an ecological niche absent of competition with other herbivores. Habitat preference of female caribou with calves is governed by lower risk of predation (Hirai, 1998). Habitat on treed islands in muskeg provides adequate forage availability with protection from predators since caribou are likely to have more advantage in mobility over wolves and other predators in muskeg as compared to dry lands. In addition, the approach of predators is more easily detected when wolves have to travel noisily across open muskeg to approach caribou. Other factors associated with selection of treed islands by woodland caribou include avoidance of human disturbance and insect release. Treed islands also are of low value to moose, possibly reducing wolf density (Hirai, 1998) and snow is softer and shallower (Stardom, 1975).

The response of caribou to human activities varies depending on the situation. It has been reported that caribou habituate to various degrees of human disturbance when they are exposed to it continuously, rather than seasonally (Hirai, 1998). Caribou abundance increases with distance from mine sites in all seasons and caribou avoid areas within 4 km of mine sites in most seasons (Weir *et al*., 2007). Responses of caribou to periods of low activity in evolving oilfields, suggest that caribou do not respond to sedentary industrial developments *per se*, but to the vehicular traffic associated with them (Dyer, 1999). In the presence of ecotourists, caribou increase time vigilant and standing, mostly at the expense of time spent resting and foraging, with the impact of ecotourists decreasing as caribou become habituated to them (Duchesne *et al*., 2000). Caribou never leave their winter quarters because of human presence, however caribou will abandon their wintering areas in response to wolf presence (Duchesne *et al*., 2000). Weclaw and Hudson (2004) state that the most detrimental factor on caribou population dynamics is the functional loss of habitat due to avoidance of good quality habitat in proximity of industrial infrastructures.

Woodland caribou have been documented to select specific habitats during migrations, including conifer dominated forests and waterways (Ferguson and Elkie, 2004). Caribou do not avoid disturbed habitat, such as recent burnt or cut areas during migrations (Ferguson and Elkie, 2004). However, caribou avoid recently burned areas as winter or summer habitat to such a great degree that analysis of both data sets from GPS-collared cows and very high frequency (VHF) transmitter tracking datasets were able to reveal this relationship (Joly *et al*., 2003).

In the case of the Minago Project area, the habitat is of limited value to woodland caribou because treed islands of black spruce do not occur within open muskegs and any individual caribou migrating south from the Wabowden herd will encounter a large area of burned-over land to the north and west of the project area that is occupied by moose, a species they are not competitive with. In addition, the moose population may have increased wolf densities and the primary forage in these areas is shrub habitat, rather than the niche forage of lichens utilized by woodland caribou. Caribou migrating or repopulating habitat south of the main body of the Wabowden herd are more likely to move through the region to the east of Highway 6, where dense stands of mature black spruce provide good migration habitat and there are treed island present with large areas of open muskeg. A similar situation exists for individual caribou moving north from the main body of the William Lake herd. In addition, William Lake caribou would have to cross the headwater region of Oakley Creek, an area dominated by extensive regions of riparian shrub habitat and beaver ponds. William Lake Caribou are unlikely to select this area for movement to the north, while the area east of Highway 6 provides a better migratory corridor. The scope of this report did not include an analysis of the region west of the 18 km by 16 km area surveyed for the winter survey, so it is possible that suitable habitat exists to the west of the surveyed area for the migration and expansion of both the Wabowden and William Lake herds. However, future expansion of the herds into the project area is unlikely due to unsuitable habitat within the Minago Project area. Any woodland caribou entering the project area at this time and for the foreseeable future are likely to be stray individuals from the main bodies of the two herds and the project area is not likely to provide critical habitat for either herd.

<u>Beaver</u>

Beavers are not listed under the *Species at Risk Act*. Conservation concerns for this species are relatively few given the beaver's adaptability to human encroachment. Beavers, in fact, find roadbeds and culverts very attractive due to the reduced effort it takes to dam a road or culvert instead of a whole waterway in order to flood land. Beaver problems where roads cross a stream can be remedied by using beaver exclusions. Beavers were chosen as a VECC species due to their socio-economic value as a fur bearing species as well as their important role in wetland habitat construction. The habitat beavers create is used by other trapped species such as mink, muskrat and otter.

Lynx and Snowshoe Hare

Lynx and snowshoe hare populations are known to fluctuate over time with one population being dependent upon the other. Neither lynx nor snowshoe hare are listed under the *Species at Risk Act*. Lynx has been selected as one of the VECC in this assessment.

The major factors responsible for a decline in lynx numbers occurs following a crash in the hare population where juvenile lynx mortality increases from starvation and possibly from failure of yearling females to breed. Other than their close association to the distribution of snowshoe hare, typically lynx habitat is found within climax boreal forests including both coniferous and mixed-woods with a dense undercover of thickets and windfall. The snowshoe hare is a common and widely distributed resident of the boreal forest region, inhabiting forests, swamps and riverside thickets primarily having extensive shrub understories.

American Marten

The marten is not listed as a species at risk by COSEWIC (2004) or as a species of concern. The main rationale for the selection of this species as a VECC is due to their socio-economic value as a trapped species in the area. The marten is primarily carnivorous, generally nocturnal and active throughout the year. Prey abundance (e.g., voles) appears to be a critical factor affecting marten population dynamics. The marten's prominence in the trapping records indicates that it is likely relatively abundant in the region. Marten in the northern boreal forest are closely associated with late successional coniferous stands, especially those dominated by spruce and fir, with complex structure near the ground (i.e., coarse woody debris) but will inhabit a variety of forests and even shrublands if food is available. Commonly reported refuge sites include ground burrows, rock piles and crevices, downed logs, stumps, snags, brush or slash piles and squirrel middens.

Marten are only moderately abundant in and around the LSA. No marten or marten signs were recorded during the field sessions associated with this project. However, several records of observed marten were noted at the Minago exploration camp. Suitable habitat for marten is found within the LSA. Baseline habitat availability in the LSA was assessed and quantified for marten.

Songbird Community

Songbirds (i.e., passerines), as a community, were selected as a VECC and an assessment of abundance for various bird species was included. The songbird community was chosen as a VECC because of their combined sensitivity to disturbances and international conservation concerns. This songbird community included long-distance migrants, short-distance migrants and resident birds, and included birds in the families Tyranidae, Laniidae, Vireonidae, Corvidae, Alaudidae, Hirundinidae, Paridae, Sittidae, Regulidae, Turdidae, Motacillidae, Bombycillidae, Parulidae, Emberizidae, Icteridae, and Fringillidae. None of these bird species are listed as a species at risk.

7.10.7.4 Assessment Details

7.10.7.4.1 Wildlife Habitat Models

Wildlife habitat modeling is a predictive tool that provides a representation of a species' probability or density of occurrence (habitat use during a given season) in an area based on the biophysical attributes of the landbase. The following three approaches were used in this assessment:

- **Habitat Suitability Index (HSI)** - provides a probability that the habitat is suitable for the species, and hence a probability that the species will occur where that habitat occurs. If the value of the index is high in a particular location, then the chances that the species occurs there are higher than if the value of the index is low.
- **Animal Abundance Estimates** - calculates animal abundance by multiplying animal density (number/ha) within a given habitat unit by the area (ha) of the given habitat unit that is available within a study area. In order to apply this approach, estimates of animal density within habitat units are required.
- **Animal Presence and Habitat Suitability** - uses observational or other data (GPS or telemetry tracking) to confirm animal presence within suitable habitats (often defined using an HSI or similar approach). An animal presence approach is best suited for non-migratory species that have relatively small annual home ranges and or species that have a high rate of habitat (seasonal or other) fidelity (i.e., traditional habitat use behaviours). In such cases, habitats with confirmed occupancy are likely a stronger spatial predictor of areas having future presence and are thus considered to have a higher habitat value. This method requires an adequate collection of habitat use data for a species.

7.10.7.4.2 Assessment Scenarios

As noted in the previous Section, the assessment focused on three scenarios representing the full range of potential project effects and the site condition when the project is complete:

- **Baseline** – the baseline condition represents the habitat availability and use of the project area by wildlife prior to project-related habitat disturbances. This condition is the yardstick by which project effects are measured.
- **Full Build-out** – representing the maximum level of habitat and wildlife disturbance during the life of the project. It will be most intense during construction, as a result of site clearing and building activities across the site, and will persist during operation and the early stages of decommissioning with gradual reductions, as a result of progressive reclamation. In terms of

habitat effects, full build-out assumes a conservative disturbance footprint, that is, the total of all claim areas touched by project facilities and the access road (approximately 1400 ha). The use of the conservative footprint addresses all eventualities in the event that project facilities are modified or moved within that footprint. It also provides a worst-case assessment of potential effects.

- **Closure** – Reclamation of the mine site will replace some of the habitat lost, but it will be a relatively small component of the overall disturbance footprint. Accordingly, the change in habitat availability at closure while positive is relatively small.

7.10.7.4.3 Effects Attributes

Predicted project and cumulative effects on wildlife derived from quantitative and qualitative assessments were characterized using effects attributes defined in Table 7.10-7. Ecological and social contexts of effects were integrated in the attributes for effect magnitude and elaborated upon in the text where relevant.

7.10.7.4.4 Determination of Effects Significance

The significance of residual project related effects and cumulative effects will be determined based on the defined effects criteria as follows.

A residual adverse effect will be considered significant, if it is:

- a moderate magnitude adverse effect that is far future (> 10 years) in duration;
- a high magnitude adverse effect unless it is site-specific in geographic extent;
- a high magnitude adverse effect that is site-specific in geographic extent and far future in duration.

Otherwise, residual adverse effects will be rated as not significant.

7.10.7.4.5 Cumulative Effects Assessment

The general approach for the cumulative effects assessment for wildlife is as follows:

- determine conditions for the local wildlife species within the RSA (i.e., conditions at baseline and into the foreseeable future in combination with the project effects;
- identify any further mitigation measures (in addition to those identified for project effects) for reducing or eliminating cumulative effects;
- characterize and evaluate the significance of any residual cumulative effects on VECC species within the RSA; and
- characterize the project contribution to cumulative effects on VECC species within the RSA for the development phases under consideration.

Cumulative effects were assessed within the RSA. Residual cumulative effects and the project contribution to these effects were evaluated using the same effect attributes used for the project effects (Table 7.10-7). The significance of cumulative effects was determined using the same criteria used to determine significance of projects effects. Whether or not a residual cumulative effect is significant is, in theory, based on a threshold between 'acceptable' (not significant) and 'unacceptable' (significant) conditions. For wildlife, such thresholds are little understood and this determination was qualitative rather than quantitative.

If a residual cumulative effect is significant (i.e., unacceptable), one of the following conclusions applies:

1. The project contribution to cumulative effects is responsible for causing the unacceptable (significant) shift. If this is the prediction, then the project contribution to cumulative effects is considered to be significant.
2. Other projects are already responsible for the unacceptable condition. In this case, the project is contributing incrementally to already significant cumulative effects.

Contributions by the project may or may not be significant, depending on the degree of change predicted and the land use priorities for the region.

7.10.7.5 Project Effects

Potential impacts on wildlife from the project may occur from changes to habitat availability, landscape disturbance creating disruptions to animal movement patterns, and population declines related to increased mortality risk. These potential effects were assessed for the seven VECCs. Project effects were highlighted for species of conservation concern.

The greatest direct loss of habitat will occur during construction as a result of clearing for the mine site facilities and the transportation corridor (TC). One of the most important project effects will be the potential for increased rates of wildlife mortality resulting from human access provided by the proposed TC, since the project area has to date been inaccessible by vehicle. Noise and traffic flow will cause behavioural disturbance and increased mortality from collisions, as well as increased access for legal hunters and poachers. At closure, there is some concern regarding wildlife access to the TWRMF with potential for mortality (if trapped in the pond) or contaminant bioaccumulation.

In the following sections, project effects are assessed for each VECC, the three key project issues and the three assessment scenarios are undertaken. Mitigation measures are identified and residual effects are characterized and significance determinations made.

Table 7.10-7 Effect Attributes for Wildlife

Attribute	Definition
Direction	
Positive	Condition of VECC is improving.
Adverse	Condition of VECC is worsening or is not acceptable.
Neutral	Condition of VECC is not changing in comparison to baseline conditions and trends.
Magnitude	
Low	Effect occurs that might or might not be detectable, but is within the range of natural variability, does not comprise economic or social/cultural values.
Moderate	Clearly an effect but unlikely to pose a serious risk to the VECC or represent a management challenge from an ecological, economic or social/cultural standpoint.
High	Effect is likely to pose a serious risk to the VECC and represents a management challenge from an ecological, economic or social/cultural standpoint.
Geographic Extent	
Site-specific	Effect on VECC confined to a single small area within the Local Study Area (LSA).
Local	Effect on VECC within Local Study Area (LSA).
Regional	Effect on VECC within Regional Study Area (RSA).
Duration	
Short term	Effect VECC is limited to 1 year.
Medium term	Effect on VECC occurs between 1 and 4 years.
Long-term	Effect on VECC lasts longer than 4 years but does not extend more than 10 years after decommissioning and final reclamation.
Far future	Effect on baseline conditions or VECC extends > 10 years after decommissioning and abandonment.
Frequency (Short Term duration effects that occur more than once)	
Low	Frequently within range of annual variability and does not pose a serious risk to the VECC or its economic or social/cultural values.
Moderate	Frequently exceeds range of annual variability, but is unlikely to pose a serious risk to the VECC or its economic or social/cultural values.
High	Frequently exceeds range of annual variability and is likely to pose a serious risk to the VECC or its economic or social/cultural values.
Reversibility	
Reversible	Effect on VECC will cease during or after the project is complete.
Irreversible	Effect on VECC will persist during and/or after the project is complete.
Likelihood of Occurrence	
Unlikely	Effect on VECC is well understood or not well understood but, in either case, is not predicted to pose a serious risk to the VECC or its economic or social/cultural values.
Unknown	Effect on VECC is not well understood and based on potential risk to the VECC, effects will be monitored and adaptive management measures taken, as appropriate.
High	Effect on VECC is well understood and there is a high likelihood of effect on the VECC as predicted.

7.10.7.5.1 Caribou

Habitat Availability

Mine construction and transportation corridors development may result in some alteration of caribou late winter and fall habitat types, key seasonal habitat requirements to sustain caribou. However, there were no caribou recorded during the Environmental Baseline Study, and the well-known Wabowden herd is using habitat located at least 30 km north of the proposed site. Moreover, trappers have also not observed this species in the area.

The majority of this effect is related to sensory disturbance from mine-related activities in the fall season for caribou, if at any moment the caribou moves near the mine site. There will likely be some recovery of habitat suitability in this area at closure. Given these projections on habitat availability, project effects although adverse are considered low in magnitude for availability of caribou winter and fall habitats. Effects will be local, long-term and reversible in the mine site area only.

Disruption to Movement Patterns

Conservation concerns exist about potential project effects on caribou habitat fragmentation and interference with caribou moving to and from important wintering ranges and calving or post-rut habitat. This could have a serious adverse effect on caribou recruitment and over-winter adult survival.

The project is likely to have unavoidable and adverse impacts on movement patterns by caribou in the area if the herd moves in the vicinity of the Project Area. However, these effects are considered low in magnitude due to the following factors:

- No caribou were observed during the wildlife surveys and by the local trappers. If they migrate to the project area, there will be extremely limited fragmentation effects on caribou movements between wintering areas and spring calving areas or post rut habitat areas for this herd.
- The following mitigation measures will be implemented, as per the project Wildlife Protection Plan (Section 9.5):
  - Access to the mine transportation corridors will be restricted to employees and contractors only during the construction, operations, and decommissioning phases of the project.
  - Vehicle traffic volumes will be monitored by VNI.
  - Wildlife will have the right-of-way on all roads, except where it is judged to be unsafe to do so.
  - Maximum speed limit on all transportation corridors will be 60 km/h.

- Traffic signs will be posted at sensitive wildlife areas.
- Snow clearing requirements will include wildlife escape routes as identified by the Environmental Superintendent.
- Project-related traffic (including ATVs and snowmobiles) will be restricted to designated transportation corridors and trails (with certain exceptions).
- Access and use of ATVs and snowmobiles for recreational purposes on the mine haul road and the mine site will be prohibited.

Additionally, a monitoring program to specifically assess caribou movements would allow managers to monitor the effects of the project on caribou movement patterns and may also provide alternative management options. Accordingly, project effects on caribou movement patterns are expected to be adverse, low magnitude, regional, and long-term.

Mine site related disturbance will cease at closure, largely reversing the low magnitude effects on caribou movement from that source.

Mortality Risk

There are conservation concerns related to project effects on regional caribou populations as a result of increased mortality risk. These include the potential for illegal harvest of the caribou resulting from increased road access into the local area by hunters, and increased caribou mortality associated with caribou-vehicle collisions. However, this has never been a problem due to the presence of PTH6 and it is assumed that it will remain unchanged. Project effects on mortality risk are considered low in magnitude during the construction, operations, and decommissioning phases for the following reasons:

- Legal hunting within the RSA and surrounding area is by a permit hunt only. This requires candidate hunters to apply for a hunting permit issued by the Manitoba Government. It is unlawful to hunt in these areas without a valid permit. In addition, no caribou hunting is permitted.
- The project transportation corridors are minor in nature and do not go far enough into the unknown range of the caribou herd.
- No caribou signs were noted in the area during the 2007/2008 field survey.

The following mitigation measures will be implemented as per the Wildlife Protection Plan (Section 9.5):

- Access to the mine haul road will be restricted to VNI employees and associates during the construction, operations, and decommissioning phases of the project.
- Firearms will not be permitted. This includes the carrying of firearms in private vehicles to and from the project site on workdays.

- Hunting and fishing are prohibited at all times on or in the vicinity of the project site, including travel to and from the project site on workdays. This restriction is applicable to all mine employees, managers and contractors. It will be in effect throughout the life of the project from construction through to closure and reclamation. Infringement of this policy is to be reported.
- Vehicle traffic volumes will be monitored by VNI on the proposed transportation corridors.
- Maximum speed limit on all access roads is set at 60 km/hr.

Project effects on caribou mortality during the life of the project are expected to be adverse, low magnitude, regional and long-term. The adverse project effects are expected to remain low in magnitude for the following reasons:

- Legal hunting within the RSA and surrounding area is by a permit hunt only. This requires candidate hunters to apply for a hunting permit. It is unlawful to hunt caribou in these areas.
- Ongoing Provincial monitoring programs to specifically assess trends in the William Caribou Herd population and movement patterns will allow managers to monitor the effects of the project on the caribou population. A cooperative program to systematically record caribou movements in the project area may support Manitoba Government studies and provide alternative management options.
- Exploration activities have already been taken place in the Minago Project Area so that it already represents a disturbance that caribous tend to avoid.

Accordingly, there will be no changes to the effects attributes at closure. The likelihood of effects as predicted is high based on knowledge of the caribou herd distribution and regulatory requirements.

Residual Project Effects and Significance

Residual project effects on caribou habitat availability during operations, for the most part, will result from sensory disturbances related to mining activities in the fall season. Thus, there will likely be some recovery of habitat suitability at closure. Mine related disturbance causing disruptions of caribou movement patterns will be greatly reduced at closure corresponding with a dramatic decrease in traffic volumes and human presence in the area. Risks of increased caribou mortality due to increased access during operations and closure will be low due to hunting restrictions and location of the project at the perimeter of the known range of the William Herd. In summary, all residual project effects on caribou are expected to be low in magnitude and therefore, are determined to be not significant using the criteria in Table 7.10-7. Mitigation measures are summarized in Table 7.10-8. Effects are tabulized at the end of this Chapter.

Table 7.10-8 Mitigation Measures for Effects on Wildlife

Potential Project Effect	Mitigation Measures
Potential exposure of wildlife to contaminants, directly and through bio-accumulation	• Mine waste segregation and management to minimize potential ARD. • Collection of waste rock drainage for treatment, if required. • Long-term storage of PAG waste rock in non-oxidizing environments (TWRMF) to minimize the potential for acid generation. • Water management to protect water quality at closure. • Environmental Effects Monitoring (EEM) and setting aside contingencies to initiate monitoring metals accumulation in vegetation and biota, and adaptive management based on monitoring results. • Implementation of the Wildlife Protection Plan (Section 9.5).
Increased wildlife mortality risk from vehicle collisions and hunting during operations	• Implementation of the Wildlife Protection Plan (Section 9.5).
Increased wildlife mortality risk, with potential effects on moose populations, from hunting and road access at closure	• Continue to implement mitigation measures identified for the project by the responsible agency at closure. • Restrict road access onto the haul road following mine closure. • Limit hunter harvest for moose in the localized area surrounding the mine haul road. • Establish no-hunting zones for moose in the localized area surrounding the mine road. • Conduct regular enforcement monitoring in the local area, including on and surrounding the mine road.
Reduction in habitat availability for all VECCs at full build-out and closure	• Compact project footprint. • Progressive and final reclamation (Section 3.4).
Wildlife and human safety risks from problem wildlife	• Refer to Wildlife Protection Plan (Section 9.5). • Refer to Solid Waste Management Plan (Section 9.4).
Increased bird mortality due to destruction of nests, collisions	• Where possible/practical, avoid clearing in nesting season (May through July). • Properly dispose of food wastes that might attract bird into collision paths. • Implement an environmental orientation program for staff and contractors of wildlife harassment.
Potential effects of aircraft on wildlife	• Adopt and follow available guidelines for helicopters and flight paths and altitudes in the vicinity of wildlife. • Provide orientation and training to all staff, helicopter pilots, guests and contractors with respect to wildlife harassment policies.
Potential Cumulative Effect	**Mitigation Measures**
Increased mortality risk for caribou, moose, bear, marten and lynx due to cumulative effects of project	• Harvest management including hunter harvest and trapping will continue to be managed and monitored by Manitoba Conservation with the intent to maintain a sustainable or below sustainable harvest of wildlife species in the area. • The hunting of wildlife within and surrounding the project area will remain a permit hunt on a quota based management system.

7.10.7.5.2 Moose

Habitat Availability

The majority of the effects on moose late-winter habitat availability are related to habitat loss and alteration rather than sensory disturbance during the construction, operations, and decommissioning phases of the project. The project effect is considered low in magnitude for the following reasons:

- The assessment of habitat loss is a conservative overestimate, by assuming all claim areas are to be fully developed as a component of the mine and transportation corridors footprint while in reality the actual footprint will be significantly smaller in area.
- The LSA provides a relatively small amount of high quality late-winter moose habitat compared to other localized areas on a regional scale.

Accordingly, project effects on moose habitat availability are expected to be adverse, low magnitude, local, and long-term. At closure, effects will be largely reversible in the mine site area but will persist at lower levels along the access road. The likelihood of this effect occurring as predicted is high based on knowledge of the moose habitat availability and use in the vicinity of the project.

Disruption to Movement Patterns

The project will have unavoidable and adverse effects on movement patterns by moose in the area. However, these project effects are considered to be low in magnitude given several mitigation measures that will be implemented during the construction, operations and decommissioning phases.

These measures include the following:

- Access to the transportation corridors will be restricted to employees and VNI associates during the construction, operations, and decommissioning phases of the project.
- Vehicle traffic volumes will be monitored.
- Wildlife will have the right-of-way on all roads, except where it is judged to be unsafe to do so.
- Maximum speed limit on all access roads will be 60 km/h.
- Traffic signs for sensitive wildlife areas will be incorporated.
- Road snow clearing requirements will be conformed to at the discretion of the Environmental Superintendent.

- Project-related traffic (including ATVs and snowmobiles) will be restricted to designated access roads and trails (with certain exceptions).
- A policy prohibiting recreational use by employees and contractors of all-terrain vehicles and snowmobiles. Access and use of ATVs and snowmobiles for recreational purposes on the mine haul road and the mine site will be prohibited. All traffic will be restricted to designated transportation corridors and trails.

Accordingly, project effects on moose movement patterns are expected to be adverse, low magnitude, local, and long-term. The likelihood of this effect occurring as predicted is low based on VNI's commitment to mitigation measures. Mine site related disturbance and traffic will cease at closure, largely reversing the low magnitude effects on moose movement from that source.

Mortality Risk

Potential increases in mortality risk to local moose populations are a concern to the Communities of Interest (COI). The primary concerns are the potential for a higher and unsustainable harvest rate on the moose population resulting from increased transportation corridors into the local area for legal and illegal hunting and increased moose mortality associated with moose-vehicle collisions.

Localized effects of the project transportation corridors are not expected to increase the average harvest rate for the regional moose population during the construction, operations, and decommissioning phases assuming implementation of the following mitigation measures:

- Access to the mine transportation corridors will be restricted to VNI employees and related associates during the construction, operations, and decommissioning phases of the project.
- Firearms will not be permitted. This includes the carrying of firearms in private vehicles to and from the project site on workdays.
- Hunting and fishing will be prohibited at all times on or in the vicinity of the Project site, including during travel to and from the Project site. This restriction is applicable to all mine employees, managers and contractors. It will be in effect throughout the life of the project from construction through to closure and reclamation. Infringement of this policy is to be reported.
- Vehicle traffic volumes will be monitored on the proposed transportation corridors.
- Maximum speed limit on all transportation corridors will be set at 60 km/h.

Project effects on moose mortality risk are therefore considered to be adverse, low magnitude, local, and long-term during the construction, operations, and decommissioning phases of the project. The likelihood of effects as predicted is high, assuming implementation of identified mitigation measures.

At closure, some of the mine transportation corridors will remain in place, if requested by the COI. VNI will not be responsible for road management at that time. If public use of the access road is allowed during and after closure, there will be a risk of increased moose mortality from legal and illegal hunting that could increase mortality rates. This would constitute a significant adverse effect on the moose population. There are various mitigation options that could be employed at closure to mitigate this effect. These include:

- Continue to implement mitigation measures identified for the project, by the responsible agency at closure;
- Close and decommission the unused transportation corridors following mine closure;
- Restrict road access onto the site following mine closure;
- Depend on the Manitoba Government to limit hunter harvest for moose in the localized area surrounding the mine transportation corridors;
- Request the Manitoba Government to establish no hunting zones for moose in the localized area surrounding the mine site and related transportation corridors; and/or
- Request the Manitoba Government to conduct regular enforcement monitoring in the local area, including on and surrounding the mine site.

If adequate mitigation measures to decrease mortality risk to moose will be established at closure, this residual project effect will likely remain non significant.

Accordingly, project effects on moose mortality at closure are expected to be adverse, moderate magnitude, regional, and far future in duration. The likelihood of this effect occurring as predicted is unknown due to the current uncertainty about implementation of mitigation measures at closure.

Residual Project Effects and Significance

Residual project effects on moose winter habitat availability and on disruption to moose movement patterns at closure are considered to be low magnitude since: (1) the mine area will be reclaimed and re-vegetated following the closure phase and (2) the volume of mine traffic on the transportation corridors will decrease following mine closure. Accordingly, project effects at closure are expected to be not significant.

The likelihood that effects on habitat availability will occur as predicted is high, based on conservative assumptions regarding the actual project disturbance footprint, the abundance of available habitat in the area, and the proposed mitigation measures.

Residual effects on moose mortality during the life of the project are expected to be not significant given the proposed mitigation measures. However, residual project effects on moose mortality risk at closure and following closure are considered to be low in magnitude at this time as some of the transportation corridors will be decommissioned, thereby restricting access to the site.

Accordingly, project effects at closure are expected to be adverse, low magnitude, regional, and potentially far future. This would constitute an insignificant effect.

The likelihood that effects on mortality rates will occur as predicted during the life of the project is high, based on the proposed mitigation measures. The likelihood that effects on mortality rates will occur as predicted at closure is unknown, as the management regime and implementation of mitigation options cannot be confirmed at this time. Potential effects at closure are mitigable. Agreements and mechanisms for management of some of the transportation corridors, if they remain open at closure, will be determined by the Manitoba Government in consultation with the COI and other interested parties. Until these measures are confirmed, the significance of this effect has been determined to be “unknown”. If all the transportation corridors (TC) (incl. the access road) are decommissioned, then the effect will be low. The decision whether to decommission the TC will be undertaken in consultation with the COI.

7.10.7.5.3 Black Bears

Habitat Availability

There were no bears sited during the wildlife survey. The large decrease in very high and high quality black bear habitat availability in the LSA at full build-out is considered to be a low magnitude effect because:

- relatively large amounts of very high and high quality habitat remain abundant outside the zone of project influence after development;
- on a regional scale, these losses are not expected to be substantial;
- very little bear signs were noted in the area during the 2007/2008 field surveys;
- an increase in moderate quality habitat moderates the losses to high quality sites to some degree; and
- the assessment of habitat loss is based on a conservative overestimate, by assuming all affected claim areas will become low quality or unusable habitat. The actual footprint will be considerably smaller, but use of this conservative method ensures that project related sensory effects for this disturbance-sensitive species are fully accounted for.

The food sourcing habits of black bears living in the northern boreal forest are understood only in general terms, especially in and surrounding the project area where black bears are not well studied. The omnivorous and opportunistic feeding behaviour of bears means that they will use a variety of foods according to availability within their ranges. Generally, black bears in more southerly regions prefer to feed on vegetation. More northerly ecotypes often feed on proportionally more animals, such as caribou, though they continue to rely heavily on vegetation. Due to the habitat requirements of black bears for specific vegetative units and soil types, project effects on habitat loss are deemed likely to have a long-term impact on a local scale because of the long time period required for the vegetation to regrow to a state preferred by the bears along disturbed and reclaimed areas of the Transportation Corridors (TC), mine site, the Tailings and Ultramafic Waste Rock Management Facility (TWRMF) and the waste rock dumps.

Accordingly, project effects on black bear habitat availability at full build-out are expected to be adverse, low magnitude, local, and long-term. The likelihood of this effect occurring as predicted is high based on VNI's commitment to mitigation measures.

Mine site related disturbance and traffic will cease at closure, reversing the effects on habitat availability in much of the project site. Traffic on the TCs at closure is expected to be greatly reduced at closure. Therefore, effects at closure are reduced to low magnitude but will be far future in duration. The likelihood of effects as predicted is high based on the conservative approach used in the assessment. Any changes from predicted effects would be expected to be towards a lower level of impact.

Disruption to Movement Patterns

Overall, most carnivores are intimidated by highways and TCs and tend to avoid them when possible (Jalkotzy et al., 1997). Black bears use areas near low use roads, but tend to avoid high use roads (Chruszcz et al., 2003). Bears tend to cross near areas of high quality habitat, or when traveling from low to high quality sites. As well, they are at extra risk of mortality, when crossing roads to reach required high quality habitats at different seasons or due to temporal foraging requirements (Chruszcz et al., 2003).

Copeland (Western Forest Carnivore Committee, 1994) and others (Gibeau and Heuer, 1996) have noticed that carnivore home ranges tend to be along highways, rather than crossing them, implying that movement behaviour is being disrupted, with the road forming an artificial boundary of an individual animal's home range. In addition to traffic volumes and vehicle types, road design itself can become part of the reason carnivores fail to cross. Fences, right-of-way clearance widths, cut slope grade and line of sight are design elements that can affect the ability of wildlife to attempt to cross and to cross safely (Ruediger, 1996). As traffic volume increases on roadways, the impacts of habitat fragmentation, mortality and displacement increase. However, there is a growing body of knowledge that two lane highways with low or moderate traffic volume can be negotiated by many wildlife species, particularly when long traffic pauses occur.

Based on these findings, bears are expected to avoid areas around the TCs and mine site during full build-out. Projected traffic volumes on the TCs will be monitored and will be relatively low, and bears are expected to avoid the road but remain able to cross in periods between vehicles.

In summary, the project will result in avoidance around the mine site and some movement disruptions due to the TCs, resulting in an adverse, low magnitude, local and long-term effect. Mortality on the TCs will be monitored during operations to check this prediction and implement adaptive management measures, if required. Project disturbance will cease at closure, reversing much of this effect. Effects at closure will persist into the far future.

Mortality Risk

Carnivores are particularly susceptible to mortality because of their large home ranges, low biological productivity, and the extensive areas required for sustaining stable populations and individuals. Due to the long life span of bear (over 30 years), they can persist as individuals, without persisting as populations. In this context, human caused mortalities can be important. Bears are rarely killed on highways. The rare occurrences of bear mortality are likely due to their general avoidance of highways and their low population numbers and densities. However, to a species with such a low reproductive rate as bears, even a small number of deaths can be of great importance to the population (Gibeau and Heuer, 1996). At some combination of traffic volume and road design, roads become barriers or mortality sinks for carnivores, even when adjacent land uses and habitat availability are compatible with their existence there. Increasing evidence shows that this occurs when highways are 4-laned or twinned, which is usually correlated with increased traffic volumes. At some point, large and mid-sized carnivores cannot compensate for the increased mortality, or they stop trying to cross busy highways. There is also a growing body of knowledge indicating that two lane highways with low or moderate traffic volume can be negotiated by many wildlife species, particularly when long traffic pauses occur.

Project effects on bear mortalities from collisions during full build-out are expected to be adverse, low magnitude, local and long-term, because of the fact that traffic volumes will be confined largely to the LSA and the PTH6, black bear avoidance of human use areas, and the related low probability of black bear mortality observed on other roads of this type. Wildlife mortalities in the LSA and along PTH6 will be monitored during operations. If bears are struck on the road, adaptive management measures, such as institution of traffic pauses to allow wildlife to cross will be considered. At closure, project related traffic will cease, with a corresponding reduction in the risk of wildlife collisions. Effects at closure are predicted to be low magnitude and far future. The likelihood of effects as predicted are high based on observations of road-related mortality elsewhere and mitigation measures for other wildlife such as speed limits, and environmental orientation for project personnel and contractors.

Human conflicts can also result in bear mortality. Neilsen et al. (2004) found that the highest risk of mortalities for bears in the Central Rockies Ecosystem was related to proximity to human disturbances. Areas nearer than 500 metres from human habitation or roads and closer than 200 metres from human use trails were, where bears were at greatest risk of mortality. This was due to increased problem human-bear interactions revolving around food and increased hunter and poacher access.

The mine will bring an increase in human activity to the area and increase the risk of human-bear conflicts due to food waste attractants and maybe increased access for hunter sand poachers. Proper management of food waste attractants (Section 9: Environmental Management Plan) will minimize risks of mortality to problem wildlife. As noted earlier, controlled access and prohibition of firearms or hunting by project personnel along the access road will prevent wildlife mortality from this source during operations. The risk of mortality from hunting may increase at closure, if access is not controlled. While various measures are feasible to reduce this risk, management of the site at closure is currently unknown, as some COI may want to keep some of the facilities and infrastructures open for other uses. Project effects on black bear mortality at full build-out and closure are expected to be adverse, low magnitude, local and long-term to far future in duration. The likelihood of effects as predicted is high during operations based on the effectiveness of mitigation measures. The likelihood of effects at closure is unknown as access management measures are uncertain.

At closure there is potential for wildlife, including black bears, to be exposed to contaminants accumulated in vegetation affected by contaminated discharges or drainage.

Collection and treatment of site drainage and process waters to achieve high quality effluent during operations, and measures to prevent mobilization of contaminants will minimize the risk of bioaccumulation in the vegetation on site. No effect on wildlife is anticipated.

Residual Project Effects and Significance

All residual project effects on black bear are expected to be low magnitude and local in extent. Based on criteria listed in Table 7.10-7, these effects are determined to be not significant (as tabulized at the end of this Chapter). Potential adverse effects on habitat availability, while moderate in the context of the LSA, are low in a regional context and largely reversible at closure. Disturbance to movement patterns is unlikely, due to the low level of bear activity in the area.

Black bear mortality from road collisions and hunting can be effectively mitigated during operations and at closure. The likelihood for effects occurring as predicted at full build-out is high, based on conservative assumptions for disturbance footprint, the effectiveness of mitigation measures and observations of black bear behaviour in comparable circumstances. Management measures at closure have not been confirmed, the likelihood of mortality effects occurring as predicted is unknown, as some COI may want to keep some of the facilities and infrastructures open. Should this be the case, appropriate management measures will be developed by the Manitoba Government in consultation with the COI and other interest holders. Observations of bear activity in the vicinity of the project during operations and reporting of mortalities, should they occur, will provide information for adaptive management measures, if necessary.

7.10.7.5.4 Beaver

Habitat Availability

Conservation concerns for this species are relatively few due to the beaver’s adaptability to human disturbance (Foote, 2005). Beavers, in fact, find road beds and culverts attractive due to the reduced effort it takes to dam a culvert instead of a whole waterway in order to flood land (Martell, 2004).

Project disturbances within 50 m of beaver habitat were considered as impacts and are assessed in terms of effects on habitat area. The overall decrease in the available beaver habitat (confirmed use and potential wetlands) in the LSA during full build-out is low. Effects therefore are characterized as adverse, low magnitude, local and long-term. The small habitat reductions due to disturbance effects at full build-out are expected to be largely reversible at closure. The likelihood of this effect occurring as predicted is high based on knowledge of beaver activity in relation to human disturbance.

Disruption to Movement Patterns

Disruption to movement patterns is a concern for beavers in areas where project roads and mine development cross streams, fragmenting suitable habitats for beavers. This effect is expected to be low in magnitude given:

- Facility siting and road routing attempts to avoid wetland habitats as much as possible as part of the engineering design. However, this will not always be possible because the site is predominantly muskeg.
- Beavers adapt well to disturbances including roads and project developments.
- Mitigation measures to reduce potential effects on beaver movement patterns include:
  - Restricting use of machinery and vehicles in beaver wetlands and surrounding riparian areas, where possible.
  - Access to the mine site will be restricted by a locked gate during the construction, operations and decommissioning phases of the project. Only project related users will be allowed.

Project effects on beaver movement patterns are expected to be adverse, low magnitude, local and long-term to far future. Effects of disturbance on beaver movements will be largely reversed at closure. The likelihood of this effect occurring as predicted is high based on knowledge of beaver activity in relation to human disturbance.

Mortality Risk

Mortality risk to beaver may result from vehicle collisions and/or from direct removal of beavers from the project area by mine staff and associated personnel. However, conservation concerns for this species are relatively few due to the beaver's adaptability (Foote, 2005). Beavers are known to have a fast rate of population recruitment and may rapidly colonize areas. Furthermore, the areas within the local and regional study areas support relatively healthy beaver populations. Project effects on beaver mortality are expected to be low in magnitude based on the following mitigation measures:

- Access to the mine will be restricted by a locked gated during the construction, operations, and decommissioning phases of the project.
- Firearms will not be permitted on site. This includes the carrying of firearms in private vehicles to and from the project site on workdays (for project related employees and associates).

- Hunting and fishing will be prohibited at all times on or in the vicinity of the project site, including during travel to and from the site on workdays. This restriction is applicable to all mine employees, managers and contractors. It will be in effect throughout the life of the project. Infringement of this policy is to be reported.
- Vehicle traffic volumes will be monitored on mine roads.
- Maximum speed limit on all access roads is set at 60 km/h.

Project effects on beaver mortality, while potentially adverse, are expected to be low in magnitude, local, long-term and largely reversible at closure. The likelihood of effects occurring as predicted is high, based on the effectiveness of mitigation measures.

Residual Project Effects and Significance

All project effects on beaver are expected to be of low magnitude, local extent and long-term in duration. Based on criteria, defined in Table 7.10-7, these effects are determined to be not significant. The likelihood of effects occurring as predicted is high, based on the knowledge of beaver response to human behaviour and the effectiveness of identified mitigation measures.

7.10.7.5.5 Lynx Habitat Availability

Although there is a large decrease in high and moderate quality lynx/snowshoe hare habitat availability in the LSA at full build-out, this is considered to be a low magnitude effect because:

- high quality habitat is not abundant within the LSA;
- there are no structurally complex forests within the LSA;
- on a regional scale, these losses are not expected to be substantial; and
- the assessment of habitat loss is based on a conservative overestimate, by assuming the total area of all affected claim areas will become low quality or unusable habitat.

The actual footprint will be smaller, but use of this conservative method ensures that project related sensory effects for this disturbance-sensitive species are fully accounted for.

Lynx depend on more structurally complex forests (Mowat et al., 2000), though they may use young forests with sufficient structural complexity to provide hunting cover. Based on this requirement for older and more structurally diverse forests, project effects of site and access road clearing are deemed to be far future in duration, because of the long time period required to regenerate mature forest.

Accordingly, project effects on lynx habitat suitability are expected to be adverse, low magnitude, local and far future. Reductions in habitat availability due to disturbance will be reversible at closure, but loss of habitat on the transportation corridors may persist. The likelihood of effects occurring as predicted is high based on the conservative disturbance footprint and abundance of available high quality habitat.

Disruption to Movement Patterns

Lynx, because of their requirements as a large predatory animal, require relatively large areas of land in which to hunt and live. This means that individuals need to move large distances on the landscape in order to fulfill their minimum requirements for survival.

Lynx are a shy ‘stalk-and-pounce’ predator that prefers to avoid human contact, and they have been observed to avoid large openings during daily movements within their home ranges (Koehler,1990; Staples, 1995). This is partially due to a lack of hiding cover for hunting and avoiding possible exposure to larger predators. A study of lynx behaviour in relation to intensity of traffic on roads and highways found that this species is reluctant to cross high-use roads, but will more readily cross those with lower traffic volumes, and with no centerline barrier.

The transportation corridors are unpaved and will have less traffic volume than the roads in the studies cited above. Lynx are thus expected to cross any forest gap caused by the haul road without great difficulty. Any avoidance of the haul road traffic or reluctance to cross by lynx should be reversible at closure.

Changes in the landscape from project development will break formerly contiguous blocks of suitable lynx habitat into smaller patches, and will create some impediment to movement of lynx across the haul road and in the vicinity of the mine site and TWRMF. Potential habitat fragmentation caused by the location of the mine site will occur in generally low suitability habitat; therefore, effects to movement are considered to be low magnitude, and ultimately reversible.

In summary, project effects on lynx movements are expected to be adverse, low magnitude, local and far future. Disturbance barriers to movement will be reversible at closure while any physical barrier caused by the road corridor will persist. The likelihood of effects occurring as predicted is high, based on knowledge of lynx behaviour related to crossing roads like the transportation corridor.

Mortality Risk

Due to the relatively long life spans of lynx (over 12 years), they can continue existing as individuals without persisting as populations, making assessments of population effects difficult without long-term assessment or resorting to population modeling. Despite behavioural avoidance of roads, lynx are occasionally killed on the Trans-Canada Highway in Banff National Park (Gibeau and Heuer, 1996). In the north, occurrences of lynx highway mortalities have been documented in Alaska (Staples, 1995). Given the reported occurrence of lynx mortality on roads, it is possible that haul roads traffic could result in lynx mortality.

The risk and magnitude of mortality at full build-out is expected to be low given the speed restrictions (60 km/h), in comparison to situations in other studies where road related mortalities were observed (Gibeau and Heuer, 1996; Theil, 1987; Staples, 1995). In addition, lynx are expected to change their behaviour to avoid the cleared and high human-use mine site area.

At closure, there is a risk that the presence of the transportation corridor may increase trapping success. Effects on the local and regional lynx population could increase to moderate magnitude in years when the lynx population cycle is low. The project may give access to habitat that was once a refuge, and depress the population when it is in a vulnerable recovery phase. Depressing population growth at such a site may reduce overall lynx population recovery by removing individuals that could spread to re-establish populations at other sites (Ruediger, 1996). However, it is unlikely that these effects will occur as there are numerous areas of refuge habitat in the vicinity of LSA to support the regional lynx population.

Accordingly, project effects on lynx mortality are expected to be adverse, low magnitude, local and far future. Effects will be partially reversed at closure. The likelihood of effects occurring as predicted is high, based on knowledge of lynx behaviour related to crossing transportation corridors and the abundance of refuge habitat in the project area.

Residual Project Effects and Significance

All adverse residual project effects on the lynx VECC and snowshoe hare are expected to be low magnitude and local (as tabulized at the end of this Chapter). Effects in the LSA are largely offset by the abundance of lynx/snowshoe hare habitat in the area. Effects of clearing on habitat availability are expected to be far future in duration, based on the time required for recovery of more mature forest stands that are the preferred habitat of lynx.

Using the criteria listed in Table 7.10-7, project effects on lynx/snowshoe hare are determined to be not significant. The likelihood of these effects occurring as predicted is high, based on available information concerning lynx response to human disturbances and the abundance of high quality habitat in the project area.

7.10.7.5.6 American Marten

Habitat Availability

The majority of the effects on marten habitat availability are related to habitat loss and alteration rather than sensory disturbance during full build-out. Moderate winter habitat for marten within the LSA represents a relatively small proportion of habitat available within the RSA. There is no high quality winter habitat rated in the LSA relative to a broader boreal forest scale benchmark for marten. This region contains no area of high suitability habitat, under full build-out. However, since the projected footprint of the mine road is overestimated and as there are no high quality habitats for marten in the LSA, the project effects, although adverse, are judged to be low in magnitude. Since marten depend on older and more structurally complex forests (Poole et al., 2004), this effect is deemed likely to have a far future duration due to the long time period required for the re-growth to a mature forested state.

In general, habitat availability is expected to decrease at full build-out and return to slightly lower than baseline values at closure. This change is expected because construction and operational activities will remove some available habitat (through direct habitat loss and sensory disturbance), which will then be reversed by lower activity and mitigation measures such as re-vegetation at closure. During operations, the effects of cleared land on marten habitat may be mitigated to some degree by leaving slash piles for cover enhancement. Marten are known to use slash piles as a preferred part of their habitat (Slough, 1989; Buskirk and Powell, 1994; Poole et al., 2004), and leaving the brush and woody debris from the road clearings may add some habitat quality for marten following post closure.

Project effects on habitat availability for marten are expected to be adverse, low magnitude, local and far future. Effects will be partially reversible at closure, but those associated with the road corridor will persist. The likelihood of effects occurring as predicted is high given the lack of good habitat in the LSA, the conservative size of the disturbance footprint and the opportunity for some mitigation of habitat loss.

Disruption to Movement Patterns

Some behavioural effects causing disruption to the movement patterns of marten may result from vegetation clearing and vehicle traffic associated with the transportation corridors (TCs) and mine site. Project effects associated with habitat loss and alteration will fragment moderate habitat patches into several disjunct smaller blocks, and potentially cause disruptions to marten movements between these patches.

Marten have been observed to cross high-use roads less frequently than low use roads (Alexander and Waters, 2000; Clevenger et al., 2001), implying that movement disruptions may occur for marten due to the haul road. However, because the mine site transportation corridors will be confined to the LSA and will have less traffic volume than did the roads in those studies, marten are expected to cross the forest gap caused by the TCs without great difficulty. Similarly, the width of the TCs and adjacent clearings is expected to be relatively narrow (less than 35 m), which is likely to facilitate marten movements.

It has been shown that small territorial animals such as marten will avoid project footprints during actual construction, but will not significantly shift their territorial distributions in response to rights-of-way activities (Eccles and Duncan, 1987; Morgantini, 1994). As the density of disturbance is low in the project areas, impacts resulting in habitat fragmentation and isolation are unlikely.

Project effects on disruption to marten movement patterns are expected to be adverse, low magnitude, local and long-term. Effects will be partially reversible at closure. The road will remain, but traffic will be substantially reduced. The likelihood of effects occurring as predicted is high based on observations of marten movements related to similar sized TCs and the fact that the disturbance footprint will be confined to one area (LSA), with no other habitat fragmentation in the project area.

Mortality Risk

Mortality risk to marten from the project development is expected to arise from two separate sources: collisions with project vehicles or machinery and direct mortality from road collisions or machinery.

Although expected to some degree, mortalities caused by collisions and machinery are expected to be minimal because of the controlled traffic volume. Other traffic control measures (speed limits, signage) will reduce the risk of collisions during operations. If traffic volume increases, vehicle departures could be staggered, to create gaps, which would allow marten and other wildlife to cross the road. Since marten tend to change their use behaviours in relation to areas of high human use, it is expected that they will avoid the mine site unless attracted by poorly managed food wastes. Indeed, it is likely that martens have already started to avoid the Minago Project Area, since exploration activities have been taken place in the area.

Residual Project Effects and Significance

All project effects on marten are expected to be low magnitude and local. Based on criteria listed in Table 7.10-7, effects are determined to be not significant. Effects on habitat in the mine site area and those related to human disturbance and road traffic will be largely reversible at closure, but effects associated with the road right-of-way will persist. The likelihood of effects occurring as predicted is high.

7.10.7.5.7 Song Bird Community

Habitat Availability

Edges in the landscape are important because they interface between two different types of environment or habitat. They share characteristics of both adjacent areas but have a unique character of their own. Some species require large sections of contiguous habitat and may not be able to live in areas where edges occur, a process referred to as ‘edge effects’ (Ries et al., 2004). For example, individuals of a forest-dependent species living in an area adjacent to a disturbance may become more susceptible to predators that use the clearings to move around the landscape. At the regional scale, human developments often contribute to creation of edge environments, and there is potential for edge effects as a result of project development. The very conservative approach taken in this habitat analysis implicitly accounts for the possibility of ‘edge effects’, by assuming that a large area around the construction sites will become unsuitable habitat.

Disturbance by roads and construction is known to negatively affect the habitat use by passerine birds, reducing densities of many species in broad zones of woodland and open habitat adjacent to noisy developments and busy roads (Reijnen et al., 1997). To avoid this potential problem, construction activities for the project may be timed to avoid the time of year when migrant passerine birds are living in the area (the incubating and fledging period for most species is May to July). Winter-resident species are highly mobile and, in the event of disturbance from project construction, will be able to select alternate habitat situated away from the source of disturbance along the project footprint. Year-round resident bird species may be exposed to sensory disturbance and reduced habitat availability. These individuals will likely relocate away from the sources of disturbance.

Estimated effects are very conservative to ensure that they encompass any potential effects. During full build-out, actual losses are predicted to be minor within the LSA/RSA. Where possible, efforts will be made to minimize the effects of forest loss, but may impact species that prefer open spaces. However, there were no signs of migrant birds recorded during the survey. Residual project effects are expected to be adverse, low magnitude, local, long-term and partially reversible at closure when the mine site is revegetated and traffic is greatly reduced. The likelihood of effect is unknown, but the conservative assumptions used in the assessment suggest that effects are not likely to be greater than predicted.

Disruption to Movement Patterns

Movement of individuals at local, regional and even global scales is a key process in maintaining animal populations. Usually disturbance results in a primary effect from the simple loss of habitat area. Fragmentation of habitat caused by breaking up larger contiguous blocks of habitat by natural and anthropogenic disturbances has been shown to strongly affect most species, including birds, by affecting their movement behaviour (Bélisle and St-Clair, 2001). For example most birds were found to follow strips of forest (travel corridors) to avoid crossing forest gaps of greater than 25 m (St-Clair et al.,1998). However, when relocated across the road they were reluctant to re-cross rivers and noisy roads such as the high-use Trans-Canada Highway (~50 m width), but were not averse to crossing smaller forest gaps or quieter roads (St-Clair, 2003). If the density of disturbances reaches a critical threshold, there may also be a state where the remaining patches of habitat have become isolated from each other (Andren,1996). This results in even lower habitat quality. The combined effect of habitat loss and isolation of remaining habitat patches act synergistically to have a negative impact on the disturbance affected species.

In the LSA, some unavoidable disturbance to movements is expected to occur around the pit, the TWRMF, and the waste rock dumps due to habitat clearing and heavy machinery. Both factors are expected to result in some reluctance by the birds to cross road right-of-ways. The haul road right-of-way is expected to be under 35 m and birds have been noted to cross natural gaps of up to 200 m (St-Clair et al., 1998). For the project area, the density of disturbance is low because there is only one haul road proposed. This means that cumulative development impacts resulting in habitat fragmentation and isolation are unlikely. Currently, birds have been observed to cross PTH6.

Accordingly, effects of full build-out on songbird movement patterns are expected to be adverse, low magnitude, local, long-term and partially reversible at closure. The likelihood of effects occurring as predicted is high, based on the project design and observations of bird behaviour at road crossings.

Mortality risk

Direct mortality of individuals may also affect bird populations. Potential sources of bird mortality at the project include:

- bird strike by vehicles or machinery while attempting to cross project clearings; and
- direct or indirect destruction of nests by clearing or disturbance causing nest abandonment.

Mitigation measures include:

- waste management to minimize bird attraction into oncoming vehicles or flight paths; and
- avoidance of clearing during the nesting season (May to July).

Monitoring to check water and sediment quality and vegetation analysis will examine potential pathways of bird exposures to contaminants and flag any concerns that might require adaptive management. Based on these measures, residual project effects on songbird mortality are expected to be adverse, low magnitude, local, and long-term. Effects due to clearing and traffic during full build-out will be reversed at closure. The likelihood of effects occurring as predicted is high based on the effectiveness of mitigation measures.

Residual Project Effects and Significance

All residual project effects on songbirds are expected to be of low magnitude and local extent. Based on criteria listed in Table 7.10-7, these effects are determined to be not significant. Effects will be partially reversed at closure due to mine site reclamation and reduced traffic and human disturbance. Persistent effects due to ongoing road use will be functionally irreversible. The likelihood of effects on habitat availability is unknown, but predictions are considered to be conservative and effects are unlikely to be of higher magnitude than predicted. The likelihood of project effects due to movement barriers and mortality occurring as predicted is considered high, based on the effectiveness of mitigation measures.

7.10.7.6 Residual Project Effects and Significance

Residual project effects on wildlife VECCs and significance determinations were made at the end of each preceding section.

7.10.7.7 Cumulative Effects

Based on the project effects described in this section, the main concern with respect to potential cumulative effects is increased mortality risk for VECC species, with extensive home ranges or movement patterns that might encounter other sources of mortality risk in daily or seasonal movements. This concern is low for caribou, black bear, marten, and lynx.

Residual project effects were identified for the VECCs; all were low magnitude except for moose, which were expected to be low to moderate at closure.

Other facilities or activities within the range of these species that could contribute to cumulative effects include:

- PTH6 - increased traffic on the southern and northern legs of the PTH6 associated with operation of the mining operations in Snow Lake and Thompson. The likelihood of effects from this is unknown due to various factors (e.g., potential highway improvements, traffic volumes, and associated effects on nonindustrial traffic).
- Harvest management including hunter harvest and trapping will continue to be managed and monitored by Manitoba Conservation with intent to maintain a sustainable or below sustainable harvest of wildlife species in the area.
- The hunting activities within and surrounding the Project area will remain a permit hunt on a quota based management system as per Manitoba Government Regulations.

7.10.7.8 Residual Cumulative Effects and Significance

Given the general uncertainty with expected management directions of the project road networks (as some COI may want them to stay open) at closure, it is difficult to accurately assess the residual cumulative effects on mortality risk for moose. If all TCs associated with the project are decommissioned, there will be no mortality due to the project. During construction, operations, and decommissioning, the Project will be able to largely control access and subsequent effects of mortality along the TCs. Following closure and in the event that COI want some of the infrastructures to be left in place for other uses, the management of TCs will no longer be in the proponent’s control. If not managed well, the increased access into high quality moose habitat may have significant effects on local moose populations. However, it is likely that residual cumulative effects at a regional level will not be significant for the following reasons:

- Moose mortality risk associated with the TCs is minimal;
- Traffic volumes on the site road network are likely to decrease following closure;
- Traffic volumes and traffic speed on the PTH6 have a limited potential mortality risk for moose in the RSA;
- Agreements and mechanisms for management of the site TCs at closure will likely be determined by the Manitoba Government and the COI, in consultation with interested parties.

Residual cumulative effects for mortality risk associated with caribou are considered to be adverse and not significant. These effects are considered low in magnitude for several reasons. First, mortality resulting from caribou–vehicle collisions is considered to be low in the LSA since traffic volume associated with the site wide road network will decrease following Project closure and traffic volumes are not predicted to change along the PTH6 within areas overlapping the range of the William Caribou Herd in the future. Second, the harvest of caribou within and surrounding the LSA and RSA is not permitted. Residual cumulative effects on caribou are thus considered to be not significant with a high prediction confidence given mitigation measures already in place and ongoing monitoring of the regional caribou population by Manitoba Government.

Residual cumulative effects on mortality risk to black bears are considered to be adverse and not significant, low in magnitude and far future in duration. The magnitude of these effects was considered low since: 1) black bear-vehicle collisions within the LSA and RSA affecting mortality are likely to be minimal as traffic volumes are likely to decrease following project closure; 2) black bear and human interactions are likely to decrease in the area following project closure since there is likely to be less human presence in the area after project closure; and 3) black bear density in the area is relatively low when compared to the remainder of the Manitoba and surrounding areas that likely support the area's bear population. Prediction confidence for this residual cumulative effects assessment on black bear mortality risk is considered to be moderate given a limited understanding of black bears in the region.

Residual cumulative effects on American marten and lynx VECCs and snowshoe hare are considered not to be significant, low in magnitude, and far future in duration. The potential residual cumulative effects of greatest concern are from wildlife-vehicle collisions, increased trapping harvest and chronic poisoning by ingestion and maybe by bioaccumulation of residual contaminants from the mine tailings and milling waste that may potentially increase the mortality risk to the respective species population. These mortality risks are, however, expected to be minimal since: (1) mining operations in the LSA and RSA mitigate wildlife interactions with residual contaminants during the life of mine operations and as well as plan for remediation after project closure; and (2) Manitoba Conservation monitors trapping harvest in the area.

The prediction confidence is considered moderate to high in this assessment given the minimal level of cumulative disturbances currently assessed within the RSA and the mitigation processes already in place, as discussed. Several monitoring and mitigation practices are recommended with respect to improving predictive capabilities of this residual cumulative effects assessment and/or for implementing a process of adaptive management practices to learn from potential mitigation measures.

7.10.7.9 Mitigation Measures

Many mitigation measures for wildlife have been compiled into the Wildlife Protection Plan in Section 9.5. Other measures are integrated into the site waste management plans including water management and tailings management to achieve high quality discharges and minimize the risk of metals accumulation in vegetation used by wildlife. At closure, the pit and TWRMF will be reclaimed as a permanent pond facility and contents will be physically and chemically stable. The risk of wildlife exposure to contaminants will be minimal. TCs, if requested to remain open by COI, will need to be addressed accordingly. Mitigation options will be developed by the Manitoba

Government, the COI and other interest holders as appropriate to support preferred use and minimize potential adverse effects on wildlife (Table 7.10-8).

7.10.7.10 Monitoring and Follow-up

Follow-up Studies

In order to improve predictive capabilities for project effects at closure, it is recommended that follow-up work includes development of an Access Management Plan for the TCs (if some COI want the roads to remain open) at closure, with emphasis on measures to minimize risk of moose mortality and associated effects on regional population sustainability. As the agents responsible for management of the road at closure, it is recommended that the COI and Manitoba Government lead this work, in consultation with other interested parties.

Monitoring Programs

Onsite wildlife monitoring programs will be conducted by VNI during the life of the project that will include:

- where practical, systematic documentation wildlife sightings in or near the project area, road kills, and problem wildlife incidents; and
- systematic documentation of wildlife use of reclaimed habitats.

These programs are specifically intended to check mortality predictions and mitigation effectiveness (Section 9.5: Wildlife Protection Plan) and guide adaptive management as required.

The onsite environmental monitor will maintain systematic records of wildlife observations, and incidents (e.g., wildlife-vehicle collision, aggressive bear observation) in or near the project area, which will be kept in a 'wildlife log'. Reports will include the date, time, description of location, species, number of individuals, and the activity (e.g. feeding, nesting).

The following monitoring programs and, where applicable, adaptive management strategies, are proposed:

- **Wildlife-vehicle mortalities** – Large mammal mortalities or accidents along TCs will be recorded and reviewed, where possible. If road kills occur within the LSA, corrective actions or additional mitigation measures (e.g., lower speed limits, warning signs, improvement of visibility, worker advisories) may be implemented.
- **Problem wildlife** – Problem wildlife incidents will be monitored and recurrent incidents will precipitate a re-evaluation of the effectiveness and enforcement of existing prevention measures.

- **Black bears** – Observations of black bears or their signs (e.g., tracks, scat) in and around the project area will be recorded. These observations will informally track black bear use patterns within the project area through all development phases.

The proposed monitoring program and follow-up programs for wildlife are summarized in Table 7.10-9.

7.10.7.11 Summary of Effects

Residual project and cumulative effects are summarized in Table 7.10-10 during construction and in Table 7.10-11 during Closure.

Table 7.10-9 Monitoring and Follow-up Programs for Wildlife

Potential Project Effect	Program Objectives	General Methods	Reporting	Implemen-tation
Follow-Up Programs				
Management of the TC at closure	• Confirm the accuracy of the effects predictions. • Initiate contingency plans to address unexpected effects, as required.	• Consult with Manitoba First Nations, Norway House Resource Management Board and other interested parties relevant to the development of a Wildlife Protection Plan for the TC at closure.	• N/A	MB Gov.'t
Wildlife vehicle mortalities	• Confirm the accuracy of the effects predictions. • Initiate contingency plans to address unexpected effects, as required.	• Record and report incidents.	• MB Gov.'t as required	Proponent
Problem Wildlife	• Confirm the accuracy of the effects predictions. • Initiate contingency plans to address unexpected effects, as required.	• Record and report incidents.	• MB Gov.'t as required	Proponent
Bear/project interactions	• Confirm the accuracy of the effects predictions. • Initiate contingency plans to address unexpected effects, as required.	• Record observations of bear signs and activities in the project area.	• MB Gov.'t as required	Proponent
Exposure to contaminants and potential bioaccumulation of metals	• Confirm the accuracy of the effects predictions. • Initiate contingency plans to address unexpected effects, as required.	• Conduct Environmental Effects Monitoring (EEM). • Conduct vegetation metals analysis.	• EEM reports as required	Proponent
Monitoring Programs				
Moose and caribou mortality	• Confirm the accuracy of the effects predictions. • Initiate contingency plans to address unexpected effects, as required.	• Conduct ongoing Manitoba regional population monitoring.	• N/A	MB Gov.'t

Table 7.10-10 Program Effects on Wildlife during Construction

VECC	Potential Effect	Level of Effect[1]						Effect Rating[2]	
		Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effective
Construction									
Moose	Reduction in seasonal habitat availability due to clearing and sensory disturbance	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	Not significant
	Disruption to movement patterns due to habitat fragmentation and sensory disturbance	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	Not significant
	Increased mortality risk from collisions	Adverse	Low	Local	Long-term	Irreversible	High	Not significant	Not significant
Woodland Caribou	Reduction in seasonal habitat availability due to clearing and sensory disturbance	Adverse	Low	Local	Long-term	Partially reversible	High	Not significant	Not significant
	Disruption to movement patterns due to sensory disturbance	Adverse	Low	Regional	Long-term	Reversible	High	Not significant	Not significant
	Increased mortality risk from collisions	Adverse	Low	Regional	Long-term	Irreversible	High	Not significant	Not significant
Bears	Reduction in seasonal habitat availability due to clearing and sensory disturbance	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	Not significant
	Increased mortality risk from collisions and site conflicts	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	Not significant
	Disruption to movement patterns from sensory disturbance	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	Not significant

Table 7.10-10 (Cont.'d) Program Effects on Wildlife during Construction

VECC	Potential Effect	Level of Effect[1]						Effect Rating[2]	
		Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effective
Beaver	Reduction to seasonal habitat availability from wetland removal	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	Not significant
	Disruption to movement patterns from sensory disturbance	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	Not significant
	Increased mortality risk from collisions	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	Not significant
Lynx	Reduction in seasonal habitat availability due to clearing and sensory disturbance	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	Not significant
	Increased mortality risk from collisions	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	Not significant
	Disruption to movement patterns from disturbance or habitat fragmentation	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	Not significant
American Marten	Reduction in seasonal habitat availability due to clearing and sensory disturbance	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	Not significant
	Increased mortality risk from collisions	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	Not significant
	Disruption to movement patterns from sensory disturbance or habitat fragmentation	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	Not significant
Songbird community	Reduction in seasonal habitat availability due to clearing and sensory disturbance	Adverse	Low	Local	Long-term	Partially Reversible	Unknown	Not significant	N/A
	Disruption to movement patterns due to habitat fragmentation and sensory disturbance	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	NA
	Increased mortality risk due to nest destruction, collisions or contaminant exposure	Adverse	Low	Local	Long-term	Partially Reversible	High	Not significant	NA

Table 7.10-10 (Cont.'d) Program Effects on Wildlife during Construction

Notes:

1 Based on effects attributes in Table 7.10-7

2 Based on significance criteria

The significance of Project effects and cumulative project effects are unknown at this time since the management regime and implementation of mitigation options for the site road networks following project closure cannot be confirmed at this time. Agreements and mechanisms for management of the site wide road networks at closure will be determined by Manitoba Government and the First Nations in consultation with interested parties. It is likely that once mitigation measures have been established that project effects and cumulative effects will not be significant.

Partially reversible effects refers to the reduction of effects due to mine site reclamation and reduction in human activity and traffic.

N/A = not applicable

Table 7.10-11 Program Effects on Wildlife during Closure

VECC	Potential Effect	Level of Effect[1]						Effect Rating[2]	
		Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effective
Moose	Reduction in seasonal habitat availability due to access road	Adverse	Low	Local	Far Future	Irreversible	High	Not significant	N/A
	Disruption to movement patterns due to access road	Adverse	Low	Local	Far Future	Irreversible	High	Not significant	N/A
	Increased mortality risk from collisions, hunting and poaching	Adverse	Moderate	Regional	Far Future	Reversible	Unknown	Unknown[3]	Unknown[3]
Woodland Caribou	Reduction in seasonal habitat availability due to TC	Adverse	Low	Local	Far Future	Partially Reversible	High	Not significant	N/A
	Disruption to movement patterns due to TC	Adverse	Low	Regional	Far Future	Irreversible	High	Not significant	N/A
	Increased mortality risk from collisions, hunting and poaching	Adverse	Low	Regional	Far Future	Irreversible	High	Not significant	Not significant
Black bear	Increased mortality risk from collisions and hunting	Adverse	Moderate	Local	Far Future	Reversible	Unknown	Not significant	Not significant
	Disruption to movement patterns from sensory disturbance	Adverse	Low	Local	Far Future	Irreversible	High	Not significant	N/A
	Reduction to seasonal habitat availability from TC	Adverse	Low	Local	Far Future	Irreversible	High	Not significant	N/A
Beaver	Reduction in seasonal habitat availability from TC	Adverse	Low	Local	Far Future	Irreversible	High	Not significant	N/A
	Disruption to movement patterns from sensory disturbance	Adverse	Low	Local	Far Future	Irreversible	High	Not significant	N/A
	Increased mortality risk from hunting and collisions	Adverse	Low	Local	Far Future	Irreversible	High	Not significant	N/A

Table 7.10-11 (Cont.'d) Program Effects on Wildlife during Closure

VECC	Potential Effect	Level of Effect[1]						Effect Rating[2]	
		Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effective
Lynx	Reduction in seasonal habitat availability due to TC	Adverse	Low	Local	Far Future	Irreversible	High	Not significant	N/A
	Increased mortality risk from hunting and collisions	Adverse	Low	Local	Far Future	Irreversible	High	Not significant	Not significant
	Disruption to movement patterns from sensory disturbance or habitat fragmentation	Adverse	Low	Local	Far Future	Irreversible	High	Not significant	N/A
American Marten	Increased mortality risk from collisions and harvest	Adverse	Low	Local	Far Future	Partially Reversible	High	Not significant	Not significant
	Disruption to movement patterns from access road	Adverse	Low	Local	Far Future	Partially Reversible	High	Not significant	N/A
	Reduction in seasonal habitat availability from access road	Adverse	Low	Local	Far Future	Partially Reversible	High	Not significant	N/A
Songbird Community	Disruption to movement patterns from sensory disturbance or habitat fragmentation	Adverse	Low	Local	Far Future	Irreversible	Unknown	Not significant	N/A
	Increased mortality risk from collisions and exposure to contaminants	Adverse	Low	Site Specific	Far Future	Irreversible	Unknown	Not significant	N/A
	Reduction in seasonal habitat availability from access road	Adverse	Low	Local	Far Future	Irreversible	Unknown	Not significant	N/A

Table 7.10-11 (Cont.'d) Program Effects on Wildlife during Closure

Notes:

1 Based on effects attributes in Table 7.10-7

2 Based on significance criteria

The significance of Project effects and cumulative project effects are unknown at this time since the management regime and implementation of mitigation options for the site road networks following project closure cannot be confirmed at this time. Agreements and mechanisms for management of the site wide road networks at closure will be determined by Manitoba Government and the First Nations in consultation with interested parties. It is likely that once mitigation measures have been established that project effects and cumulative effects will not be significant.

Partially reversible effects refers to the reduction of effects at closure due to mine site reclamation and reduction in human activity and traffic. At closure, habitat alienation and sensory disturbance associated with ongoing use of the haul road is expected to persist and will be functionally irreversible.

N/A = not applicable

7.11 Land Use and Tenure

This section examines the potential effects of routine project activities and operations on non-traditional land and resource use in the vicinity of the project. Non-traditional land uses include activities that take place under formal tenures and licenses, and informal activities, such as recreational use. Traditional land uses, defined by First Nations with an interest in the project area, are discussed in Section 7.12: First Nations and Traditional Knowledge. Potential effects of accidents and malfunctions are discussed in Chapter 8.

7.11.1 Scope of Assessment

Issues and Selection of Valued Ecosystem and Cultural Components

Potential adverse effects of the project on land use and land tenure can include alienating or inhibiting access for other land uses (e.g., presence of project facilities conflicts with other resource extraction activities or non-consumptive use of the area), or changing the amount or quality of the resource or land use activity (e.g., increased access or presence of industrial facilities reduces quality of the area for wilderness recreation and guide outfitting; effluent discharges may affect the water quality for consumption or fishing).

Due to the nature of the LSA and RSA being predominantly wetlands and the somewhat remote location of the project, there are relatively low levels of use, although there are numerous mineral claims in the area. No specific issues have been raised during regulatory, public and First Nations consultations concerning potential conflicts of the project with existing and planned land use. The selected VECCs (Table 7.11-1) provide the basis for a systematic inventory of existing land tenures and existing and planned land use activities in the area, and an assessment of potential project effects during the project construction, operation, decommissioning and closure phases. The time frame for other land use activities in the area has been inferred from the status of tenures and consultation with land management and tenure granting agencies.

Temporal Boundaries

The timeframe for the assessment encompasses baseline conditions, as characterized from available information, compiled in 2007 and 2008, and all project phases from construction through closure. Incremental effects in relation to baseline conditions will be greatest during construction and persist through operations and the early stages of decommissioning. Progressive reclamation and phased decommissioning of facilities will result in a gradual reduction of effects until final reclamation and closure, when effects will be limited to those associated with the access road and airstrip, which will be left in place. In order to characterize the range of project and cumulative effects on land use and land tenure, effects characterization will focus on the baseline, full build out and operation of facilities and closure phases.

Table 7.11-1 Land Use and Land Tenure VECCs, Selection Rationale and Data

Proposed VECC	Rationale for Selection	Linkage to EAP Report Guidelines or Other Regulatory Drivers	Baseline Data for EAP
Settlement and transportation infrastructure	▪ Project development could affect exising roads, power lines or other Infrastructure.	▪ Information requested in the EAP Report Guidelines.	• Provincial mapping • 2007 - 2008 tenure information • Government and industry maps and data
Mineral and oil and gas activity	▪ Potential for project effects due to the presence of numerous other tenures in the immediate vicinity of the project.	▪ Information requested in the EAP Report Guidelines.	• 2007 – 2008 tenure information • Government and industry maps and data • Consultation with COI
Forestry and agriculture	▪ Clearing for site development could affect productive land base.	▪ Information requested in the EAP Report Guidelines.	• 2007 - 2008 tenure information • Government and industry maps and data
Non-traditional fishing	▪ Ground disturbance and erosion during construction and potentially ontaminated site drainage or effluent discharges could effect fish and associated fishing activity.	▪ Information requested in the EAP Report Guidelines.	• Government and industry maps and data Consultation with Aquatics discipline
Non-traditional hunting	▪ Project transportation corridors could affect nature and level of hunting activity in the area.	▪ Information requested in the EAP Report Guidelines.	• Government and industry maps and data Consultation with Wildlife discipline
Trapping	▪ Project access could affect level of trapping activity. ▪ Project-related disturbances could affect fur-bearer habitat and abundance.	▪ Information requested in the EAP Report Guidelines.	• 2007 – 2008 tenure information • Government maps and Data Consultation with Trapline Owners • Consultation with Wildlife discipline
Tourism and non-consumptive recreation	▪ Project could affect level of recreation activity.	▪ Information requested in the EAP Report Guidelines.	• Government and industry maps and data
Guide-outfitting	▪ Project site and access development could affect guide-outfitting areas.	▪ Information requested in the EAP Report Guidelines.	• 2007 – 2008 tenure information • Government and industry maps and data
Protected and environmentally significant areas (ESAs)	▪ Project site and access development could conflict with conservation areas or objectives.	▪ Information requested in the EAP Report Guidelines.	• 2008 tenure information • Government maps and data

Study Area

Project effects on identified VECCs include potential direct effects of the project disturbance footprint on existing tenures and the resource or land use they host, and potential indirect effects on wildlife and fisheries resources, which support hunting, trapping, fishing and guide outfitting. Accordingly, the LSA for the land use assessment includes the project disturbance footprint, conservatively defined as the total area of all claim areas affected by project facilities and construction (Figure 7.11-1).

The RSA for land use is the same as the RSA for wildlife (Section 7.10), which is the area within which the project may affect hunting, trapping and guide outfitting, or contribute to a reduction in the productive capacity of wildlife populations to support these activities. The land use RSA also encompasses the RSA for potential effects on fisheries (Section 7.8) and associated capacity of the area to support fishing.

7.11.2 Baseline Conditions

7.11.2.1 Methodology

The objectives of baseline data collection for the land use and tenures assessment are to identify existing land uses and resource users in the region and establish land use and tenure trends and, where possible, indicate possible future uses.

Baseline land use and tenure data was collected for the LSA and RSA through a combination of reviewing and incorporating the findings of past studies in the project area and the surrounding region and collecting additional baseline information as necessary to update existing information and address data gaps.

Information sources include:

- government data bases, digital data and maps;
- hunting, trapping and outfitting areas;
- websites for government and non-government agencies and organizations; and
- personal communications with key government agency representatives regarding known resource requirements of other disclosed projects.

7.11.2.2 Results

Baseline conditions for selected VECCs are described in the following sections.

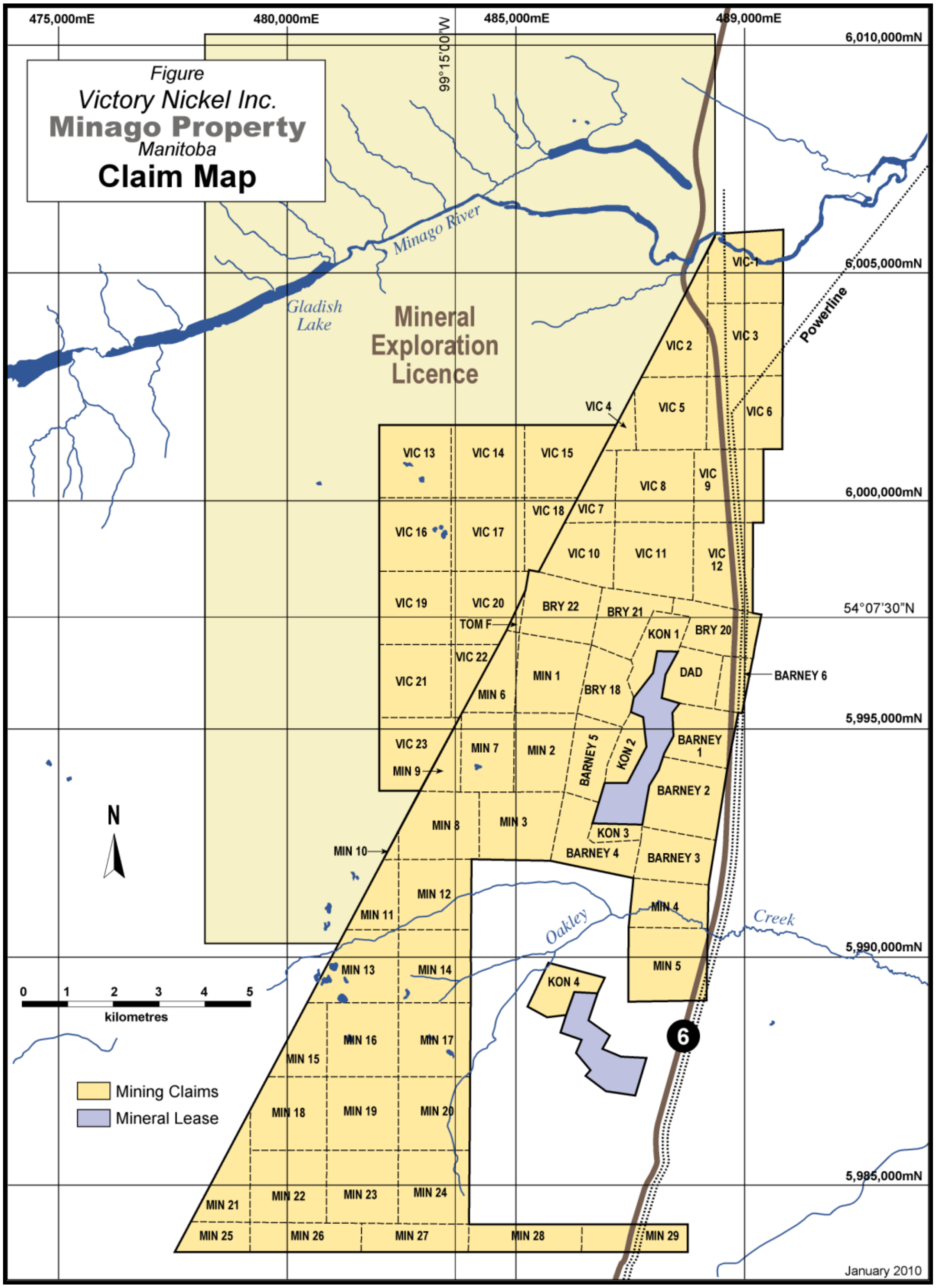


Figure 7.11-1 Minago Mineral Dispositions and Property Boundaries

Land Use Planning and Zoning

The Minago Project is located in the Norway House Resource Management Area (RMA). Lands within Manitoba are controlled by various levels of government:

- vacant lands within the territory are governed by the Manitoba government;
- First Nations control their settlement area;
- municipalities administer lands, community plans and zoning bylaws within their jurisdictions; and
- the Federal government controls lands consisting of National Parks.

The Resource Management Areas have been established by the Manitoba government. The RMA, in which the project area is located, is currently an inactive area so there are no current land use plans developed for the project area. As no development are currently occurring in these areas, they will not be directly affected by the development of the project in a cumulative manner.

Land Use Dispositions

In the RSA, there are land dispositions in the southern, northern and western sides of the Project area. The dispositions are in the Moose Lake territory, Cross Lake territory and Norway House Management Area.

Settlement and Transportation Infrastructure

Settlement

There are no established communities within the LSA or RSA. However, the nearest communities to the project area are:

- Grand Rapids First Nation and Town of Grand Rapids located approximately 110 km south of the project. Grand Rapids First Nation is governed by a Chief and Council. The Town of Grand Rapids is governed by a Mayor and Council. The population of Misipawistik Cree Nation (Grand Rapids First Nation) was 1,394 (Aboriginal Business and Communities Directory – Prairie Region, 2006 - 2007). Community services and facilities include postal service, Fire hall, band hall, RCMP, service station and restaurant, general store, fisherman’s co-op, trucking, freight service, lodge, hotel, motel, campground, medical transportation, education authority, school buses, dental office, health authority, day care and school. The economic base is hunting, commercial fishing and trapping.

  The population of the Town of Grand Rapids was 336 (Statistics Canada, 2006 Census). The economic base is hunting, commercial fishing and trapping.

The Town of Grand Rapids is located on the northwestern shore of Lake Winnipeg, at the mouth of the Saskatchewan River. Just over 400 kilometres from Winnipeg (Manitoba's Capital) along Provincial Trunk Highway 6, Grand Rapids is part of the Norman Region of the province. At one time, the community was an important hub of activity for many northern settlements. Today, Grand Rapids is an enterprising community, making its living off the abundant natural resources and tourist activities the area has to offer.

The economy of the area is based on tourism, commercial fishing, a forest products operation and trapping. A hydro electric generating plant located adjacent to the Town of Grand Rapids on the Saskatchewan River, is the largest employer. Tourist related occupations also provide employment for many residents of the town and surrounding area. The area is known for having some of the finest master angler fishing lakes in the province, and many tourists arrive each year to lodges and outposts, looking for guides and other services.

- Thompson is located approximately 225 km north of the project and is governed by an elected municipal council consisting of a mayor and council. The population of Thompson was about 13,300 in 2006. Thompson is the largest city in Northern Manitoba. Major economic activities include mining, government services, tourism, and transportation. Mining has shown steady growth over the years. The main mining company in the area is Vale Inco.
- Snow Lake is a small town located approximately 140 km northwest of the project area. The town is governed by an elected mayor and council. Snow Lake has experienced mine closures from time to time and the population of Snow Lake has had wide fluctuations, but has been stable at approximately 870 for the last two years. The main industry is and always has been mining; currently with one mine producing zinc and lately (late 2009) it was discovered that it could have the largest deposit of gold in Canada.
- Wabowden – located about 115 km north of the project and 111 km south of Thompson. From a high of over 1,000 during the mining boom years, Wabowden's population has since stabilized at a level just under 700. The local economy is now based on commercial fishing, hunting and trapping, logging, mining, rail transportation, government operations and tourism. The nearby Setting Lake Park, scenic attractions such as Sasagiu Rapids and Pisew Falls, and an abundance of clean lakes, rivers and streams make Wabowden a popular vacation spot. One of the main employers is Crowflight Minerals.
- Moose Lake is located approximately 240 km (by road) of the Project. Moose lake consists of Mosakahiken Cree Nation with a population of 1,635 and the Town of Moose Lake. Community services and facilities include postal service, First Nation constable, RCMP, general store, taxi, medical transportation, education authority, school buses, dental office, health authority, day care and school. The economic base is hunting, commercial fishing and trapping.
- Cross Lake is located approximately 190 air kilometers (118.5 miles) south of Thompson and 520 air kilometers (325 miles) north of Winnipeg along the shore of the Nelson River,

where it enters Cross Lake. It is approximately 227 km by road from the Minago Project. The Cross Lake Indian Reserve consists of Reserve No. 19, 19A, 19B, 19C, 19D, and 19E, which are adjacent to each other.

According to the regional population statistics as of December 31, 2002, the Band has an on-reserve population of 4,216 and an off-reserve population of 1,733. The total Band population is 5,949. There are individuals of non-aborginal origin, as well as a number of Métis and others, residing on-reserve bringing the total population of Cross Lake to approximately 7,000 people. The majority of the population is treaty status. On-reserve facilities include a Band Administration Building, Community Hall, Awasis, Tobacco Sales office, Arena, Construction and Maintenance garage, Housing Warehouses, Daycare, Playgrounds, Ball fields, a fully developed track and field area, Royal Bank, and a Radio and TV Station building. There are facilities for fire and police (RCMP) protection, hydro services (from Jenpeg Generating Station), Postal Services (daily), Health Care (variety of services), and Child and Family services. The economic base is hunting, commercial fishing and trapping.

- Norway House is located approximately 264 kilometres by road from the Minago Project. The population of the Norway House Cree Nation (NHCN) is approximately 6,229. NHCN is governed by a Chief and Council and the Norway House Township is governed by a mayor and council. The main industries are fishing, trapping, hunting and logging. The community services and facilities include postal services, RCMP, First Nation Constable, fire hall, various government offices, health office, schools, family services, airport and marine operations, community and youth correctional services, gas and convenience stores, restaurants, taxi services, auto service and garage, small motor repairs, lodge, hotels, sports and recreation multiplex, industry mall, video store, hydro, landscaping, pharmacy, hospital, bakery, insurance and bank.

The locations of these communities are shown in Figure 7.11-2. Further information on these settlements is contained in Section 7.14: Socio-Economic Conditions. The major Aboriginal groups affected by the project are the Grand Rapids Cree Nation, Cross Lake Band of Indians, Norway House Cree Nation and Moose Lake Cree Nation.

Transportation Infrastructure

Transportation infrastructure affected by the project includes air and road transport systems in Manitoba. National airlines provide regular daily service from Thompson to Winnipeg, which is also the base for a number of charter companies. The Thompson airport has paved runways and a terminal that is staffed full-time and served by charter air services. The Pas, Cross Lake, Norway House have full service airports. Grand Rapids has a good quality gravel strip owned and operated by Manitoba Hydro. This gravel strip is only about 500 metres long and is unsuitable for upgrading to handle twin engine commuter airplanes.

The project will make use of the PTH6 which connects Winnipeg and the Northern communities. The project is located off PTH 6 (Figure 7.11-2). Highway traffic is minimal during the winter

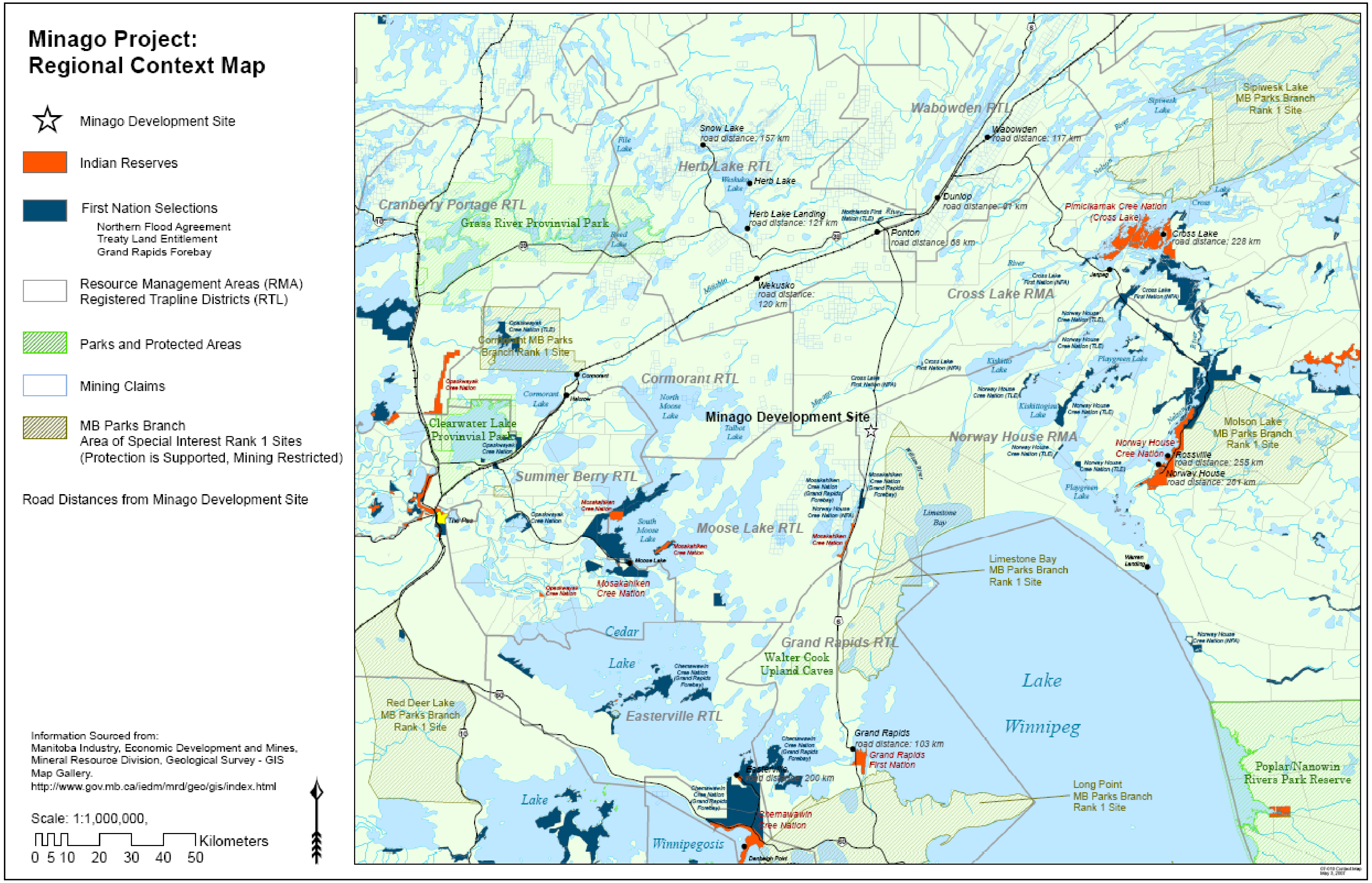


Figure 7.11-2 Context Map and Transportation Infrastructure

months and, although it increases in the summer months with the tourist traffic, it is still not yet up to design capacity.

Minerals

Mining is the primary sector of industrial development in the north. Today there are many companies conducting mineral exploration or active mining in Northern Manitoba. The Mines Branch is responsible for the development and management of Manitoba minerals. The project is situated within the Thompson Nickel Belt Mining District.

The area surrounding the project is very active from mineral exploration and mining perspectives. To the North there are operating mines in Thompson (Vale Inco), Snow Lake (HudBay), and Wabowden (Crowflight Minerals). In the RSA, there are many registered mineral dispositions (active and expired).

The status of activities at identified exploration areas, prospects, the past mines could not be found at the Mines Branch website. No coal mining leases, placer claims or potential diamond mining areas have been identified within or adjacent to the RSA. Just outside the RSA, however, there are operating mines (Vale Inco – Thompson and HudBay - Flin Flon), and some recent discoveries near Snow Lake, Manitoba.

Forestry

The Forestry Branch of Manitoba Conservation is one of several resource branches responsible for ensuring sustainable resource management for present and future generations of Manitobans.

Under the authority of the *Forest Act*, the Forestry Branch manages provincial Crown forests by setting forest harvest levels, monitoring forest management activities, ensuring forests are regenerated, providing protection from insects and diseases and collecting revenues for use of Crown timber.

The Forestry Branch also supports forest management programs outside of Crown forests. Through the Manitoba Habitat Heritage Corporation and the Manitoba Forestry Association, Manitoba Conservation delivers woodlot management programs to private landowners in southern Manitoba.

The department assists co-operating communities with urban forest management, in part, by administering the *Forest Health Protection Act*, *Forest Health Protection Regulations* and *Arborists Regulations*.

Applications for and allocation of wood and timber permits on Manitoba land are issued by Manitoba Conservation. Throughout the forest zone, regional forestry personnel implement forest management programs on behalf of the department. Regional personnel supervise the forest industry and work with other natural resources managers to provide maximum benefits relating to wildlife, recreation and water to name a few. Regional forestry offices are located in Lac du Bonnet, Steinbach, Gimli, Swan River, The Pas, and Thompson.

Currently there are no pending woodlot application for the LSA and RSA.

Agriculture

Manitoba has vast amounts of land devoted to agriculture (for commercial crops and food crops production and pasture/grazing). The majority of the agricultural lands in Manitoba are located near in southern Manitoba.

There are no lands used for existing agriculture or slotted for future agricultural development in the LSA and RSA.

Non-traditional Sport Fishing

Both Manitoba Conservation and the federal Department Fisheries and Oceans (DFO) regulate fishing and angling in the Province. DFO protects the fish habitats under the *Fisheries Act*. The Manitoba government manages all fish species. Fisheries management is achieved through size selective harvest and the encouragement of live release fishing. Fishing during spawning seasons is prohibited.

Walleye or Pickerel is one of the most popular commercial and sport fish in the Manitoba.

Numerous studies have been conducted on watersheds in the project area at various times and locations between 2006 and 2008. Refer to Section 7.8: Fish Resources for the methods and findings of these investigations. Overall, six species of fish have been recorded in the lake systems around the project area and these include Northern pike, Walleye, Rainbow smelt, Yellow perch, White sucker and Longnose sucker. White and Longnose suckers are common in the Oakley Creek and the Minago River.

Non-traditional Hunting

The LSA and the RSA contain somewhat low wildlife values. Wildlife resources in the immediate project area and surrounding region include moose, black bear, fox, coyote, marten, beaver, various waterfowl, and a variety of other forest birds (Refer to Section 7.10: Wildlife). The lakes and small ponds/wetlands provide breeding and migratory habitats for waterfowl and other aquatic birds (Section 7.10: Wildlife).

Target species for hunting in Manitoba is mainly moose.

Trapping

The LSA and RSA are home to a number of furbearing mammals that are trapped for their fur, including beaver and marten. In the LSA, there is one trapping license holder. To the southwest and north, there are more trapping license holders. Most of them are registered trapping concession holders, and the others are assistant trappers.

Manitoba has established trapping areas to regulate the harvest of fur-bearing species. A registered trapping concession (RTC) is a parcel of land on which the holder is given exclusive rights to harvest furbearing animals.

Manitoba conservation keeps track of the annual fur harvest by monitoring trapping licences, export permits, fur dealer and taxidermist records, and sealing certificates. Individual harvest information is confidential and is not normally released without the written permission of the RTC holder.

Guide Outfitting

There are no outfitters within the LSA and RSA.

Tourism and Non-Consumptive Recreation

The region surrounding the project supports little formal recreation or tourism. Lake Winnipeg to the south provides more formal recreational and tourism opportunities. There are no wilderness lodges or campgrounds in the LSA and in the RSA.

There are several recreational opportunities outside the RSA, including campgrounds in Grand Rapids, The Pas and Thompson.

Protected Areas

No special management or habitat protection areas, heritage rivers, National Wildlife Areas, or wildlife sanctuaries have been identified within the LSA and RSA.

There is a Reserve Park outside the RSA known as the Little Limestone Lake Park Reserve. The 4,095 hectare Little Limestone Lake Park Reserve is located amid unique "karst" (limestone) geology in the Manitoba Lowlands region. Located just north of Grand Rapids, this distinctive landscape is pockmarked with sinkholes and underlain by caves that have been largely shaped by the dissolving action of water on the limestone bedrock.

Little Limestone Lake is a majestic turquoise body of water. It is a marl lake that visibly changes colour as the calcite in the water, dissolved from the limestone bedrock, chemically reacts with the heat of the sun. On hot days the water turns a rich milky blue. It is considered by experts to be the largest and most outstanding example of a marl lake in the world.

The Little Limestone Lake Park Reserve lies in the traditional territory of Mosakahiken Cree Nation. All of the eastern shore of the lake is reserve land and the community will play a role in managing and protecting the lake.

Little Limestone Lake overlies the Thompson Nickel Belt, an area of high mineral potential. The park reserve was designated in co-operation with the mining industry. Xstrata Corporation made protection of Little Limestone Lake possible by removing its mining claims under and adjacent to the lake.

Designation of Little Limestone Lake as a park reserve will provide protection for the lake while allowing time for a public review to take place regarding the management of the lake and the future of this area. Little Limestone Lake Park Reserve is categorized as an IUCN (International Union for Conservation of Nature) protected area Management Category III, that is, a protected area managed mainly for conservation of a specific natural feature of outstanding or unique value.

Furthermore, there is the proposed National Park outside of the RSA. The proposed National Park is distinct in that it consists of separate components - the Long Point area and some nearby islands in Lake Winnipegosis, the Limestone Bay area and the Black and Deer Islands - which together can represent the diversity of the Manitoba Lowlands natural region better than one site could on its own. There are mixed opinions regarding the establishment of the National Park and to date no agreement has been reached.

7.11.3 Effects Assessment Methodology

To characterize the potential range of project effects on land use and land tenure, activities and operations were assessed for the nine VECCs for the construction/operations and closure phases. Where effects are identified, mitigation measures are recommended to reduce or eliminate these effects. Residual effects remaining after mitigation are characterized.

The level of project effects is difficult to determine for the non-traditional land use discipline, as there is a lack of specific guidelines or thresholds set regarding acceptable levels of activity. In part, this is due to the inability to quantitatively determine impacts on a VECC for which there is no numerical base. For example, it is difficult to predict a quantitative change in informal recreational activities, perceived enjoyment of an activity, or harvest levels for sport hunting and fishing. Therefore, a qualitative method based on professional judgement and with linkages to other disciplines was employed. The determination of the level of project effects on land and tenure use were characterized in terms of direction, magnitude, geographical extent, duration, frequency, reversibility and likelihood of occurrence of the impact according to criteria, detailed in Table 7.11-2.

A project or cumulative effect is deemed significant if it is adverse, high magnitude, local to regional extent and medium to long-term. Otherwise, effects are rated as not significant.

7.11.4 Project Effects

The project will include the construction, operation, decommissioning and closure of mining and ore processing facilities and associated infrastructure. Development of the project has the potential to effect resources on the land and, in-turn, how those resources are used (i.e. land

Table 7.11- 2 Effect Attributes for Land and Tenure Use

Attribute	Definition
Direction	
Positive	Effect improves the status or condition of VECC.
Adverse	Effect worsens the status or condition of the VECC.
Neutral	Effect has no change on the status or condition of the VECC.
Magnitude	
Low	No effect or negligible effect to VECC.
Moderate	Effect on VECC is detectable, but within a normal range of variation.
High	Effect on VECC is detectable, but outside normal range of variation.
Geographic Extent	
Site-specific	Effect on VECC within disturbance footprint.
Local	Effect on VECC within Local Study Area (LSA).
Regional	Effect on VECC within Regional Study Area (RSA).
Duration	
Short term	Effect on VECC is limited to the construction period.
Medium term	Effect on VECC occurs through the operational phase.
Long-term	Effect on VECC lasts extends beyond the operational phase.
Frequency (Short term duration effects that occur more than once)	
Low	Effect occurs once.
Moderate	Effect occurs more than once.
High	Effect occurs continuously.
Reversibility	
Reversible	Effect is reversible.
Irreversible	Effect is irreversible.
Likelihood of Occurrence	
Unknown	Effect on VECC is not well understood and based on potential risk to the VECC or its economic or social/cultural values, effects will be monitored and adaptive management measures taken, as appropriate.
High	Effect on VECC is well understood and there is a high likelihood of effect on the VECC as predicted.

use). Project activities are identified as having either a direct or an indirect effect on land use and tenure. Direct effects (e.g., loss of land base and change in access) result from site clearing and construction of facilities and the access road. Indirect effects (e.g., changes in available resources resulting from effects to wildlife and fish abundance and distribution) may result from physical effects and disturbance related to construction, operation and decommissioning.

7.11.4.1 Settlement and Transportation Infrastructure

Approximately 422 people will be required for both the mine and mill operations. The majority of these people will come from the local communities of Grand Rapids, Norway House, Moose Lake, Snow Lake and Cross Lake, resulting in an economic benefit and increased employment in these communities.

Project effects on settlements are expected to be mainly socio-economic. Socio-economic effects on settlements are discussed in Section 7.14: Socio Economic Conditions.

During operations, transportation of concentrate and supplies will result in additional truck traffic on the PTH 6. Impacts may include slowing traffic movement. The potential for accidents and collisions with wildlife, and increasing noise in communities along the highways. The increase in traffic load on the PTH 6 between Grand Rapids and the site will be most noticeable, especially during the winter. Other mining operations such as those in Thompson and Snow Lake have similar effects on the PTH 6. Effects of traffic increases and mitigation measures are discussed in Section 7.10: Wildlife.

The effect of the project on road transportation during operation are expected to be adverse in direction for the PTH 6 and neutral to positive for the other highways. Effects for all highways will be of moderate magnitude, regional, medium term and ultimately reversible.

A majority of the employees required for operations will be transported by bus from the local communities and Winnipeg. Project effects on land transportation are expected to be mainly economic. Increased land freight in the project area could affect other land uses.

In order to minimize disturbances from land transportation on local residents and wildlife and associated land use activities, VNI will establish standard procedures, with appropriate avoidance windows in consultation with the Manitoba Government and the affected communities. As a result, disturbance effects of land transportation on other users are expected to be low.

During decommissioning, there will be a 6-year period of ongoing activities associated with reclamation, monitoring and related site access, accommodation and power supply. At closure, all mine site facility areas will be reclaimed and revegetated. The TWRMF will be reclaimed as a permanent pond and will remain in place. The pit will be flooded and left in place. There will be no residual effects of project-related transportation activities on existing infrastructure at closure.

Accordingly, effects of the project on transportation infrastructure at closure will be positive to adverse, moderate magnitude, long-term and reversible, depending on the ultimate fate and management of the transportation corridors.

7.11.4.2 Mineral and Oil and Gas Activity

The project will not alienate mineral resources from exploration or development by other interests. The effect on mineral activities will be neutral to positive in direction, low in magnitude, site-specific in extent, long-term in duration and reversible at closure. Since the extent of existing developments and disclosed mining proposals in the area is known, the likelihood of effects on mineral activities is high.

A majority of the oil and gas rich basins in Manitoba are located in the southern portion of Manitoba. There are currently no oil and gas wells, seismic exploration or dispositions located within or adjacent to the RSA. There will be no effect on oil and gas activities from any phase of the project.

7.11.4.3 Forestry and Agriculture

Currently, no forestry or agricultural tenures have been identified close to or in the LSA or RSA. The nearest agricultural tenures are in the vicinity of Gypsumville.

There are no existing environmental assessments for forest management plans in the RSA. Therefore, there will be no impact on forestry or agricultural resources from any phase of the project.

7.11.4.4 Non-traditional Sport Fishing

Aquatic resources (fisheries and benthic communities) can be directly affected through physical alteration of habitat for development purposes or indirectly affected by changes in water quality and hydrology resulting from mine construction and operation activities. These can, in turn, potentially affect the productivity of the fishery for sports fishing purposes. Increased number of people can also affect the level of fishing activity at the project site or at near-by fishing areas and lodges.

The nearest sport fishing lodges to the project area are located north of Wabowden (located outside the RSA). Increased visitation and awareness of the area due to project personnel may result in increased visitation to these lodges. On the other hand, increased truck traffic on the highway from the project may discourage use of the highway. Thus, effects of the project could range from positive, through neutral to adverse.

In the project area, much of the headwater and tributary reaches of Oakley Creek, potentially affected by the project, support limited fish habitat values. There is no major sport fishery in the project area. No effects on fisheries in the Minago River and Oakley Creek due to potential changes in water quality are expected during operations.

An increased workforce in the area may potentially result in increased fishing pressures on fish stocks in lakes and fish-bearing streams in the area. The employees and contractors will be restricted from fishing. The potential impacts of increased fishing pressure from project personnel will be managed through government imposed harvest and seasonal restrictions. As noted in Chapter 9, an employee environmental awareness program will support sustainable fishing practices in accordance with Manitoba regulations.

In summary, the effects of the project on non-traditional fishing activity are expected to be positive through adverse in direction, low to moderate in magnitude, regional in extent and medium to long-term in duration and ultimately reversible, depending on the long-term fate and management of the access road and airstrip. The likelihood of effects on existing sport fishing lodges and on fishing opportunities and activities in the project area is unknown due to the subjective nature of user response to project effects and the unknown status of management measures on the access road at closure.

7.11.4.5 Non-traditional Hunting, Guide Outfitting and Trapping

Project facilities and operations have the potential to affect wildlife numbers and the distribution for wildlife species that inhabit or migrate through the area and indirectly affect hunting, trapping and guiding opportunities and success. The project can also directly affect these activities due to potential changes in the local access patterns. Since local trappers have management responsibilities for the Traplines in the Local Study Area and Regional Study Area, project effects on trapping will be considered, as appropriate, in the context of the traditional knowledge (First Nations and Traditional Knowledge). Effects will be mitigated to the mutual satisfaction of VNI and the trapline owners.

No significant effects on wildlife populations that support hunting and guiding are expected during the life of the project, because of the low level of project effects on habitat availability and implementation of various mitigation measures to prevent wildlife mortality (controlled access, prohibition of fire arms, speed limits on transportation corridors, etc.) (Section 7.10: Wildlife). The presence of transportation corridors will not enhance opportunities for hunting or outfitting during operations, due to these same mitigation measures. There is no guide outfitting in the LSA and RSA. Therefore, presence of the mine will not limit suitability of the immediate area for guide outfitting.

The project effects on hunting and guide outfitting during operations are expected to be neutral to adverse, low magnitude, local, medium term and reversible. The likelihood that effects on hunting during operations will occur as predicted is high because of VNI's commitment to mitigation measures. The likelihood of effects on guide outfitting concessions is unknown, because the current level of guiding in the RSA is uncertain and the potential for increased business to local guide outfitters from project personnel is unknown.

At closure, there is low potential for increased mortality and potentially significant effects on moose populations. The effect on hunting and guiding activity could be initially positive due to an increased population, changing to adverse, if moose populations decline. In the context of opportunities for moose hunting in the RSA, effects are expected to be moderate in magnitude, regional, long-term and reversible in the context of regional moose population management options.

7.11.4.6 Tourism and Non-consumptive Recreation

Enhanced maintenance and potential improvements to the PTH 6 as a result of project related traffic might attract increased tourist use for non-consumptive recreation or use of existing campground and lodge facilities. As noted above, increased awareness of the area by project personnel might result in increased use of recreational facilities and opportunities in the area. On the other hand, increased truck traffic for mine operations may counteract the potential positive effect.

The project transportation corridors will not affect tourism and recreation during the operations as the transportation corridors do not go to any touristic facilities or amenities. Accordingly, project effects on tourism and non-consumptive recreational effects are expected to range from positive through adverse, low to moderate magnitude, regional, medium to long-term and potentially reversible, depending on the management of the access road at closure.

7.11.4.7 Protected and Environmentally Significant Areas

No special management or habitat protection areas, Heritage Rivers, National Wildlife Areas, or wildlife sanctuaries are identified within the LSA and RSA. Therefore, there will be no effect on these areas from any phase of the project.

7.11.4.8 Residual Project Effects and Significance

The project is expected to have low magnitude of effects on PTH 6 transportation, mineral activities, sport fishing, hunting, guide outfitting and tourism and recreation. Positive effects include enhanced opportunities for mineral development, fishing, hunting, outfitting and non-consumptive recreational activities associated with enhanced access at closure. Negative effects include potential reduced attractiveness for some recreation uses due to project-related traffic and potential reduction in regional moose populations due to over-hunting during operations. Effects will mostly be local, but some will extend to regional transportation infrastructure and tourism facilities, and regional opportunities for moose hunting. All effects will be moderate to long-term and ultimately reversible. Based on the criteria and effects assessment provided in Section 7.10: Wildlife, these effects are determined to be not significant. The likelihood of effects is unknown due to a host of external (e.g., mineral prices, economic conditions) and internal (e.g., subjective response of land users to project effects, uncertainties regarding the wildlife hunting due to the presence of PTH 6) factors that will affect land use patterns in the area.

7.11.5 Cumulative Effects and Significance

The only other known project activities that could interact with project effects on land use is the increased traffic on the PTH 6 associated with the operation of the mines in Thompson and Snow Lake. Transportation of Vale Inco's concentrate from Thompson to Winnipeg also has the same effects as the Victory Nickel's concentrate transportation. PTH 6 already attracts more use of the highway and higher levels of activity associated with mining and recreational facilities, informal recreation, hunting, fishing and potential guide outfitting.

Effects of increased truck traffic on the highway due concentrate and Frac Sand hauling for the Minago project could deter the use of the highway. Accordingly, cumulative effects on land use from these sources are expected to be positive to adverse, low to moderate in magnitude, regional, long-term and reversible. The potential effects are determined to be not significant. The likelihood of effects is unknown due to a host of external (e.g., potential highway improvements, economic conditions and associated levels of tourism activity) and internal (e.g., subjective response of land users to project effects) factors that will affect traffic and associated land use patterns in the area.

7.11.6 Mitigation Measures

Mitigation measures identified in other sections pertaining to protection of fish, wildlife, traditional use, and socio-economic conditions also protect the land use and tenure.

Follow-up consultation with the Manitoba government, the COI and other interested parties is required to develop suitable management approaches to road infrastructure affected by the project. Based on the predicted insignificant effects of the project on land use and tenure, no additional impact mitigation measures are proposed. Table 7.11-3 summarizes mitigation measures that will be applied to reduce the effects on land use and tenure.

7.11.7 Monitoring and Follow-up

No project-specific monitoring programs are required related to effects on land use and tenure. Monitoring programs used for other disciplines will contribute to the understanding of effects on land use and tenure. As noted above, follow-up consultation with the Manitoba Government, COI and other interested parties is required to develop and confirm suitable PTH6 management practices during the life of the project and to address project and cumulative effects on the use of the PTH 6 and related effects on land use in the area.

7.11.8 Summary of Effects

Table 7.11-4 provides a summary of project effects assessment conclusions for the land use and tenure component.

Table 7.11-3 Mitigation Measures for Effects on Land Use and Tenures

Potential Project Effect	Mitigation Measures
Potential project effects on settlement and transportation infrastructure during operations	• Refer to Section 7.14: Socio Economic Conditions • Consultation with the Manitoba Government, COI and other interest holders
Project effects on fish and wildlife affecting fishing, hunting, trapping and guide outfitting uses	• Refer to mitigation measures for fish (Section 7.8), wildlife (Section 7.10), and First Nations and Traditional Knowledge (Section 7.12).
Potential Cumulative Effect	**Mitigation Measures**
Potential effects of the project, and other road users (Vale Inco) and mine traffic on the PTH 6, affecting highway use and related tourism and recreational activity	• Consultation with the Manitoba Government, COI and other interest holders

Table 7.11-4 Program Effects on Land Use and Tenures

Potential Effect	Level of Effect						Effect Rating	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effect
All Phases								
Transportation infrastructure – increased traffic on PTH 6 during operations	Positive to Adverse	Moderate	Regional	Medium term	Reversible	High	Not significant	Not significant
Non-traditional fishing activities – increased use of lodges outside the RSA, effects on LSA watershed fishery (water quality and access) and fishing pressure from project personnel	Positive to Adverse	Low to Moderate	Regional	Medium to Long-term	Reversible	Unknown	Not significant	N/A
Hunting and Guide Outfitting - Operations effects of access on opportunity, effects on wildlife populations, business for outfitters, decreased attractiveness of area for guiding	Neutral to Adverse	Low	Local	Medium term	Reversible	High to Unknown	Not significant	N/A
Tourism and non-consumptive recreation – Operations effects (increased traffic in region affecting use of facilities)	Positive to Adverse	Low	Regional	Medium term	Reversible	Unknown	Not significant	N/A

Note: N/A not applicable.

7.12 First Nations and Traditional Knowledge

7.12.1 First Nations Communities around the Minago Project

The Minago Project is situated in undeveloped, low, water-saturated muskeg terrain. Coniferous vegetation and small to medium sized lakes are typical at the Minago Project and its surrounding area. The Minago River and Hargrave River catchments, surrounding the Minago Project Site to the north, occur within the Nelson River sub-basin. The William River and Oakley Creek catchments surrounding the Minago Project Site to the south occur within the Lake Winnipeg sub-basin, which flows northward into the Nelson River sub-basin. The Nelson River sub-basin drains northeast into the southern end of the Hudson Bay.

The Project is located in the Norway House Resource Management Area. Neighbouring communities to the Minago Property include Grand Rapids (GR), Moose Lake (ML), Cross Lake (CL), Snow Lake (SL) and Norway House (NH). With the exception of Snow Lake the other four communities are members of Treaty 5. The communities outside Treaty 5 have their own community councils and mayors. The First Nations have their own governing infrastructure usually collectively known as the First Nations in the Northern Region of Manitoba.

7.12.2 Traditional Knowledge

Traditional knowledge (TK) includes an understanding of the functioning of ecosystems (resource abundance, distribution and cycles); land and resources management; social, economic and cultural conditions; and the relationships between these factors. VNI made reasonable efforts to collect and facilitate the collection of traditional knowledge for integration into the EIS Report in collaboration with First Nations communities and organizations as well as local trappers.

VNI considered traditional knowledge in various stages of the project assessment including the scoping of VECCs, the description of existing environmental conditions, predictions of environmental effects, development of mitigation measures, evaluation of significance, and monitoring and follow-up as required.

7.12.2.1 Actions to Solicit Traditional Knowledge

Victory Nickel together with their consultants held a series of meetings and interviews throughout 2007 and 2008 with a wide range of key stakeholders to identify their views and opinions with respect to the Minago Project. The stakeholders included Norway House Cree Nation (NHCN) and Norway House Community (NHC); Grand Rapids Cree Nation (GRCN) and Grand Rapids Community (GRC); Cross Lake Band of Indians (CLBI) and Cross Lake Community (CLC); Moose Lake Cree Nation (MLCN) and Moose Lake Community (MLC); Snow Lake; Manitoba Metis Federation (MMF); Trapline Owners (TLO); Norway House Resource Management Board (NHRMB) and Government Agencies. Consultation and community engagement sessions, small group and open house meetings were held in the communities of Norway House, Cross Lake, Grand Rapids, Moose Lake, Snow Lake, Thompson, The Pas and Winnipeg. Through these meetings, VNI solicited Traditional Knowledge.

VNI consulted with the various land users from the area with a goal to gather, document and preserve traditional knowledge by working in a genuine partnership.

In order to collect traditional knowledge for use in the EIS, VNI's consultants and personnel met with various community members from the Communities of Interest (Grand Rapids, Cross Lake, Moose Lake and Norway House). In addition, VNI's consultants conducted interviews with traplines owners (see Figure 7.12-1). Information gathered through Archaeological assessment was also used to determine valued ecosystem components of the area.

Figure 7.12-1 Meeting with the Trapline Owners (Land Use Meeting) in Norway House, May 23, 2007

Overall, the archaeological field investigations determined that archaeological potential of the Minago area is extremely low and it is highly improbable that the area was used by inhabitants prior to the introduction of the fur trade. The possibility of finding any evidence of pre-contact utilization of the area is next to impossible and likelihood of locating any evidence of Fur Trade or later use, other than prospecting and mining activities is extremely minimal.

Existing information on First Nations land use, water use, fish and terrestrial wildlife use was reviewed and compiled to assist in the identification and mitigation of the potential impacts from the project. Information provided during community engagement meetings with government and community members was also used to guide the development of baseline studies. In addition to the Communities of Interest, early input to baseline studies and information provided in subsequent meetings to VNI by members of the communities and Chiefs and Councils were used to guide project planning. It must be noted that VNI has not assumed that comments provided during meetings or during visits to the Minago site, while perhaps useful to the proponent, are Traditional Knowledge.

7.12.2.2 Incorporation of Traditional Knowledge

VNI will not compromise any aspects of traditional knowledge during any project phases.

In recognition of the principles of confidentiality with respect to TK, only impact mitigative measures are included in the EIS. For example, the local traplines owners did not want their historical harvest values made public. It is VNI's plan to incorporate traditional knowledge into the final project design work, the development of site-specific protection and management plans, and the development of monitoring programs.

7.13 Archaeology and Heritage Resources

Victory Nickel retained Quaternary Consultants Ltd. to conduct an archaeological impact assessment of the Minago Property as part of an Environmental Impact Statement for the site. The archaeological survey was conducted under the terms of Heritage Permit A40-08, issued by Historic Resources Branch, Manitoba Culture, Heritage and Tourism on June 19, 2008 (Appendix 7.13).

7.13.1 Scope of Assessment

Quaternary Consultants Ltd. (2008) investigated the Minago Property by foot traverses through the forest to the proposed open pit area and visually examined the ground surface. This was augmented by shovel testing in areas which could hold archaeological potential.

The archaeological impact assessment was directed by Sid Kroker, Senior Archaeologist of Quaternary Consultants Ltd. The field investigation team was led by David K. Riddle with Mark Paxton-MacRae as field assistant.

On the day of the survey (June 19, 2008), the archaeological field crew used the very wet, but useable, winter road (Figure 7.13-1) to gain access to the proposed mine location from Highway 6. In some areas, that road was too wet to walk and the crew utilized undeveloped edges of the road instead.

7.13.2 Archaeological Survey Results

Quaternary Consultants Ltd. (2008) found that the general Minago area is very low and wet and speculated that conditions in the past were probably much wetter than the current situation.

It quickly became obvious to the archeaological field crew that the thick, saturated sphagnum layer would cover any archaeological resources that would date back beyond twenty years. Shovel tests were attempted on route from the highway to the mine pit location (Figure 7.13-2), on cut lines radiating from the winter road (Figure 7.13-3), and on side roads (Figure 7.13-4). Once the upper layer of sphagnum was removed, standing water would infill the hole where the moss had been. It was impossible to see through this dark water. The base of each test pit appeared to be solid limestone, approximately 50 centimetres below the top of the existing sphagnum cover (Quaternary Consultants Ltd., 2008).

At the proposed pit location, the crew observed that, further to the south, water ponded on the surface. In non-flooded areas, there was no chance of locating heritage resources due to the impenetrability of the terrain and the thick sphagnum cover. Based on these results, a decision was made to terminate the archaeological field survey (Quaternary Consultants Ltd., 2008).

Source: Quaternary Consultants Ltd., 2008

Figure 7.13-1 Winter Road into Minago Site (facing west)

Source: Quaternary Consultants Ltd., 2008

Figure 7.13-2 Excavating Test Pit along Winter Road

Source: Quaternary Consultants Ltd., 2008

Figure 7.13-3 Excavating Test Pit on Cut Line (Quaternary Consultants Ltd., 2008)

Source: Quaternary Consultants Ltd., 2008

Figure 7.13-4 Secondary Access Road within the Minago Property (Quaternary Consultants Ltd., 2008)

Quaternary Consultants Ltd. (2008) stated that it is virtually impossible that any use could have been made of the mine site vicinity during Pre-contact times. The area is located at a considerable distance from lakes or navigable rivers and access at any time of the year would have been very difficult. Any use of this location that might have occurred would have happened during the winter months and probably would have been related to the fur trade. It would be impossible to predict where such activity would have taken place as traplines are relocated every year to accommodate animal movement. Even if resources from this activity were present, they would be buried deep in the sphagnum moss that covers the area and would be impossible to locate. Comprehensive testing in such conditions would prove nearly impossible and the odds of finding anything using such a technique would be astronomical (Quaternary Consultants Ltd., 2008).

7.13.3 Baseline Conditions

A desktop analysis of the Minago Property indicated a very low potential for archaeological resources. Field investigations by Quaternary Consultants Ltd. (2008) confirmed that archaeological potential is extremely low in this area.

None of the creeks surrounding the Minago Property are navigable and it is doubtful that the Minago area was ever utilized by Pre-contact people (Quaternary Consultants Ltd., 2008). Minago River, located a distance (approximately 12 km) north of the development, is somewhat navigable but too far away to be an influence in the development zone (Quaternary Consultants Ltd., 2008).

7.13.4 Project Related Effects

Quaternary Consultants Ltd. (2008) found that:

- it is highly improbable that the area was used by inhabitants prior to the introduction of the fur trade,
- the possibility of finding any evidence of Pre-contact utilization of the area is next to impossible, and
- the likelihood of locating any evidence of Fur Trade or later use, other than prospecting and mining activities, is extremely minimal.

Based on their work, Quaternary Consultants Ltd. (2008) concluded that the proposed mine development will have no impact upon archaeological resources.

7.14 Socio-Economic Conditions

As part of an Environmental Impact Statement (EIS) of the potential mine development, a Socio-Economic Assessment (SEA) of the communities surrounding the development area was undertaken from May to August 2007. Victory Nickel Inc. retained DHR Associates to conduct a socio-economic assessment of the development area.

Neighbouring communities to the Minago Property include Grand Rapids (GR), Moose Lake (ML), Cross Lake (CL), Snow Lake (SL) and Norway House (NH). All of these communities, with the exception of Snow Lake, are covered by Treaty 5 (Figures 7.14-1 and 7.14-2) and have their own governing infrastructure usually collectively known as the First Nations in the Northern Region of Manitoba. Community members residing outside of Treaty 5 lands have their own community councils and mayors.

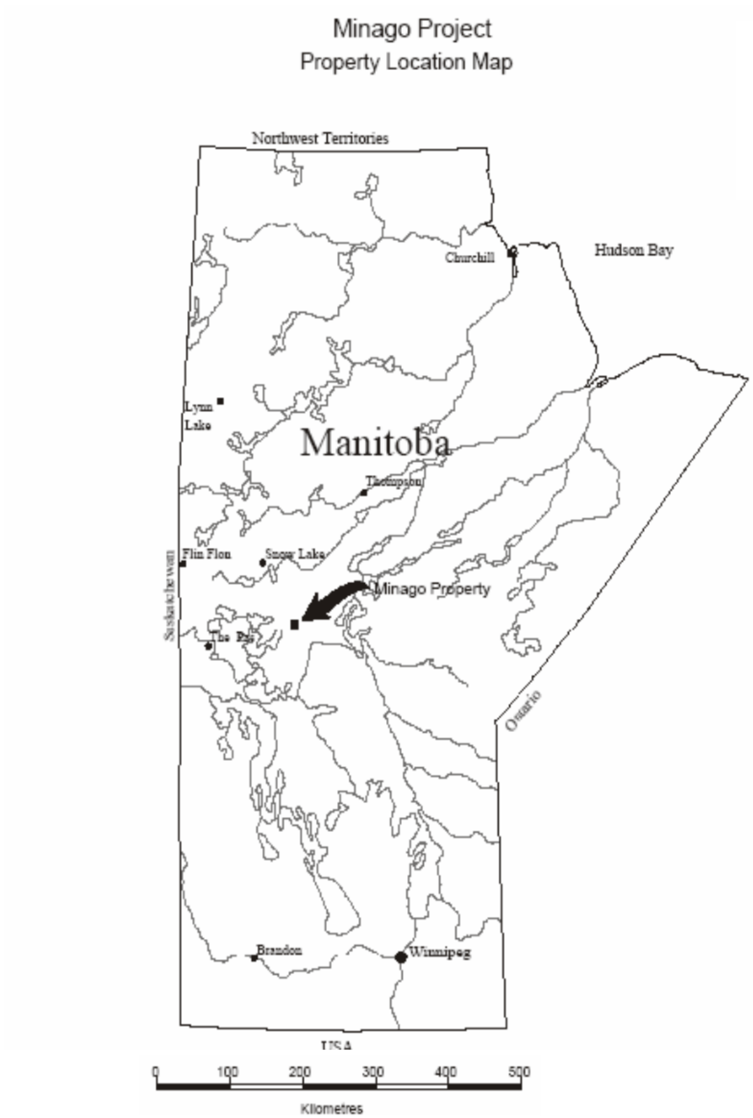
To undertake the Socio-Economic Assessment (SEA), a series of meetings and interviews were held with a wide range of key stakeholders to identify their views and opinions with respect to the Minago Project. The stakeholders included Norway House Cree Nation (NHCN) and Norway House Community (NHC); Grand Rapids Cree Nation (GRCN) and Grand Rapids Community (GRC); Cross Lake Band of Indians (CLBI) and Cross Lake Community (CLC); Moose Lake Cree Nation (MLCN) and Moose Lake Community (MLC); Snow Lake; Manitoba Metis Federation (MMF); Trapline Owners (TLO); Norway House Resource Management Board (NHRMB) and Government Agencies. Consultation, small group and open house meetings were held in the individual communities (Norway House, Cross Lake, Grand Rapids, Moose Lake, Snow Lake), Thompson, The Pas and Winnipeg. Figures 7.14-3 through 7.14-6 give snapshots of meetings that took place in the respective communities.

Victory Nickel also has developed a Memorandum of Understanding with Cross Lake, Moose Lake and Grand Rapids First Nations' Bands (Fig. 7.14-7).

7.14.1 Objectives of the Socio-Economic Assessment

The objectives of the Socio-Economic Assessment (SEA) for the Minago Project were as follows:

- Introduce the Minago Project complete with its major components to a wide range of key stakeholders;
- Inform communities and stakeholders of potential impacts (positive and negative) and their relative magnitude on the communities' social and economic well-being;
- Provide an opportunity for the integration of diverse community values into the decision making process for the mine development;
- Understand the concerns of the communities and stakeholders to develop potential mitigative measures that are practical, cost effective and sustainable;
- Provide information to address potential impacts of the Minago Project on the socio-economic resources of the communities.



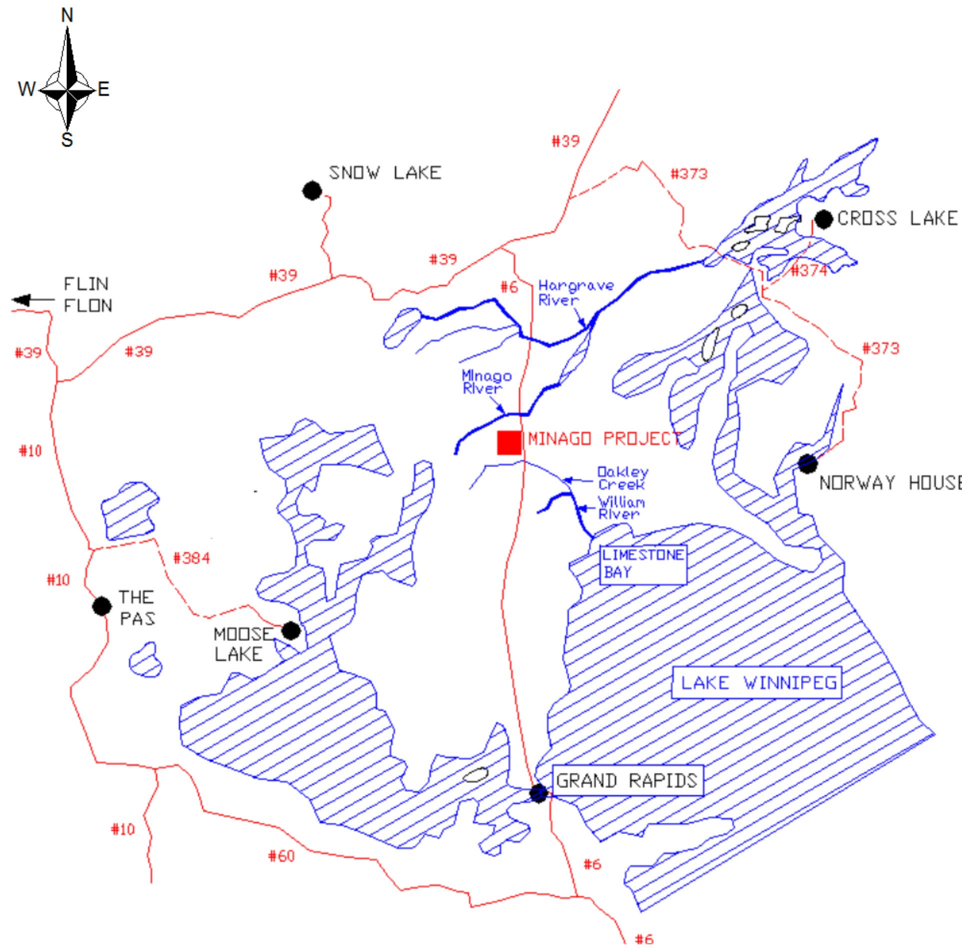
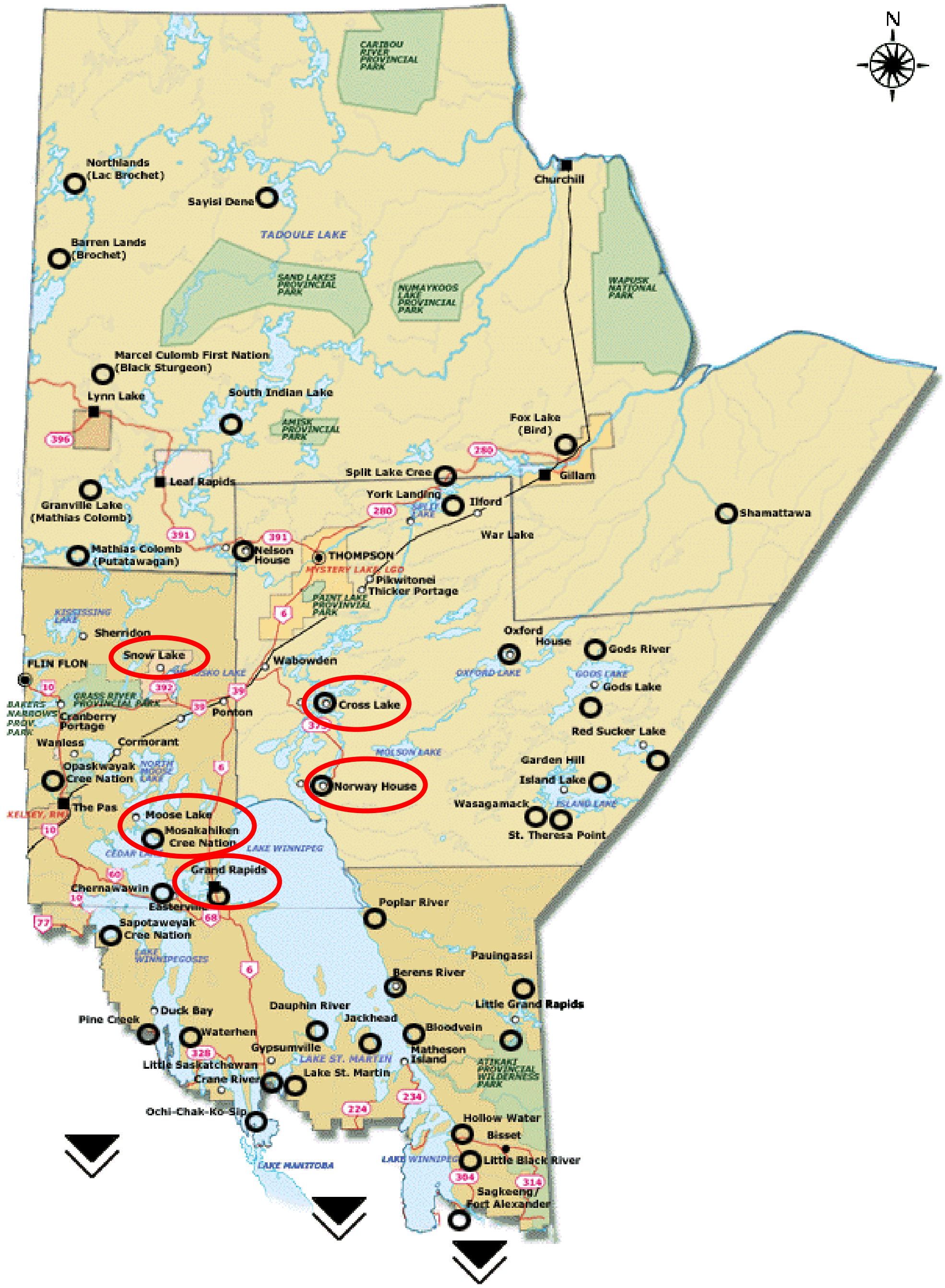


Figure 7.14-1 Site Location Map



Source: Manitoba Government, Manitoba Community Profiles

Figure 7.14-2 Communities of Interest Surveyed

Figure 7.14-3 Open House Meeting in Cross Lake held on 17 May, 2007

Figure 7.14-4 Open House Meeting in Grand Rapids held on May 08, 2007

Figure 7.14-5 Open House Meeting in Norway House held on May 23, 2008

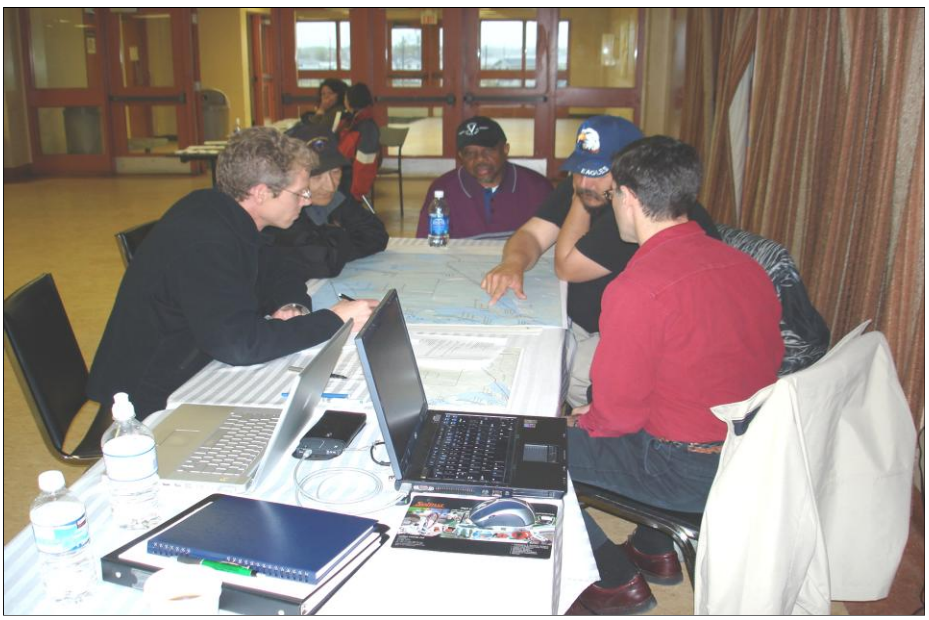


Figure 7.14-6 Meeting with the Trapline Owners (Land Use Meeting) in Norway House held on May 23, 2007

Figure 7.14-7 Signing of the MOU – Victory Nickel Inc. and Cross Lake, Moose Lake and Grand Rapids (December 07, 2007)

7.14.2 Assessment Approach of the Socio-Economic Assessment

The Socio-Economic Assessment examined how the proposed mining project would change the lives of current and future residents of the surrounding communities; both socially and economically. Indicators used to measure the potential social-economic impacts included:

- Demographics,
- Market analysis – businesses and services,
- Public services,
- Social structure,
- Social well-being,
- Occupational skills, and
- Aesthetic quality.

7.14.2.1 Data Sources and Limitations

The Socio-Economic Assessment essentially relied on available data in the public domain. Economic and social data on small rural communities is sparse. An important data source was information collected through the Canadian Census. A Canadian Census is conducted every five years and contains information on a number of important economic and social indicators. Economic data available includes information on population, education, labour force, employment and unemployment, income, occupational information, and employment by industry. The censuses also have a number of different social indicators including religion, age and sex distribution, education, family composition and housing. These formal data have been supplemented and complemented with more qualitative information about the communities. Based on a set community profiles and field assessments through interviews with various community members, qualitative information was collected to provide a more holistic sense of baseline socio-economic conditions of the study area.

Census Data

Starting in 1971, Statistics Canada began publishing community profiles. At first, profiles were only available for communities over 5,000 people, but beginning in 1981 profiles have been done on all communities. However, hardly any economic data is published for communities with fewer than 200 people to protect the confidentiality of Census respondents. There are also other sources of population information for the communities of interest. These include, but are not limited to, Indian and Northern Affairs Canada (INAC) and individual Bands and Municipality databases.

Income Tax Data

Another source of information was the Canada Customs and Revenue Agency, which publishes income tax statistics for every community in Canada. However, for small communities both the Census and income tax data is not complete to protect people's confidentiality.

Data on Business and Tourism

Data on businesses is even more limited. The only source of information on small communities are the local Chambers of Commerce. But even then, the available data is limited to protect the unintentional revealing of confidential business data.

7.14.2.2 The Assessment Process

The Socio-economic assessment process consists of two stages. During Stage 1, DHR Associates:

- profiled Victory Nickel Inc. and communities surrounding the Minago Property (SL,GR,CL,ML,NH) based on a questionnaire and personal interviews and meetings;
- identified key stakeholders and relevant issues related to the socio-economic impact indicators, and
- interviewed key stakeholders to elicit the positive and negative impacts of the project.

In Stage 2, the socio-economic impacts will be assessed and results will be shared with stakeholders. The process will involve the following three steps:

- Step A: Identification of significant impacts;
- Step B: Integration of environmental assessment findings; and
- Step C: Assessment of the project's mitigation measures and initiatives.

7.14.3 Socio-economic Profiles

Following are summaries of the socio-economic profiles for the communities of interest surrounding the Minago Project. These summaries are based on the DHR Associates (2008) report and commence with general descriptions of the communities followed by a comparison of their community characteristics in terms of:

- Population and age distribution,
- Labour force activity,
- Educational attainment,
- Experienced Labour Force 15 years and over by Industry, and
- Vocational Skills.

7.14.3.1 Misipawistik Cree Nation and Grand Rapids

The community of Grand Rapids is governed by two authorities: Misipawistik Cree Nation, a community of 651 (Statistics Canada, 2006 Census) and the Town of Grand Rapids, a community of 336 (Statistics Canada, 2006 Census). The Grand Rapids community is divided into three distinct areas: the Misipawistik Cree Nation, the Town of Grand Rapids, and the Hyrdo Sub-division. The Misipawistik Cree Nation (Misipawistik CN) constitutes the part of the community, which is located on reserve land, and is governed by a Chief and Council (1 Chief and 3 Councillors). The Town of Grand Rapids and the hydro sub-division are situated on land under provincial jurisdiction. The hydro sub-division is the area in the community where many of the staff and families who work for Manitoba Hydro reside. The Town of Grand Rapids was incorporated on January 1, 1997. A Mayor and Council govern both the town and the hydro sub-division (Source: NOR-MAN Regional Health Authority, 2007).

7.14.3.1.1 Misipawistik Cree Nation

The Misipawistik Cree Nation (or Grand Rapids First Nation (GRFN)) is located 426 kilometres north of Winnipeg on Highway #6 (PTH #6). It is situated at the confluence of the Saskatchewan River with Lake Winnipeg on the east and south banks of the Saskatchewan River, immediately across from the town site of Grand Rapids. The total land area of the Misipawistik Cree Nation is 18.52 square km.

The Misispawistik Cree Nation is still reliant upon the traditional pursuits including fishing, trapping and hunting (Fig. 7.14-8). Community members are also employed by Manitoba Hydro and in forestry and mining sectors. The Misipawistik Cree Nation is also looking towards developing opportunities in eco-tourism (Source: National Cree Gathering 2007 Web Site).

Alcohol and drug abuse within the community are rampant. Assaults, break-ins and thefts are common occurrences, as is armed robbery and rape (DHR Associates, 2008). As well, family violence and divorces are common within the community. There is a high rate of school drop-out, and a large number of people within the community depend on social assistance – 80% of members of the reserve and 20% of those within the town. The standard of housing within the community is poor to average (DHR Associates, 2008).

Figure 7.14-8 Fishing and Recreational Activities (Lake Winnipeg)

7.14.3.1.2 The Town of Grand Rapids

Grand Rapids is located on PTH #6 approximately 250 kilometres south east of the Town of The Pas and 400 kilometres north of the City of Winnipeg (Fig. 7.14-1). Grand Rapids is situated at the confluence of the Saskatchewan River with Lake Winnipeg and has a land area of 85.95 square km.

The economic base of the Town of Grand Rapids depends on commercial fishing, tourism, to some extent trapping, and the Manitoba Hydro Plant. The School Board is also one of the largest employers in the area. Manitoba Hydro is the largest public employer with 58 employees. The town of Grand Rapids has established infrastructure to accommodate commercial development in the service and tourism sectors. Tourism and related activities provide employment for many residents of the town and surrounding area. The area is known for having some of the finest master angler fishing lakes in the province, and many tourists arrive each year and stay at lodges and outposts and look for guides and other services (DHR Associates, 2008).

7.14.3.1.3 Businesses in Grand Rapids

The Misispawistik Cree Nation and the Town of Grand Rapids offer various commercial and business services (Tables 7.14-1 and 7.14-2). Half of the businesses are owned by Aboriginals. In spite of it being a small community with a population of 336 people, the town offers a large number and variety of services (DHR Associates, 2008).

7.14.3.2 Norway House Cree Nation and Community

Norway House is a northern community, located 30 km north of Lake Winnipeg on the bank of the eastern channel of Nelson River. The community has two settlements - Norway House Cree Nation (NHCN Indian Reserve) and the Norway House community (NHC) settled by Métis and Non-Aborginals. The community is 456 air kilometres north of Winnipeg, 208 air kilometres east of The Pas and 190 air kilometres south of Thompson, Manitoba. Norway House has a land area of 72.99 square km, which is less than one percent of the whole province of Manitoba (Manitoba has 552,369.9 sq. km).

Major economic activities include government services (NHCN, NHC, and Provincial government), commercial fishing, trapping and logging in the community. Because of these activities, seasonal unemployment varies, with peaks as high as 70%. The overall community's unemployment rate was approximately 24% (DHR Associates, 2008). This means that a lot of people depend on social welfare for their living.

Norway House Cree Nation and Community offer several public services. In fact, Norway House is one of the most well developed reserves and in many ways in Canada. There are

Table 7.14-1 Commercial Business and/or Services operated by GRFN, Métis or Others

	GRAND RAPIDS FIRST NATION (GRFN)	MĖTIS	OTHER
Esso Service Station/ Restaurant (off-reserve; non-Aboriginal owned)			X
Grand Rapids Fishermen's Co-op (on-reserve; commercial fishermen owned; bulk are Aboriginal	X		
E.T. Trucking Freight service (on-reserve; privately owned by First Nation)			X
Grand Rapids Lodge (off-reserve; Métis owned)		X	
Grand Rapids Laundromat (off-reserve)			X
Hilltop Motel (off-reserve; Métis owned)		X	
Riverview Campground (off-reserve)			X
Moak Lodge (off-reserve)			X
Pine Grove Cabins (off-reserve)			X
Herb Cook & Sons/heavy machines (off-reserve; privately owned by First Nation)			
Riverview Video (off-reserve)			X
Consumer Co-op Grocery (on-reserve; member owned)	X		
Pelican Landing Gas Station (on-reserve; First Nation owned)	X		
Grand Wish Restaurant (@ Pelican Landing; privately owned leased from Band)			X
Median Credit Union (@ Pelican Landing; on reserve member owned; all members Aboriginal)	X		
Maskiki Health (@ Pelican Landing; First Nation owned)	X		
Misipawistik Telecommunications Coop (on reserve; First Nation owned)	X		
King's Boat Repair (off reserve; non-Aboriginal owned)			X
Johnnie's Garage (off-reserve; Métis owned)		X	
Big Joe's Convenience Store (off-reserve; Métis owned)		X	
Northbrook Inn (off-reserve; privately owned)			X
Siggy's Taxi (health trips only)			X
Little Niska Day Care (on-reserve; First Nation owned)	X		
Little Minnow Day Care (off-reserve)			X
TOTAL	**7**	**4**	**12**

Source: DHR Associates Survey (2008)

Table 7.14-2 Business, Trades and Professional Services in the Town of Grand Rapids in 2008

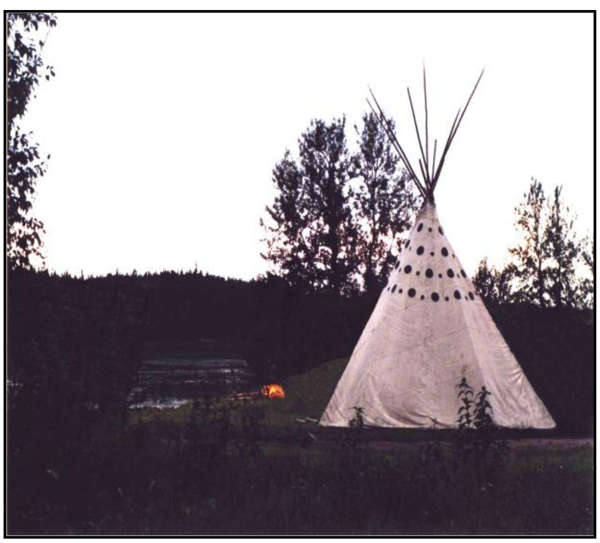
Businesses, trades and professional	Number
Accommodations	
Campgrounds	1
Hotels	2
Automotive	
Auto body repair	2
Auto fuel sales (no mechanic-gas	1
Auto/truck parts / accessories (new)	1
Auto/truck parts / accessories (used)	1
Diesel sales	1
Propane gas	1
Service stations with mechanic(s)	1
Specialty auto parts / service (tires,	1
Construction / Hardware	
Concrete / Cement suppliers	1
Gravel, sand suppliers	1
Lumber / Hardware stores	1
Road construction	1
Financial	
Credit unions / Caisse Populaire	1
Food And Beverages	
Beverage rooms, lounges, etc.	1
Candy stores	2
Coffee / Tea Rooms, Donut shops	1
Convenience stores	2
Grocery stores	2
Liquor stores	1
Meat shops, butchers	1
Restaurants, drive-through or drive-in	2
Restaurants, licensed	1
Restaurants, sit-down, not licensed	1
General Merchandise	
Hobby / craft shops	1
Hunting, fishing, bait stores	1
Other Services	
Barber shops / hair salons	1
Repair Services	
Machine shops / welding	2
Small engine repair	1
TOTAL	37

Source: Government of Manitoba. The Town of Grand Rapids Community Profile, Web site accessed: July, 2008 several restaurants, two hotels, a Royal Bank with ATM facilities, an insurance company (Ranger Insurance Broker), two Northern stores, a full service post office, a video store, a school (kindergarten to high school) and paved roads within the community. The Kinosao Sipi Mall and the recently added cell phone service are improvements to this northern community. It is home to a regional centre of the University College of the North and has a satellite degree programming from Brandon University's Faculty of Education and the University of Manitoba (DHR Associates, 2008).

Both the Norway House Cree Nation (Indian Reserve) and the Community have reported many incidences of drug addiction, alcohol abuse and several suicides, property damage, shoplifting, break-ins into houses. Also reported are many incidences of family violence, divorces and incest (DHR Associates, 2008). This has been happening mainly because of lack of employment and high dependency on social welfare (DHR Associates, 2008).

7.14.3.3 Pimicikamak Cree Nation and Cross Lake Community

Cross Lake is located in Northern Manitoba approximately 520 air kilometres north of Winnipeg along the shores of the Nelson River, and 130 air kilometres south of Thompson, Manitoba. It is accessible by aircraft with two daily flights from Winnipeg via Perimeter Air. With a newly constructed bridge, there is also all weather road access from provincial roads 373 and 374 to the community. Grey Goose Bus Lines also provides daily service to Cross Lake. Most of the roads in the community are paved.



The Cross Lake Community is composed of two closely related and adjoining, but independent settlements. One is the Cross Lake Indian Reserve (Pimicikamak Cree Nation) where the main developed area is called Cross Lake, and the other is provincial Crown Land (Division No. 1 and No. 22, unorganized territory). These unorganized territories cover 91,947 square kilometres. The population density (persons per square kilometre) for this land is low at 0.035 compared to a population density of 2.1 for the Province of Manitoba. In this report, the term ‘Cross Lake Community’ is used to describe the Divisions No. 1 and No. 22 unorganized territories. In the Cross Lake Community, the two main languages spoken are Cree and English. The young population is bilingual.

The Cross Lake Band is a signatory to Treaty 5 signed in 1875 and is one of the five Bands covered by the provision of the Northern Flood Agreement. The Cross Lake Band has been affected by the Manitoba Hydro's Jenpeg Dam Project and Lake Winnipeg Control Structure located 15 kilometres upstream from the reservation.

Most full time jobs in Cross Lake are offered by the Awasis Agency, the Band office and the Cross Lake Education Authority where school teaching staff is 80% Aboriginal. The Band office and the Cross Lake Education Authority are the largest employers along with the Northern Stores and Family Foods.

Most of the individuals within the Cross Lake Community who were over the age of 65 in 2007 were self-employed. Some of the types of jobs that are available within the community are in the service, construction, electrical and mechanical industries. Businesses include those related to construction, restaurants (4), mechanical garages (2), gas vendors (2), grocery stores (2), and retail and general merchandise (Table 7.14-3). The Cross Lake Community also has a motel with a lounge and vending services (DHR Associates, 2008). However, there is a very high unemployment rate (9.1% in the Cross Lake Community of 25.4% for the Pimicikamak Cree Nation), as well as a high rate of people surviving off welfare. This has led to a high level of poverty within the community (DHR Associates, 2008).

Drug and alcohol abuse problems are common within the Pimicikamak Cree Nation, as is suicide (DHR Associates, 2008). As well, gang violence and vandalism are common. Family violence and divorce occur at an average level. The rates of school dropout are low within the community, but there have been reported incidents of bullying at school (DHR Associates, 2008).

7.14.3.4 Mosakahiken Cree Nation and Moose Lake

Mosakahiken Cree Nation (Mosakahiken CN) and the Moose Lake Métis Settlement are two closely related but independent communities located on the northern limits of the Saskatchewan River Delta, situated about 100 kilometres south east of The Pas, Manitoba. The community is only accessible by gravel road which is approximately 64 kilometres from the nearest paved highway (Highway #10).

The Mosakahiken Cree Nation is located on the adjoining Reserve 31A, Big Island, Trader’s Lake, Crossing Bay and Little Limestone.

The Band is the main employer for the Mosakahiken Cree Nation. However, there are a few businesses such as grocery and retail/general merchandise stores that offer jobs in

Table 7.14-3 Businesses and Services in Cross Lake

Allan McLeod Construction	Merle's Flower Shop and Confectionery
Bethanie's Restaurant	Mid-North Development Corporation
Blacksmith Transportation (Emergency Ambulance)	Mistasineek Gas Bar
C.F.N.C. (Local Radio Station)	Multi-Channel MCTV
Canada Post Corporation	Muskego's Service and Towing
CLEA Adult Education Centre	Natural Resources
Chicken Chef	Northern Stores
Child and Family Services	Northern Quick Stop
Cross Lake Community Council	Nursing Station
Cross Lake Day Care	Pharmacy
Crisis Centre	Dental Office
Cross Lake Family Foods	Public Health
Cross Lake Inn - Restaurant and Lounge	Perimeter Airlines
Cross Lake Sports Complex	R.C.M.P.
D.R. Hamilton School	Ross Video
Fire Garage	Royal Bank
Fire Hall	Triple R Electric
Flo's Crafts and Video Centre	William Muswagon Construction
Kasayak Center (Elderly Home)	24/7 Confectionery
Kipapanow's Restaurant	
Manitoba Hydro	

Source: Cross Lake Education Authority Web Site, consulted July 2008.

the service, clerical, management and administration fields. Fishing and trapping are the main economic activities of the community. However, approximately 95% of the community was unemployed in 2007 and relied upon welfare as their base income (DHR Associates, 2008). This unemployment rate is extremely high compared to the provincial 2007 unemployment rate of 4.0%.

The available public education is a school (from kindergarten to grade 9) within the community. Students must travel to The Pas to attend High School. The lack of high school facilities within the community is a major problem, especially considering that the closest high school is located 74 kilometres away from the community and that 39% of the population is younger than 15. However, there are plans to build a new high school.

There is gender discrimination within the community. Levels of divorce, spousal abuse (especially directed towards wives) and general abuse are all on the rise, along with domestic violence, child abuse and neglect (DHR Associates, 2008). Alcohol and drug abuse are fairly high within the community, as well as the incidence of youth gangs, fighting and vandalism. The housing is of poor quality, as most of the units are lacking general maintenance (DHR Associates, 2008). There have been a few reported incidences of public violence, including property damage.

7.14.3.5 Snow Lake

The Town of Snow Lake was brought to life by gold mining. Prospectors discovered this spectacularly beautiful place in the 1940's and officially made it a town in 1947. The town quickly became successful due to the bounty of mineral resources.

Snow lake is a small community situated mid-way between Thompson, Flin Flon and The Pas (Figures 7.14-1 and 7.14-2). The community is located along Provincial Road 392. Snow Lake is 685 km north of Winnipeg and has a land area of 1,212 square kilometres, which is 0.2% of the total land area of Manitoba.

The Hudson’s Bay Mining and Smelting facility used to be a prominent feature in the Town of Snow Lake. The mine used to employ a large number of residents of Snow Lake and its surrounding communities. The mining activity has gone down since 2001. However, most of Snow Lake’s population is still employed in mining and mining related sectors.

Another industry, that is growing, is tourism. Snow Lake is characterized by excellent fishing opportunities and a natural beauty that attract tourists from all parts of North America. The town has all businesses and facilities needed to be a wilderness vacation destination. These facilities include restaurants, hotel and motel accommodations, and facilities for recreation.

Few characteristics of Snow Lake’s social structure are (DHR Associates, 2008):

- The presence of one High school - Joseph H. Kerr School – that has 273 students and a student/teacher ratio of 13 to 1;
- The medium gross family income was between $45,000 to $50,000 per year (DHR Associates Survey-2007);
- The community is well organized in terms of Civic associations and clubs making it comparable to larger cities in the province;
- Political participation is excellent at 95%;
- The governance of the community is under the leadership of one mayor and six councillors.

The DHR Associates Survey (2008) confirmed that the social well-being of this community is good. No serious crime has been reported in Snow Lake. There has been a zero crime rate and zero public violence. Alcohol and drug abuse has been almost negligible, mental illness unknown. No family violence or family disruption has been noted. Gender discrimination is rarely experienced. The education system is excellent and the school drop out rate has been negligible. In 2007, all of the community's labour force was engaged in income generating activities. In other words, the labour force employment was 100%. Less than 5 people were welfare recipients. Accommodation and housing standards are good and comparable to standards in larger cities of the province (DHR Associates, 2008).

7.14.3.6 Overview of Community Characteristics

Following is a summary and comparison of the communities of interest in terms of the following community characteristics:

- Population and age distribution,
- Labour force activity,
- Educational attainment,
- Experienced Labour Force 15 years and over by Industry, and
- Vocational Skills.

Complete details of the Socio-economic assessment are presented elsewhere (DHR Associates, 2008).

Of the communities considered, the largest communities were Cross Lake with 3,854 Pimicikamak Cree Nation and 3,455 residents in the Cross Lake Community and Norway House with 4,071 residents. The populations of the other communities were much smaller; 837 residents lived in Snow Lake, 700 lived in Mosakahiken Cree Nation (Moose Lake), 651 lived in Misipawistik Cree Nation (Grand Rapids), and 336 lived in the Town of Grand Rapids (Tables 7.14-4 and 7.14-5).

One striking difference between the communities of interests is that the populations of the primarily native communities of Mosakahiken Cree Nation (Moose Lake), Pimicikamak Cree Nation (Cross Lake), Misipawistik Cree Nation (Grand Rapids), and Norway House Cree Nation are much younger with a median age ranging from 20.1 to 22.1 than the populations of Cross Lake community, Snow Lake, and Manitoba as the whole. The median age of the populations of the Cross Lake Community, Snow Lake, and Manitoba as the whole were 35.5, 41.9, and 38.1 respectively (Table 7.14-4). This difference in age distribution is also illustrated in Figure 7.14-9.

Table 7.14-4 Population and Age Distribution in Communities of Interest (in 2006)

Age Category		Mosakahiken Cree Nation (Moose Lake Cree Nation)	Pimicikamak Cree Nation (Cross Lake Band of Indians)	Misipawistik Cree Nation (Grand Rapids Cree Nation)	Norway House Cree Nation	Cross Lake Community (Div. 1 and Div. 22; Unorganized Territory)	Town of Grand Rapids (Grand Rapids Community)	Town of Snow Lake	Manitoba
1	0 to 14 years	39%	37%	36%	34%	23%		20%	20%
2	15 to 29 years	24%	27%	25%	26%	19%		14%	20%
3	30 to 44 years	22%	19%	20%	21%	18%		20%	20%
4	45 to 64 years	12%	13%	18%	15%	23%		35%	26%
5	65 years and over	4%	4%	5%	3%	14%		12%	14%
	Total Population in 2006	**700**	**3,854**	**651**	**4,071**	**3,455**	**336**	**837**	**1,148,400**
	Population Change from 2001 to 2006	-5.4%	51.5%	10.1%	-3.1%		-5.4%	-30.7%	2.5%
	Median age	**20.1**	**20.3**	**21.6**	**22.1**	**35.5**		**41.9**	**38.1**

Source: adapted from DHR Associates, 2008

Table 7.14-5 Labour Force Activity Data

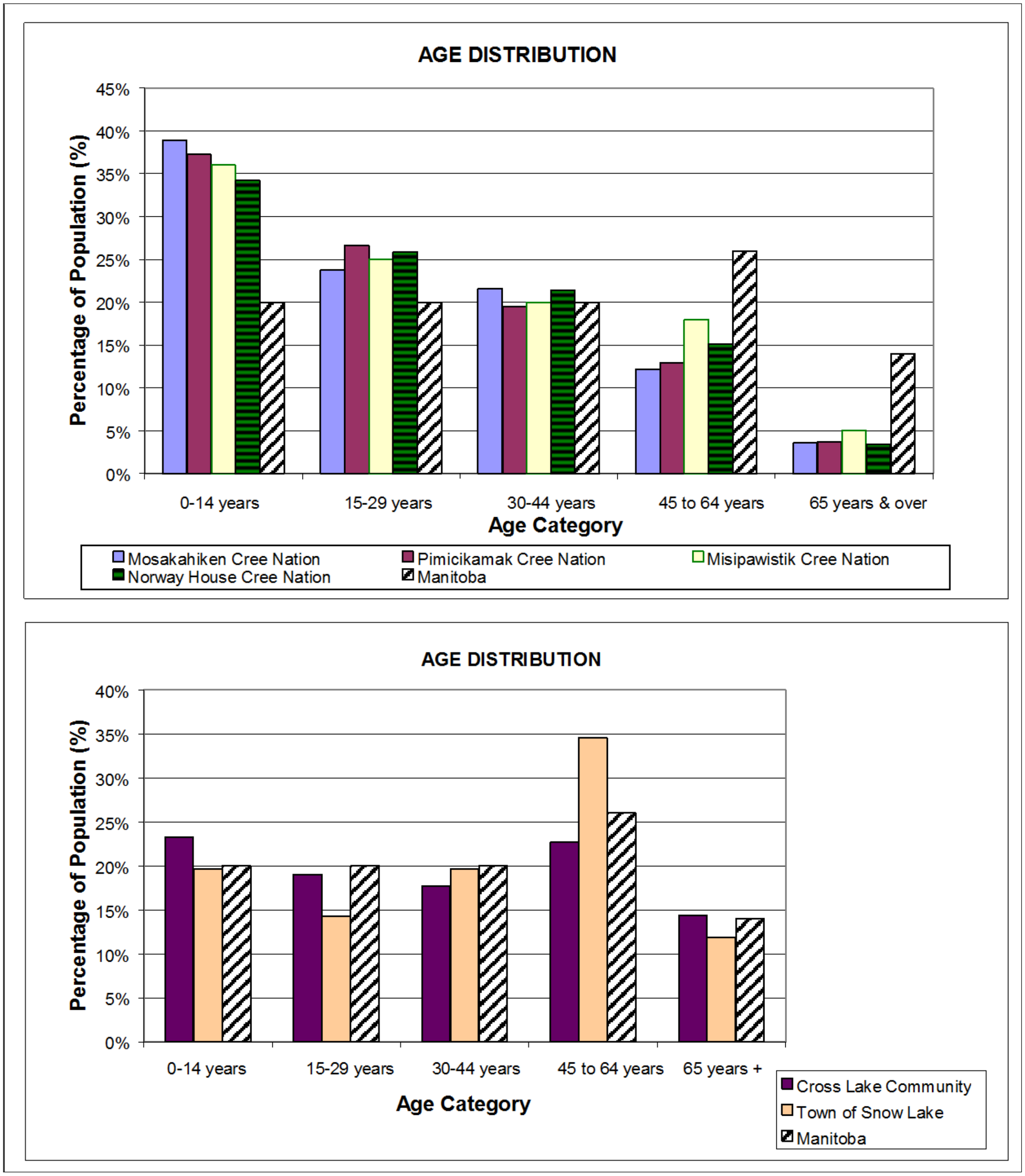
LABOUR FORCE ACTIVITY		Mosakahiken Cree Nation (Moose Lake)	Pimicikamak Cree Nation (Cross Lake)	Misipawistik Cree Nation (Grand Rapids)	Norway House Cree Nation (Norway House)	Community of Cross Lake (Div. 1 and Div. 22; Unorganized Territory)	Community of Cross Lake Division No. 1	Community of Cross Lake Division No. 22	Town of Grand Rapids	Town of Snow Lake	Manitoba
Year		**2006**	**2006**	**2006**	**2006**	**2006**	**2006**	**2006**	**2006**	**2006**	**2006**
Population	Total Population	700	3,854	651	4,071	3,455			336	837	1,148,400
	Total population 15 years and over	425	2,418	443	2,630	2,665	1,005	1,660	245	665	908,450
Native/Non-Native	Aboriginals	100.0%	98.9%	99.8%		52.7%		Majority of Community of Cross Lake Aborginals live in Div. 22	57.0%		
Population	Metis	1.4%	0.5%	3.1%						14.3%	
	Non-Aboriginal	0.0%	0.6%	0.0%		47.3%			43.0%		
Labour Force	In the labour force			415	1,190	1,490	605	885	160	395	611,280
	Employed			185	900		545	665	160	375	577,710
	Unemployed			90	290	280	55	225	0	20	33,570
	Not in the labour force			140	1,435	1,170	400	770	85	275	297,170
Employment Rate	Participation rate[1]	37.6%	42.9%	65.0%	45.2%	55.9%	60.2%	53.3%	65.3%	59.4%	67.3%
	Employment rate[2]	27.1%	30.3%	45.0%	34.2%	45.4%	54.2%	40.1%	67.3%	56.4%	63.6%
	Unemployment rate[3]	28.1%	29.3%	33.3%	24.4%	18.8%	9.1%	25.4%	0.0%	5.1%	5.5%
Income	Median income in 2005 – All private households	$28,011	$32,704		$27,456		$60,750	$51,461	$51,286	$75,515	$47,875

Source: adapted from DHR Associates, 2008

Notes: 1 Participation rate is the proportion of persons in the labour force (individuals actively employed and persons receiving unemployment benefits) compared to the population aged 15 years and over.

2 The employment rate — also known as the employment-population ratio — refers to the percentage of individuals employed compared to the population aged 15 years and over.

3 The unemployment rate represents the number of persons receiving unemployment benefits as a percentage of the labour force.



Source: adapted from DHR Associates, 2008

Figure 7.14-9 Age Distribution in the Communities of Interest in 2006

Another noticeable difference between the communities of interests is that the rate of unemployment in the primarily native communities of Mosakahiken Cree Nation (Moose Lake), Pimicikamak Cree Nation (Cross Lake), Misipawistik Cree Nation (Grand Rapids), and Norway House Cree Nation was much higher (ranging from 18.8% to 33.3% in 2006) than in Snow Lake, the Town of Grand Rapids, and Manitoba as the whole. The unemployment rate was 5.1% in Snow Lake, 0% in the Town of Grand Rapids, and 5.5% in Manitoba (Table 7.14-5).

Another noticeable difference between the communities of interests is their median income. For the primarily native communities of Mosakahiken Cree Nation (Moose Lake), Pimicikamak Cree Nation (Cross Lake), and Norway House Cree Nation the median income ranged from $27,456 to $32,704 in 2005 (Table 7.14-5). This median income was $15,000 to $20,000 below the provincial median income of $47,875 in 2005. All other communities considered had higher median incomes than the provincial average. In 2005, the median incomes were $51,286 for the Town of Grand Rapids, $51,461 for Division No. 22 of the Cross Lake Community, $60,750 in Division No. 1 of the Cross Lake Community, and $75,515 in Snow Lake (DHR Associates, 2008).

The educational attainment in the communities of interest is summarized in Table 7.14-6. The educational attainment was below the provincial average for all communities, except for the Town of Grand Rapids. In the Town of Grand Rapids, 39% of the population older than 15 years had a university certificate, diploma or degree compared to the provincial average of 19%. The percentage of the population 15 years and older that had a university certificate, diploma or degree ranged from 4.1% in Pimicikamak Cree Nation (Cross Lake) to 16.3% in Norway House Cree Nation in the primarily native communities (Table 7.14-6).

Table 7.14-7 summarizes the experienced work force by industry. In the communities of interest, the top three industries as far as employment is concerned were ‘Health Care and Social Services’, ‘Educational Services’, and ‘Agriculture and other Resource-based Industries’.

Table 7.14-8 summarizes the vocational skills of residents queried in some of the communities of interest. In total, residents possessed 31 different vocational skills. In 2007, the highest number of skilled people (354) resided in Norway House, followed by Grand Rapids (79), Cross Lake (55), Snow Lake (42), and Moose Lake (35). The top three vocational skills were truck driver, heavy equipment operator, and carpenter.

Table 7.14-6 Educational Attainment in the Communities of Interest in 2006

	Mosakahiken Cree Nation (Moose Lake)		Pimicikamak Cree Nation (Cross Lake)		Misipawistik Cree Nation (Grand Rapids)		Norway House Cree Nation (Norway House)		Community of Cross Lake (Div. 1 and Div. 22; Unorganized Territory)		Town of Grand Rapids		Town of Snow Lake		Manitoba
Total population 15 years and over	425		2,418		443		2,630		2,665		245		665		908,450
No Certificate, Diploma or Degree	376	88.5%	1,596	66.0%	265	59.8%	1,875	71.3%	1,060	39.8%	71	29.0%	163	24.5%	
Highschool Diploma									560	21.0%			235	35.3%	
Apprentiship / Trades Certificate	17	4.0%							275	10.3%			110	16.5%	
College Degree	22	5.2%	185	7.7%	N/D		N/D		290	10.9%	N/D		115	17.3%	N/D
University Certificate below Bachelor	10	2.4%	100	4.1%	N/D		N/D		90	3.4%	N/D		6	0.9%	N/D
University certificate, diploma or degree			100	4.1%	55	12.4%	428	16.3%	390	14.6%	96	39.2%	30	4.5%	172,606 (19%)

Note: N/D Not Determined

Source: adapted from DHR Associates, 2008

Table 7.14-7 Experienced Labour Force 15 Years and over by Industry in 2006

	Mosakahiken Cree Nation (Moose Lake)		Pimicikamak Cree Nation (Cross Lake)		Misipawistik Cree Nation (Grand Rapids)		Norway House Cree Nation (Norway House)		Community of Cross Lake (Div. 1 and Div. 22; Unorganized Territory)		Town of Grand Rapids		Town of Snow Lake		TOTAL
Health Care & Social Services	65	15.2%	320	21.9%	65	15.7%	220	20.0%	141	10.0%	10	6.0%	45	11.8%	**865**
Educational Services	82	19.3%	320	21.9%			165	15.0%	197	14.0%	34	20.9%	20	5.3%	**817**
Agriculture and other Resource-based Industries	50	11.8%			130	31.3%	66	6.0%	183	13.0%	29	18.0%	135	35.5%	**592**
Business Services	82	19.3%					132	12.0%	141	10.0%			20	5.3%	**375**
Retail Trade							99	9.0%	141	10.0%	38	23.9%	45	11.8%	**323**
Construction Industries	31	7.3%					88	8.0%	126	9.0%			10	2.6%	**255**
Finance and Real Estate							44	4.0%	42	3.0%					**86**
Manufacturing Industries							11	1.0%	14	1.0%			45	11.8%	**70**
Wholesale Trade							11	1.0%	28	2.0%			10	2.6%	**49**
Other Services	115	27.1%	350	23.9%	130	31.3%	264	24.0%	393	28.0%	50	31.2%	50	13.2%	**1,352**
TOTAL	**425**	**100.0%**	**1,464**	**67.6%**	**415**	**78.3%**	**1,100**	**100.0%**	**1,405**	**100.0%**	**160**	**100.0%**	**380**	**100.0%**	

Source: adapted from DHR Associates, 2008

Table 7.14-8 Vocational Skills recorded in 2007

	Mosakahiken Cree Nation (Moose Lake)	Pimicikamak Cree Nation (Cross Lake)	Misipawistik Cree Nation (Grand Rapids)	Norway House Cree Nation (Norway House)	Town of Snow Lake	TOTAL
Truck drivers	13	6	5	50	2	**76**
Heavy equipment operators	8	21	9	33	2	**73**
Carpenters	8	4	8	41		**61**
Housekeepers		6	9	14	4	**33**
Pipe Fitters			1	32		**33**
Surveyors		1	1	27		**29**
Catering	1	4	4	14	5	**28**
Electricians			1	23		**24**
Security officers	2	2	4	10	3	**21**
Clerks		1	5	10	4	**20**
Computer Technicians		1		14		**15**
Marketing Personnel				15		**15**
Supervisors			3	10	2	**15**
Mechanics	3	2	1	8		**14**
Miners		1	3		9	**13**
Accountants			2	8	1	**11**
Trainers				10	1	**11**
Administrative assistants		1	4	3	1	**9**
Millwrights			1	6	2	**9**
Assayers				7	1	**8**
Nurses			5	2	1	**8**
Welders			1	7		**8**
Drillers and blasters		2	3		2	**7**
Laboratory technicians				5	1	**6**
Engineers andTechnicians			1	3		**4**
Human Resource Specialists			2	2		**4**
Geologists		2			1	**3**
Managers and Executives			2			**2**
Public Relations Specialists			2			**2**
Safety Experts		1	1			**2**
Photographers			1			**1**
TOTAL	**35**	**55**	**79**	**354**	**42**	**565**

Source: adapted from DHR Associates, 2008

7.14.4 Key Issues raised by Stakeholders

A series of meetings were held with key stakeholders to identify their views on Victory Nickel Inc. and the Minago Project in general. It should be noted that there is a salient resentment to development projects in the area due to past adverse consequences and experience with some companies. However, many stakeholders were aware of the Minago Project and Victory Nickel Inc. and were appreciative of the company's consultation process (DHR Associates, 2008).

The results of the fact-finding process were overwhelmingly positive. Following is a summary of the expected positive and negative impacts of the Minago project as identified by the consulted communities.

7.14.4.1 Misipawistik Cree Nation and the Town of Grand Rapids

Positive Impacts

- The First Nation people living off reserve would move back here, especially if there was work available.
- Victory Nickel will create opportunities for local individuals and businesses through contracts.
- Victory Nickel would likely arouse the interest of having more resource use especially in recreation and potentially improve the quality of life in Grand Rapids.
- The mine development could lead to better sales, more workers, and possible business expansions.
- Definitely the development of the mine will lead to hiring more staff and finding a better and more convenient location for a new post office.
- Victory Nickel development will have a positive impact because it would mean more business for the lodge due to recreational use of the facilities and resources.
- The mine development will mean for us to get better school facilities.
- Development of the mine is a good idea. It may bring about the changes Grand Rapids had always wanted e.g. better grocery store, a strip mall with a variety of services.
- Victory Nickel will affect everybody in Grand Rapids because there will be more jobs, more money and less welfare.
- The mine development may bring about new positive behaviours in Grand Rapids such as shopping options and evening recreational activities.
- Victory Nickel will have a positive impact on the community. It would solidify the improvement in the relationship between the RCMP detachment, the Town of Grand Rapids, Missipawistik Cree Nation and Chemawawin (Easterville). These communities have the same goal – better and healthier community life.

- People need jobs and long-term work. The Minago Project is what we need for the future younger generation. It is true that the mine may affect trapping but the majority of the residents of Grand Rapids do not live that way anymore. Victory Nickel Inc. should study the effect of the mine in order to avoid problems in the future.
- It is great that Victory Nickel is bringing the mining industry to Grand Rapids. The company will have to train people, because the employment base is not here. The greatest opportunities would be in sub-contracting part of the mine development activities.
- The socio-economic impact of the mine will be good for Grand Rapids not just for the First Nation but for the town as well. Economically it will generate more business, which is an excellent opportunity for our grandchildren and their future.
- The mine will be good for the young people if they could be given the opportunity to work there.
- Victory Nickel will be good for the economy and will not have severe effect on fishing.
- Victory Nickel will have positive impact economically and business wise. It is great and really good because it is time to move ahead.

Negative Impacts

- There are environmental concerns, which will require more information before the Band can support the mine.
- Fishing, trapping and logging activities maybe affected negatively although Minago is located rather far from Grand Rapids.
- The open-pit operations will affect the eco-system: air, water, vegetation, animals, and humans.
- Economic benefits may be outweighed by resulting social problems such as crack and meth abuse.

7.14.4.2 Norway House Cree Nation

Positive Impacts

- The project will create jobs and generate revenue.
- The project may stimulate side economic developments and services like Mc Donald's, Wal-Mart badly needed in Norway House.
- The project will result in more people in the area for sports competitions.
- The project may bring spin off economic activities.
- The project may stimulate educational initiatives.
- The project will create an opportunity that will open doors for employment and increase the economic base of NHCN.
- The project may indirectly increase operational funds for the Norway House Cree Nation.
- The project will create jobs even though people will have to be trained.

- The project will promote community exposure.
- The project will alleviate poverty in the community.
- The youth will have something to look forward to in the future in terms of jobs.
- The project will lead to an improvement of lifestyle since people will be off social welfare.

Negative Impacts

- Environmental degradation of the Lake (Lake Winnipeg), Limestone Bay.
- The project will interfere with the water table and pollute the air (toxins) and the water.
- The project may affect the trappers and fishers.
- Economic development will come with its social problems such as drug abuse and alcoholism.
- Families may be uprooted by relocating to the campsite.
- Animals and other wildlife will be affected.

7.14.4.3 Pimicikamak Cree Nation and the Town of Cross Lake

Positive Impacts

- Victory Nickel is doing the proper thing by interviewing residents of Cross Lake. I welcome the process and the project. The residents will benefit especially from spin-off jobs.
- The project is positive because it will bring employment and jobs to Cross Lake. This means there will be more money in the community directly and indirectly through subcontracting.
- What Victory Nickel is doing is good since we will have jobs, employment and training.
- One can only think of the positives – good jobs, more money, happy families, and schools.
- The mine will bring more business to Cross Lake.
- Victory Nickel may be our chance to improve the community infrastructure and public services such as Youth Programs, Fire Protection, and Drug Enforcement.
- The mine will be beneficial to all residents of Cross Lake. It will offer employment, school improvement, and entice people to come back home. The mine may bring money in the community to build the badly needed Youth Centre and Job Centre.
- The Minago Project may mitigate the socio-economic helplessness, which is the main cause of suicide incidents in the community.
- It will definitely create a huge opportunity for employment and training. However, promises must be kept.
- Victory Nickel will benefit both businesses and the community.

- The development of the mine will give employment to our young people. It will also create awareness of and put Cross Lake on the map. This may increase economic activities in the area.
- The mine will create more business, which will result in more work and employment.
- The project will increase and improve business through gas sales and rooms/accommodation.
- There will be more jobs and business for our community.
- The mine is welcome. We need more work for the young people.

Negative Impacts

- Spillway from the mine into Minago River will affect trapping and fishing especially in Zone E.
- Currently, drug and alcohol abuse is very serious in the community and the mine may increase the problem.

7.14.4.4 Mosakahiken Cree Nation and the Community of Moose Lake

Positive Impacts

- The Minago Project is welcome. As long as Victory Nickel hires Moose Lake residents there will be socio-economic benefits.
- The mine will have economic benefit especially for the youth. It may increase the gang activities, but this can be controlled through workshops and law enforcement.
- The mine is good for the economy of all Moose Lake residents, the majority of whom are on welfare.
- The project will create work for our young people.
- In general, the mine is a good thing for Moose Lake. It will bring jobs, but the youth have to be given the training on work ethics, money management, and time management.
- It will generate a lot of work/employment opportunities for our community.
- The mine will have positive impact on the community. With more financial resources we can pave our roads and develop various business initiatives.
- There will be a lot of spin-off businesses, which will create jobs and develop a sense of purpose for the youth.
- The mine operation will help the community in mitigating the effect of welfare. There will be more jobs and luxury life.
- Victory Nickel will give jobs and employment to Moose Lake residents, but the company should take care of the environment.
- Having a big employer in the vicinity will improve family behaviour of residents.

- The mine operation will be good for the community since there will be jobs for people.

Negative Impacts

- People have not forgotten the mistreatment by other companies, which did not keep their promises.
- The mine will contaminate herbs that the locals use for medicine and food.
- Sudden influx of money in the community may cause crime to go up.

7.14.4.5 Snow Lake Community

Positive Impacts

- Victory Nickel will stimulate the economy of Snow Lake and hence improve the infrastructure to accommodate growth and increase society social interaction.
- The Mine will be good for Snow Lake's high school graduates who may be hired by the company.
- We need a company like Victory Nickel in our community. It will stimulate the economy and increase business.
- The socio-economic impact of the mine will be nothing but positive. The mine will reduce unemployment.
- The mine will bring new businesses to our town.
- The mine will give occupational focus to young people who hence will stay away from criminal activities.
- The mine will help the town regarding population growth, which is needed badly.
- The impact of the mine will always be positive to businesses and eventually to the entire Snow Lake Community.

Negative Impacts

- The mine may increase alcohol and drug abuse incidents.

7.14.5 Potential Opportunities for the Communities of Interest

7.14.5.1 Employment Opportunities

The Minago Project, should it become a reality, it will create significant number of direct employment for Northern Manitobans. The open pit (Mining, Milling, and Services) and Frac Sand Operations (Processing and Transportation) will create 410 and 200 direct jobs, respectively. In addition, there will be many more employment opportunities for the provision of transportation; maintenance; camp and hospitality services; security; and site support (services) contractors.

7.14.5.2 Business Opportunities

The Minago Project will create business opportunities for the Communities of Interest. The communities could create transportation entities to transport materials and personnel (150 to 180 employees per week) between the mine site and the communities.

Other business opportunities include, but are not limited to, camp and hospitality services (catering, camp maintenance and hospitality services); site services (garbage removal, snow removal, supply of aggregates); and suppliers (consumables, spare parts, fuels, and other services).

The Communities of Interest can also enter into Joint Ventures arrangements with major contractors responsible for Mining; Equipment Maintenance; Construction; Explosive Manufacturing and Camp and Hospitality Services. The Communities of Interest could bid for these contracts individually or in the form of Joint Venture arrangements with large companies.

Trucking of Frac Sand is also a great opportunity for a Joint Venture requiring a capital investment of about $3M. Trucking of Frac Sand will involve movement of some 900,000 tonnes of sand per annum with projected revenue of between $9M and $10M.

Mine Site Catering is another opportunity that the Communities of Interest could Joint Venture with a Company like Sodexho. A Joint Venture of this nature would create 60 direct jobs. Victory Nickel Inc. will contribute a kitchen and dining facilities. There exist successful models that the Communities could learn from. The Athabasca Catering Limited Partnership is a useful model and it is wholly owned by Aboriginal (Five First Nations) partners. This organization provides catering and janitorial services for a number of Saskatchewan mines.

Site closure and reclamation is another opportunity for the Communities to get involved. The potential here include decommissioning of infrastructure, site reclamation, maintenance and post closure environmental monitoring, if required.

7.14.6 Effects Assessment

Project effects on socio-economic environs are covered in the next Sections.

7.14.6.1 Economic Impact Assessment

The socio-economic assessment combines the quantitative tools of a conventional economic assessment with the more qualitative tools of socio-cultural effects assessment. Where appropriate, mitigation measures to optimize benefits and minimize adverse effects are identified.

An economic impact assessment is a standard economic tool designed to measure the total effect of an injection of funds into a local or regional economy. The assessment is a snapshot, measuring the impact of that injection. It cannot measure costs and benefits over time nor can it provide measures to judge whether an equivalent expenditure of funds for something else would have generated more or less benefit. Economic impacts are usually classified as direct, indirect or induced.

Direct impacts refer to the value-added increase in employment, local incomes and local Gross Domestic Product (GDP) retained in the area, and tax receipts to all governments.

Indirect impacts refer to the value-added increase in employment, local incomes and local GDP retained in the area, and tax receipts to all governments from local suppliers of goods and services to the project.

Induced impacts refer to the increase in employment and local incomes. Induced impacts include local GDP and tax receipts from the spending and re-spending of all labour incomes generated by the original expenditure.

The calculation of all impacts requires the use of multipliers. The multipliers used to calculate direct and indirect impacts for the Minago project came from Statistics Canada's 2000 Inter-provincial Open Input-Output model. Induced impacts were not calculated as Statistics Canada no longer includes these values in its models.

The findings of the socio-economic assessment were used to assess the Minago project effects on the employment and contracting opportunity. Specific parameters and assumptions used for characterizing economic effects are detailed below.

Gross Domestic Product (GDP)

There are different methods to estimate the Gross Domestic Product (GDP), which, in theory, should produce the same result:

- **Expenditure Method:** The expenditure method adds up consumer spending, gross capital expenditures by private businesses and government, government direct spending on goods and services (not transfer payments such as social assistance, employment insurance or pensions) and net exports;
- **Income Method:** The income method adds up everyone's wages and salaries, income from unincorporated businesses, corporation profits, interest income, and adjustments for depreciation and indirect taxes such as GST;
- **Value added Method:** The value added method adds up all the values directly produced by each industry. Value added is defined as the total sales of an industry minus what it buys from other industries.

Calculating direct impacts of the construction of the Minago Nickel Project can be done in two ways. For the construction phase, mine construction is part of gross capital expenditures. It can be added directly in the Expenditure Method. However, imports need to be subtracted from this figure in order to arrive at the direct impacts. In the operations phase, exports of concentrate are part of net exports, so they can also be added directly to GDP, but imports by the mine also need to be deducted.

Multipliers

The model and multipliers used for the economic assessment of the Minago Project are based on Statistics Canada's 2000 Interprovincial Open Input-Output model. Multipliers for direct impacts of mine construction and of mine operation were calculated. Direct impacts can be calculated using information from the mine plan. Indirect impacts on Manitoba and Canada as a whole can readily be calculated using published multipliers. As well, overall multipliers published for "Construction" and "Mining and Oil and Gas Extraction" can be used. Unfortunately, induced impacts are no longer available, as Statistics Canada no longer includes these in its models. While induced impacts could have been estimated, it was not done in the economic assessment for the Minago Project to not overstate the effects of spending.

Statistics Canada's 2000 Interprovincial Open Input-Output model only applies to provincial/territorial jurisdictions, but not to local communities. Other models exist to compute local economic impacts, but in the absence of knowledge about how much money and employment will be generated in each community, it is impossible to calculate local impacts.

7.14.6.2 Socio-Cultural Effects Assessment

The findings of the socio-economic assessment provided the basis for predicting effects on community health and well-being, including the potential for in-migration and out-migration and effects on local health, law enforcement and social services. Information on project shifts, personnel transportation, etc. provided further information which were used to estimate potential social and cultural effects of the Minago project on local communities and associated effects on community health and well-being Valued Socio-economic Components (VSCs). Socio-economic effect attributes are summarized in Table 7.14-9.

Information on haul frequency and scheduling and mitigation measures to address potential traffic and safety concerns were used to determine the potential effects of the traffic VSC.

The significance of residual project and cumulative effects on socio-economic conditions was determined based on the nature and magnitude of the effects, the mitigation strategies that are available for reducing or eliminating adverse effects and optimizing positive effects for the well-being of affected communities. A residual effect will be considered significant if it:

- Raises strong concern among stakeholders;
- Results in substantial changes in the well-being of affected populations of communities; and
- Significant socio-economic effects could either be positive or adverse.

7.14.6.3 Project Effects

Project effects are assessed in relation to project activities including construction and operations.

Table 7.14-9 Socio-Economic Effect Attributes

ATTRITBUTES	DEFINITIONS
Magnitude	
High	Major changes from existing baseline conditions
Medium	Moderate changes from local baseline conditions
Low	Minor changes from local baseline conditions
Spatial Extent	
Regional	Thompson/The Pas
Local	In the vicinity of the mine, including the communities the Norway House, Cross Lake, Snow Lake, Moose Lake and Grand Rapids.
Duration	
Short-term	Impact continues during construction only.
Medium-term	Impact continues beyond construction.
Long-term	Impact continues for the life of the project.
Frequency (during the Project Life)	
Continuous	Impact occurs continuously during the project life.
Frequent	Impact occurs several times during the project life.
Infrequent	Impact occurs very occasionally during the project life.
Reversibility	
Reversible	Impact can be reversed once the project activity ceases.
Irreversible	Impact that cannot be reversed once the project activity ceases.
Likelihood of Occurrence	
High	The likelihood of occurrence of the effect as predicted is high.
Unknown	The likelihood of occurrence of the effect as predicted in unknown.

7.14.6.3.1 Construction

It should be noted that the data presented and analyzed in this section are preliminary based on the Feasibility Study, and are expected to change with time as the project moves into construction.

Regional Economic Effects

Capital expenditures for the mine construction were estimated to be $596 million in the first three years as summarized in Table 7.14-10.

A construction camp with a capacity for handling 422 personnel will be required during the construction phase. It will be located near the project site, a few kilometres south of the main industrial complex. Construction of the concentrator, Frac Sand Plant, mine site buildings, power line road, and mine pre-production development is estimated to require over 600 people during the construction period. Construction workers required during the construction period will be locally sourced, if possible. On average, there will be 300 construction workers on-site per year through the construction period. Workers were assumed to work for

Table 7.14-10 Minago Sulphide Nickel Project – Capital Cost Estimates (M$ in CDN)

Description	Total Construction & Sustaining Expenditures		
	Pre-Production (CAN$)	Sustaining (CAN$)	Total (CAN$)
Direct Costs:			
General	$5,900,000	$0	5,900,000
Site Development	$37,200,000	$0	$37,200,000
Site Utilities	$45,600,000	$2,000,000	$47,000,000
Tailings Management	$15,200,000	$1,300,000	$16,500,000
Frac Sand Plant	$26,600,000	$0	$26,600,000
Mine Infrastructure	$35,600,000	$0	$35,600,000
Mobile Equipment	$107,000,000	$0	$107,000,000
Ore Processing Facilities	$146,700,000	$0	$146,700,000
Non-Process Buildings	$19,100,000	$0	$19,100,000
Total Direct Costs	$438,900,000	$3,300,000	$442,200,000
Overhead Costs:			
Indirect Costs	$91,400,000	$0	$91,400,000
Owner's Costs	$12,800,000	$0	$12,800,000
Contingency	$49,900,000	$0	$49,900,000
Total Overhead Costs	$154,100,000	$0	$154,100,000
Total Capital Costs	**$593,000,000**	**$3,300,000**	**$596,300,000**

10 hours per day and 7 days per week with turnarounds as required by the schedule of construction activities. Project work shifts will operate with two-week turnarounds.

Most economic impacts will result from the $596 million capital spending on the construction of the mine and related facilities. Construction spending will affect the Gross Domestic Product (GDP), employment, business revenues, and taxes. Multipliers for direct impacts of mining construction are kept confidential by Statistics Canada, but total direct and indirect impacts can readily be calculated using published multipliers.

Multipliers for the overall construction industry are available and were used in the economic assessment for the Minago Project (Table 7.14-11). The estimated 2000 Manitoba multipliers for construction expenditures on different components of GDP are presented below. The meaning of each multiplier is explained below in the relevant section. To calculate the final economic impact, the initial amount of expenditure ($596,000,000) was multiplied by the appropriate multiplier.

It should be noted that the Statistics Canada employment multipliers are average figures for all construction. The mine planning exercise provides more accurate numbers on direct employment for the Minago Project. So rather than using the Statistics Canada indirect impact multipliers, the ratio of the indirect to direct jobs was used to calculate indirect impacts on employment. Thus, the number of direct jobs was multiplied by the employment ratio to estimate indirect jobs.

Direct and indirect impacts on GDP are presented in Table 7.14-12. The initial $596 million in construction expenditure will result in a total of $721.2 million worth of purchases (output) in Manitoba and $1.144 Billion worth of purchases (output) in Canada as a whole. Note that the “Output” amount double-counts many expenditures. For example, a construction contract would include fuel for heavy equipment. Both the total value of the contract and the value of the fuel purchases are added up in the total output indirect impact measures.

The GDP impacts are a better measure as it eliminates double counting and takes economic leakages into consideration, i.e., it subtracts the value of those goods and services that must be imported for the project. The direct impact in Manitoba of the construction of the mine will directly increase GDP by $202.6 million. When purchases in Manitoba are accounted for, the province’s GDP will be increased to $268.2 million total. Manitoba’s GDP in the year 2008 was approximately $51,000,000,000 (Stats Canada). The $268.2 million total (direct + indirect, excluding $51 billion reported in 2008) impact in Manitoba will therefore, likely account for a 0.5% boost in GDP, which represents a substantial increase.

Note that the total impact on Manitoba’s GDP is less than half of what the project will cost. This is largely due to the need to import many goods and services needed for the project. The input-output model only calculates international imports, estimated at $125.1 million (Direct and indirect impacts in Canada).

Government Revenues and Spending

Tax Revenues

The input-output model allows calculating indirect taxes such as the GST and property taxes directly, but income taxes have to be estimated. Based on the 2009 Taxable income rates (federal and provincial), the lowest combined minimum marginal tax rate in Manitoba was 25.80% on the first $31,000 of taxable income and 27.75% on earnings between $31,000 and $40,726 of taxable income (Table 7.14-13). Between $40,726 up to $67,000 the combined (federal personal income tax rate) was 34.75%. Provincial tax was 10.8% on the first $30,544 of taxable income and 12.75% on the next $34,456 (Manitoba’s provincial income tax). Note that some of the income tax revenues could go to First Nations governments, if workers on the job live on Manitoba’s First Nation settlement land. The tax rates can be applied to wages and salaries to yield an estimate of personal income taxes. Corporation income taxes are much more difficult to estimate and the model does not yield a

Table 7.14-11 Construction Expenditure Multipliers for Manitoba in 2000

	Direct Impact in Manitoba	Direct + Indirect Impacts in Manitoba	Direct + Indirect Impacts in Canada
Total GDP	0.34	0.45	0.78
Output	1.00	1.21	1.92
International imports	0.11	n/a	0.21
Indirect taxes on products	0.00	0.01	0.01
Indirect taxes on production	0.00	0.01	0.02
Wages and salaries	0.23	0.29	0.46
Supplementary labour income	0.02	0.03	0.05
Mixed income	0.02	0.03	0.04
Other operating surplus	0.06	0.10	0.21
Employment (person-years per million $)	5.93	7.97	12.48
Employment ratios (person-years per direct job)	1.00	1.34	2.11

Table 7.14-12 Construction Impact on GDP

	Direct impact in Manitoba	Direct + Indirect Impacts in Manitoba	Direct + Indirect Impacts in Canada
Output	$596,000,000	$721,160,000	$1,144,320,000
Total GDP	$202,640,000	$268,200,000	$464,880,000
International imports	$65,560,000	n/a	$125,160,000

useful number for corporate profits. The tax effects of the mine construction are summarized in Table 7.14-14.

As detailed in Table 7.14-14, overall, construction of the project is estimated to yield $6.3 million in personal income taxes to governments in Canada and about $4.3 million in personal income taxes to governments in Manitoba.

Table 7.14-13 2009 Tax Table – Manitoba (Combined Provincial & Federal Rates)

2009 Taxable Income	Combined Tax Rates	Provincial	Federal
First $31,000	25.80%	10.80%	15%
Over $31,000 up to $40,726	27.75%	12.70%	15%
Over $40,726 up to $67,000	34.75%	12.75%	22%

Table 7.14-14 Estimated Taxes on Construction Expenditures for Manitoba and Canada (assuming 600 Construction Workers)

	Tax Revenues*
Federal income taxes	$6,358,524
Manitoba/provincial income taxes	$4,294,974
Total tax revenues	$10,653,498

Note : * based on 600 construction workers earning on average $60,000 per annum. Calculation based on tax rates cited in the above paragraph titled 'Tax Revenues'.

Government Spending

Project construction workers will be housed in an on-site camp and therefore will place little or no pressure on the housing market, local health facilities, local education facilities, local social services and recreation facilities in the project vicinity.

Construction activities will place no pressure on local waste management facilities. A package sewage treatment plant will be provided for the construction camp and construction waste will be disposed of in a landfill near the tailings facility.

There will be chemicals or hazardous wastes associated with project construction. Waste oils/lubricants will be disposed of by transferring the material to a recognized recycling plant.

There will be an increase of road use associated with the construction activities. Provincial Highway 6 will experience some increase traffic periodically during construction but little or no public inconvenience is anticipated.

Employment

Job creation numbers can also be estimated from the multipliers presented above. Construction of the concentrator, mine site buildings, power line, road and mine pre-production is estimated to directly require 600 person-years. Once employment generation in industries that supply goods and services to the contractors is factored in, the project will create an additional 1,608 person-years in Manitoba and an additional 2,532 person-years in other Canadian provinces or territories (Table 7.14-15).

On average, there will be 600 construction workers on-site throughout the construction (2 years). Workers are planned to work 10 hours per day and 7 days per week with turnarounds as required by the schedule of construction activities.

Table 7.14-15 Employment Impacts of Construction Expenditures in Manitoba and Canada (Two Year Projection)

	Manitoba Direct Impact	Manitoba Direct + Indirect Impacts	Canada Direct + Indirect Impacts
Employment (person-years)	1,200	1,608	2,532
Wages and salaries	$16,560,000	$20,880,000	$33,120,000
Supplementary labour income	$1,440,000	$2,160,000	$3,600,000
Mixed income	$1,440,000	$2,160,000	$2,880,000
Other operating surplus	$4,320,000	$7,200,000	$15,120,000
Totals	**$23,760,000**	**$32,400,000**	**$54,720,000**

Note: Approximately 2.016 million person hours will be required for construction.

Assuming a total work period of 48 weeks per annum, total work hours for one year period equal 1,680 hours per person (24x7x10). For one year, the total hours would be 1.008 million with over 2 million employable hours over the two year period, assuming two-week turnarounds. The average salary per worker was estimated to be $60,000 per annum. This results in a total base salary of $36,000,000 per annum, for two years bringing the total to $72,000,000.

Wages

As detailed in Table 7.14-15, direct wage impact paid to on-site construction workers will amount to $16.5 million dollars. If both on-site as well as wages paid to supplier industries are accounted for, the direct and indirect impacts of construction in Manitoba will be over $20.8 million and on Canada will be almost $33.1 million.

Training Plans

There are no specific training plans developed for the construction of the project. It is anticipated that normal complements of apprentices will be used on the project.

Labour Availability

While Manitoba and local communities have a reasonable complement of workers with the required skills, availability of skilled workers and contractors might be a problem because of potentially conflicting projects and high demand in parts of western Canada. A number of major projects could compete directly with the current one, including other mining developments, Manitoba Hydro Power Generation Projects and the Crowflight Project. As well, many Manitoba trades people are currently working in the Fort McMurray area and other areas in Western Canada with strong oil and gas development.

Contract and Business Opportunities

VNI is committed to providing employment and business opportunities for local residents, including First Nations to the extent possible based on qualifications, quality of service, cost and capability to deliver in a timely manner. As previously mentioned, VNI will target as high a number as possible for the construction workforce from the local labour market. This will ensure local benefits will flow during construction.

A number of contracts will be tendered for mine construction, including camp construction, camp services, access road building, mill construction, frac sand plant construction, Tailings and Ultramafic Management Facility (TWRMF) construction and mine construction. In addition to the $593 million capital costs, the mine construction will result in additional sales of $57.3 million for Manitoba businesses supplying goods and services to the companies involved in the mine construction. In the absence of current multipliers, it is difficult to estimate what business opportunities could be created by the expenditures of workers and contractors.

Effects on Community Health and Well-being

Construction is not expected to have any cost-of-living impacts in the communities of interest. The population effect during construction of a project like this, with an on-site construction camp, is very small. Construction workers typically do not relocate but tend to maintain their homes elsewhere and live in the on-site camp during their shift. As a result no excessive demands on local health, law enforcement or social services are expected.

Effects on Traffic and Safety

It is anticipated that supplies and equipment will be trucked to the project site using the Povincial Highway #6. Some modest interruption of the traffic can be expected as large pieces of equipment move through. No effect on general highway safety is anticipated.

Effects on Traditional Ways of Life

No effects on traditional ways of life are anticipated. However, opportunities for working on the construction site by local residents might reduce subsistence activities.

7.14.6.3.2 Operations

The nickel mine is slated for production start-up in 2014 with an ore production rate of 10,000 tonnes per day with total ore production and processing of 25.2 million tonnes. Annual expenditures associated with mine operations at full production were estimated in the scoping study to be $95.6 million. A breakdown of these annual expenditures is summarized in Table 7.14-16.

Table 7.14-16 Life of Mine Projected Operating Expenditures (including Frac Sand)

Minago Sulphide Nickel Project – Projected Operating Costs	
By Cost Centre	**$millions**
General and Administration	109.1
Surface Facilities	39.9
Frac Sand Plant	73.3
Ore Processing	249.3
Open Pit Mining	388.1
TOTAL	**859.7**

Note: Derived from the December 14th, 2009 Victory Nickel Inc. press release.

Regional Economic Effects

Economic impacts can be calculated using total expenditures on operations and maintenance and applying the requisite multipliers. The calculated impacts are average annual amounts over the planned mining and frac sand plant processing life of 9 years.

Multipliers for direct impacts of mining are kept confidential by Statistics Canada, but overall multiplies for direct impact of 'Mining and Oil Gas Extraction' can be used where data is not available for 'Metal Ore Mining'. The estimated 2000 Manitoba multipliers of mining expenditures on different component of the GDP are presented in Table 7.14-17.

The meaning of each multiplier is explained below in the relevant section. To estimate the final economic impact, the annual operating expenditure including concentrate haulage costs ($95.6 million) is multiplied by the appropriate multiplier.

Direct and indirect impacts on GDP are presented below (Table 7.14-18). The annual $95.6 million in output will result in a total amount of $114.7 million worth of purchases (direct and indirect impact) in Manitoba and $161.5 million in Canada (direct and indirect) as a whole. Note that the "Output" amount double-counts many expenditures.

The GDP impacts are a better measure as it eliminates double accounting and takes economic leakages into consideration, i.e., it subtracts the value of these goods and services that must be imported for the project. The direct impact in Manitoba of the operation of the mine is that it directly increases Manitoba's GDP by an annual average of $57.3 million, if purchases from Manitoba suppliers are included. Canada's estimated GDP in 2008 was $1.4 Trillion. The $50.6 million total (direct + indirect) annual impact of the Minago Project in Manitoba will therefore likely account for about 0.004% of the nations annual GDP (Table 7.14-18).

Table 7.14-17 Mining Expenditure Multipliers for Manitoba in 2000

	Mining and oil and gas extraction	Metal Ore Mining	
	Direct Impact in Manitoba	Direct +Indirect Impacts in Manitoba	Direct + Indirect Impacts in Canada
Total GDP	0.60	0.53	0.76
Output	1.00	1.20	1.69
International imports	0.09	0.00	0.23
Indirect taxes on products	0.00	0.01	0.01
Indirect taxes on production	0.01	0.00	0.01
Wages and salaries	0.14	0.28	0.38
Supplementary labour income	0.02	0.04	0.05
Mixed income	0.00	0.01	0.02
Other operating surplus	0.42	0.20	0.29
Employment (person-years per million $)	3.56	5.41	8.22
Employment ratios (person-years per direct job)	1.50	1.52	2.31

Table 7.14-18 Mine Operation Impact on GDP

	Direct Impacts in Manitoba[1]	Direct + Indirect Impact on Manitoba[2]	Direct + Indirect Impact in Canada[2]
Total GDP	57,360,000	$50,668,000	$72,656,000
Output	$95,600,000	$114,720,000	$161,564,000
International imports	$8,604,000	n/a	$21,988,000

Notes: 1 Based on “Mining and oil and gas extraction” multipliers.

2 Based on “Metal ore mining” multipliers.

Numbers are calculated based on one year of operating expenditures of $95.6 million.

Note that the total impact on the Manitoba GDP is a little more than half of what the project will cost per annum (Table 7.14-18). This is largely due to the need to import many of the goods and services needed for the project.

Government Revenues and Spending

Tax Revenues

The project will generate additional revenues for the different levels of government. This includes indirect taxes such as federal GST and municipal/territorial property taxes. As well, a number of direct taxes will be paid, including provincial, federal and potentially First Nations individual and corporation income taxes, as well as federal and territorial royalties. A summary of the impacts on taxes of mine operations expenditures is given in Table 7.14-19.

Table 7.14-19 Impacts on Taxes of Mine Operation Expenditures on Manitoba and Canada

	Direct Impact in Manitoba[1]	Direct + Indirect Impacts in Manitoba[2]	Direct + Indirect Impacts in Canada[2]
Indirect taxes on products	0	1,147,200	1,147,200
Indirect taxes on production	$956,000	0	1,147,200
Federal corporation income taxes	$19,598,000[3]	Multipliers unavailable	Multipliers unavailable
Manitoba/provincial corporation income taxes	$12,428,000[3]	Multipliers unavailable	Multipliers unavailable
Total tax revenues	**$32,982,000**	**$1,147,200**	**$2,294,400**

Notes: 1 Based on ‘Mining and Oil and Gas Extraction’ multipliers using a base of $95.6 million for GDP (Table 7.14-18).

2 Based on ‘Metal Ore Mining’ multipliers using a base of $114.72 million for GDP (Table 7.14-18).

3 Number derived from base of $95.6 million with a federal tax rate of 20.5% and a provincial tax rate of 13%.

The input-output model allows calculating indirect taxes such as the GST and property taxes directly, but income taxes and royalties have to be estimated. The current lowest minimum marginal tax rate in Manitoba is 15% for federal personal income taxes and 10.8% for Manitoba income tax. Note that some of the income tax revenues could go to First Nations governments, if mine employees live on Manitoba First Nations settlement land. The tax rates can be applied to wages and salaries to yield an estimate.

Government Spending

By creating jobs, the mine operation is likely to reduce spending on social assistance and Employment Insurance. However, depending on the effect on the population, spending on other government programs such as health care and education could increase, depending on how many people end up migrating to northern Manitoba as a result of the mine. Given the proponent’s commitment to employ as many local residents as possible, the effects are likely to be small, as the Manitoban government is already providing services to the residents.

Employment

Approximately 422 employees will be required to operate and maintain the open pit mining operation. In addition, approximately 200 employees will be required on a full-time basis.

Total payroll costs are estimated to be approximately $37 million annually during operation. This estimate is likely to be lower rather than higher than the actual payroll, once operations begin for a number of reasons. First, the base hourly wage for many of the positions appear to be on low side given the current intense competition for skilled labour in the mining and other industries such as oil and gas and construction, which tap into the same labour pool.

Regional Employment

In addition to the people directly employed by the operating mine, there will be employment created both through the mine's purchase of goods and services and through the spending of employees in their communities. The effect on employment of the mine's purchases is an indirect impact, while re-spending of employees' wages is an induced impact.

VNI plans to directly employ 422 people on a full-time basis as outlined above. This is the operation's direct employment in Manitoba.

Ratios derived from Statistics Canada's Interprovincial Input-Output model show that a hard-rock mine in Manitoba will create 1.52 person years for direct and indirect employment in the province for every job created. With annual operating employment expenditures estimated at $25.3 million, the mine will create a total of 642 person-years of employment annually directly and indirectly.

Direct and indirect employment impacts in terms of person-years on Manitoba are summarized in Table 7.14-20 whereas Table 7.14-21 details the impacts in terms of income.

There will be further employment impacts created through the spending of employee's wages and salaries, known as induced impacts. Unfortunately, Statistics Canada no longer provides the multipliers necessary to calculate these induced impacts.

Table 7.14-20 Direct and Indirect Employment

	Direct Impact Manitoba	**Direct & Indirect Impact in Manitoba**
Mining, Oil & Gass Extraction	633	
Metal Ore Mining		642
TOTAL	**633**	**642**

Note: Based on a need of 422 employees working at the mine once operational.

Table 7.14-21 Employment and Income of Operation Expenditures, Manitoba and Canada ongoing Jobs

Metal Ore Mining	**Direct Impact in Manitoba [1,2]**	**Direct + Indirect Impacts in Manitoba [2]**	**Direct + Indirect Impacts in Canada [2]**
Employment (person-years)	**633**	**642**	**975**
Wages and salaries	$3,544,800	$7,089,600	$9,621,600
Supplementary labour income	$506,400	$1,012,800	$1,266,000
Mixed income	$0	$253,200	$506,400
Other operating surplus	$10,634,400	$5,064,000	$7,342,800
TOTAL	**$14,685,600**	**$13,419,600**	**$18,736,800**

Notes: 1 Of the 422 direct jobs created, many will flow outside Manitoba initially. As familiarity with Manitoba grows, it is anticipated that families will relocate to Manitoba communities. Based on the 422 direct jobs with an average wage of $60,000 per annum, the total wages will be $25,320,000.

2 Multiplier used in column one is based on mining, oil and gas extraction, while column two and three multipliers used only metal ore mining multipliers. Wages of $25,320,000 were used as the base number for the multipliers.

The mine will also create jobs through spending on equipment and suppliers in other area of Canada. Statistics' Canada mine employment multiplier for Canada as a whole is 12.48 person-years per $1.0 million in expenditures (Table 7.14-11). The employment ratio presented in Table 7.14-17 estimates 2.31 person years of employment created in Canada for every direct mine job. This indicates that VNI's operations will create a total of 975 person-year of employment in other parts of Canada in addition to the 642 jobs in Manitoba (direct and indirect).

Local Employment

It is the Company's desire to hire and train locally as much as possible, both for the positive impact on the local community, and to reduce turnover and transportation costs. VNI stated staffing policy is that preference will be given to applicants in the following priority:

- Members of the four First Nations communities (NHCN, GRCN, MLCN, CLCN) and Métis;
- Local residents (GR/SL/NH/ML/CL);
- Manitoba residents; and
- Other applicants.

While this preferential hiring structure obviously gives advantages to local people, both First Nation and non-First nation, and to Manitobans as a whole, the key factor is how many local and Manitoban people will be considered qualified. As discussed in the section on labour availability below, it is unlikely that all qualified and experienced workers will be found in Manitoba alone. The management, supervisory and engineering positions are unlikely to be filled from the local labour pool given the competitive nature of the business today. In addition, the skilled mechanical and electrical trades are also in very short supply. However, the mine will require a wide variety of employees, from clerks to apprentice electrician to truck drivers, that the region and the current Manitoba labour is likely to supply more readily. There is also a chance that some of the workers from northern Manitoba working in places such as Alberta may choose to come back to their communities as the Minago Project will provide the necessary employment.

Unfortunately, there is no way of accurately estimating how many of the positions required to operate the Minago mine will be filled by residents of the local region or even by Manitobans as a whole.

Labour Availability

The shortage of labour – and particularly skilled labour – required for mining projects has been an increasing concern for the industry throughout Canada. A number of factors are contributing to the general shortage:

- There is very stiff competition for qualified people in a variety of trades and skills from the oil and gas construction industries. The oil sands developments in northern Alberta in particular have been attracting many skilled workers.
- The prolonged slump in the mining industry in the 1980s and 1990s led to many workers leaving the industry and to a cutback of training apprentices and other new entrants.
- There has been increasing difficult in both the mining and oil and gas industries to find people who have both the desire and stamina to work in physically demanding jobs in sometimes harsh conditions.

Anecdotal evidence is strong that Manitoba has seen a substantial number of skilled and experienced workers in mining and related fields migrate to other jurisdictions to find work or leave the industry altogether especially before the latest mining boom.

However, Manitoba retains the advantage of a relatively stable workforce – and particularly the First Nation workforce – that wishes to remain rooted in the territory.

Training

VNI will work with the Northern Sector First Nations and relevant government agencies to train the required workforce for the Minago Project. These will include but not be limited to securing funding and the right candidates for training. Victory Nickel will also provide refresher courses and on the job training for its workers.

Wages and Salaries

A breakdown of employee wages and salaries by position is shown in Table 7.14-22. Salaried positions range from an estimated base salary of $33,000 annually for a liaison officer to $150,000 annually for the mine manager. The estimated base hourly pay rate for the non-salaried positions is summed up in the Table 7.14-23. The base rates are all over $20 per hour with the highest being for the skilled trade positions.

It should be noted that, given the general difficulties faced by the mining and similar industries in finding sufficient skilled labour as noted above, the base pay rates shown may be understated. Higher pay is the most basic means of attracting workers in a tight labour market.

Contracting and Business Opportunities

As with any project of this magnitude, the opening and operation of the project will create a number of commercial opportunities both in the region and within Manitoba. The following goods and services will be required by VNI in its operation of the Minago mine and mill.

While not exhaustive by any means, the following represent opportunities for both local and Manitoba businesses:

- Trucking, both ore haul from mine to mill and concentrate haul to Ponton for Frac Sand and Concentrate to smelters,
- camp operations including catering and janitorial,
- supply of fuel and lubricants,
- supply of parts,
- supply of other goods and services,
- road maintenance, snow removal and related activities,
- site security and road patrol.

The communities of interest and their citizens are in a good position to benefit from a number of these business opportunities through their existing corporations and other firms.

Effects on Community Health

Cost of Living Impacts

The project is expected to have no measurable impact on the cost of living for Manitoba as a whole. The size of the project, while not insignificant, it is not large enough to impact the provincial inflation rate. It is also unlikely that the mine will cause any increases in cost of living, in the communities of interest, for example. There will be no sudden demand for new housing since Minago will be a camp operation. Also, almost all mine purchases will be made in Winnipeg or outside where they will not affect local cost of living.

Table 7.14-22 Breakdown of Salaries

Position	Manpower	Base Salary CDN$
Mine Site Manager	1	$150,000
Secretary	1	$36,000
Personnel Superintendent	1	$100,000
Environmental Engineer	1	$82,000
Liaison Officer	2	$33,000
Purchasing Agent	1	$82,000
Buyer	1	$66,000
Warehouseman	4	$51,000
Safety and Training Officer	1	$77,250
First Aid	1	$55,000
Controller	1	$51,000
Payroll Clerk	1	$51,000
Accounting Clerk	1	$51,000
Surface Crew		
Lead Hand	1	$77,250
Surface Operator	3	$55,000
Mine Staff		
Mine Manager	1	$90,000
Shift Forman	2	$65,000
Maintenance Foreman	1	$60,000
Chief Engineer	1	$75,000
Senior Engineer	1	$60,000
Geologist	2	$55,000
Surveyor	1	$45,000
Surveyor Helper	1	$42,000
Technician	1	$42,000
Sampler	1	$40,000
Mill Staff		
Mill Superintendent	1	$97,290
General Foreman	1	$77,250
Supervisors	3	$66,519
Metallurgist	1	$79,560
Mill Technician	1	$41,818
Environmental Technician	1	$41,818
Clerk	1	$39,140
Mill Maintenance & Assay		
Maintenance Superintendent	1	$85,000
Heavy Equipment Supervisor	1	$65,000
Electrical Supervisor	1	$65,000

Table 7.14-22 (Cont'.d) Breakdown of Salaries

Position	Manpower	Base Salary CDN$
Mill Maintenance & Assay		
Maintenance Engineer	1	$61,000
Planner	2	$55,000
Clerk	1	$41,000
Assayer	3	$69,340

Table 7.14-23 Breakdown of Hourly Pay

Description	Manpower	Base Pay Rate CDN$/hour
Jumbo Operator	8	$23.77
LHD Operator	8	$23.77
Rockbolter	4	$23.77
Ground Support	2	$23.77
Shotcrete	2	$23.77
Truck Driver	4	$23.77
Truck Loader Operator	0	$23.77
Blasting Crew	8	$21.96
Utility Crew	8	$20.08
Mechanics	16	$25.56
Electrician	2	$20.08
Crusher Operator	4	$24.09
Grinding Operator	4	$24.09
Dewatering Operator	4	$24.09
Reagents/Water Treatment Op.	4	$24.09
Tailing/Concentrate Loadout Op.	4	$22.69
Labourer	2	$22.69
Bucker	2	$22.69
Millwright	2	$26.79
Machinist	2	$26.79
Machinist Apprentice	2	$22.79
Camp Maintenance	2	$22.79
Instrument Mechanic	2	$25.56
Electrician	2	$25.56
Electrician Apprentice	2	$20.08

Migration

Operations workers from Manitoba and elsewhere will be housed in the camp at the mine site. Thus, initially it is not anticipated that many, if any, staff hired outside will relocate to Manitoba. As experience with the project grows, it can be anticipated that workers may desire to obtain housing in Manitoba communities and relocate to Manitoba.

In summary, little population change is anticipated in Manitoba as a result of worker relocation to the project area. Accordingly, no undue demands on existing health, law enforcement or social services are expected in the community of interest.

Effects on Traffic/Safety

It is currently planned that there will be 4 loads per day of concentrate and 62-63 loads of Frac Sand Plant products per day. This will result in slightly more than 3 trucks per hour, on average, passing any point on the haul route. This minor pressure is expected to pose little or no pressure on current traffic and traffic safety. The company is committed to the highest standards of safety and will closely watch the interaction of its trucks with other traffic with a view to enhance safety wherever possible.

Effects on Traditional Lifestyle

An operating mine can impact an area's subsistence economy in a number of ways. If the operation's footprint is large and/or is located directly in areas of exceptionally high wildlife values, the mine's operations can directly reduce the number or quality of the wildlife resources that subsistence depends on. The project is not expected to create this form of negative impacts during project operations (refer to the Wildlife section). At closure, it is planned that the mine access road will remain in place, but will be blocked to limit access. This will initially enhance access for the trappers and subsistence hunting. Initially, there will be enhanced opportunity for subsistence hunting, but increased hunting could reduce regional moose populations, which utilize the project area, with a resulting adverse effect on subsistence hunting in the longer term. Effects will depend on access management measures implemented at closure.

The subsistence economy can also be impacted through an increase in employment created by the mine in the region. Increasing full-time employment in communities with high levels of under-employment and unemployment both reduces the economic need for subsistence activities and reduces the amount of time available for them. However, a work schedule that gives extended periods (e.g., two weeks) at home increases opportunities for subsistence activities. Based on the project turn around of two weeks, it is unlikely that it will have a large impact – positive or negative – on the region's subsistence economy.

7.14.6.3.3 Closure

Following the final decommissioning of the mine all direct project effects on employment and business and contracting opportunities will cease.

Smaller rural communities in Manitoba as elsewhere frequently suffer from a too-narrow economic base and would benefit from greater economic diversification. The business and contracting opportunities arising from projects such as the Minago project can assist in diversifying small local economies not just for the period of operation but beyond.

One of the main means of extending the local benefits beyond the life of the project is the capacity building that occurs in the local communities. Capacity is built not just for individuals who improve their job skills and experience, but also for local businesses. The development of business skills and experience assists greatly in the economic diversification process and the skills are highly transferable to future projects and developments.

No changes in community health and well-being, apart from the potential benefits of economic diversification, noted above, are expected at closure.

As the project is not expected to have any significant effects on fish and wildlife during its operational life, no residual effects on resource bases for traditional pursuits are expected at closure. The project access road will remain at closure. This could enhance access for traditional use activities. While this could be seen as a positive effect initially, there is a risk that moose hunting in the project area could have detrimental effect on populations and ultimately have an adverse effect on moose hunting for traditional purposes.

7.14.6.4 Residual Project Effects and Significance

Tables 7.14-24 and 7.14-25 summarize the socio-economic impacts of the construction and operations phases of the project.

Table 7.14-24 Summary of Socio-Economic Impacts of the Minago Project in the Construction Phase

Valued Socio-economic Component (VSC)	Probability	Frequency	Magnitude	Spatial Extent	Duration	Reversibility	Impact
Traffic interruption/safety	Unlikely	Infrequent	Low	Local	Short-term	Reversible	Minor & Negative
Employment Opportunities	Certain	Continuous	High	Regional	Short-term	Reversible	Moderate & Positive
Contract & Business Opportunities	Certain	Continuous	Medium	Regional	Medium-term	Reversible	Moderate & Positive
Community Health	Moderate	Infrequent	Low	Regional	Short-term	Reversible	Minor
Maintenance of the traditional way of life	Unlikely	Infrequent	Low	Regional	Medium-term	Reversible	Minor

Table 7.14-25 Summary of Socio-Economic Impact of the Minago Project in the Operations Phase

Valued Socio-economic Component (VSC)	Probability	Frequency	Magnitude	Spatial Extent	Duration	Reversibility	Impact
Traffic interruption/safety	High	Continuous	High	Regional	Long-term	On-going (impact ends at closure and abandonment)	Medium to high & Negative
Employment Opportunities	Certain	Continuous	High	Regional	Long-term	On-going	Medium to high & Positive
Contract & Business Opportunities	Certain	Continuous	High	Regional	Long-term	On-going	Medium to high & Positive
Community Health	Medium	Continuous	Medium	Local	Long-term	Reversible (impact ends at closure and abandonment)	Minor
Maintenance of the traditional way of life	High	Continuous	Low	Regional	Long-term	On-going (impact ends at closure and abandonment)	Minor

7.14.6.5 Mitigation Measures

Table 7.14-26 summarizes potential effect and related mitigation measures.

Table 7.14-26   Mitigation Measures for Socio-Economic Effects

Potential Project Effect	**Mitigation Measures**
Effects on local employment	Local advertisement of opportunities; Training programs; Impact and Benefit Agreements (IBAs).
Effects on business and contracting opportunities	Local advertisement of opportunities, IBAs.
Effects on community health	Utilization of mine camp for all mine workers.
Effects on traffic/safety	Driver education; Compliance with all Manitoba and Federal traffic laws.
Effects on traditional lifestyle – increased access into project area for traditional activities	Access to the site will remain open with gated or limited access.

7.14.6.6 Cumulative Effects and Significance

Although there may be some difficulty in recruiting workers to the project given the cumulative demand for workers in the western and northern Canada, it is not anticipated that there will be any measurable cumulative effects on socio-economic conditions.

7.14.6.7 Monitoring and Follow-up

Given the size and relatively negative impacts of the project, a monitoring program will be developed to compare baseline with operation conditions.

7.15 Power Supply

7.15.1 Power Line

The primary source of electrical power will be the Manitoba Hydro 230 kV line along the east side of PTH6. The hydrogrid runs approximately 300 m east of PTH6 and is about 500 m from the Minago Property boundary. From the connection at PTH6, a 6.3-km, 230 kV power transmission line will feed the main substation located to the west of the process plant in the northwest corner of the site (i.e. Industrial Complex). The connection from the Manitoba Hydro 230 kV line will be provided with gas-filled isolation switches. The overall site plan is given in Figures 7.15-1 and 7.15-2. The related drawings for the electrical systems are given in Figures 7.15-3 to 7.15-16.

7.15.2 Main Substation

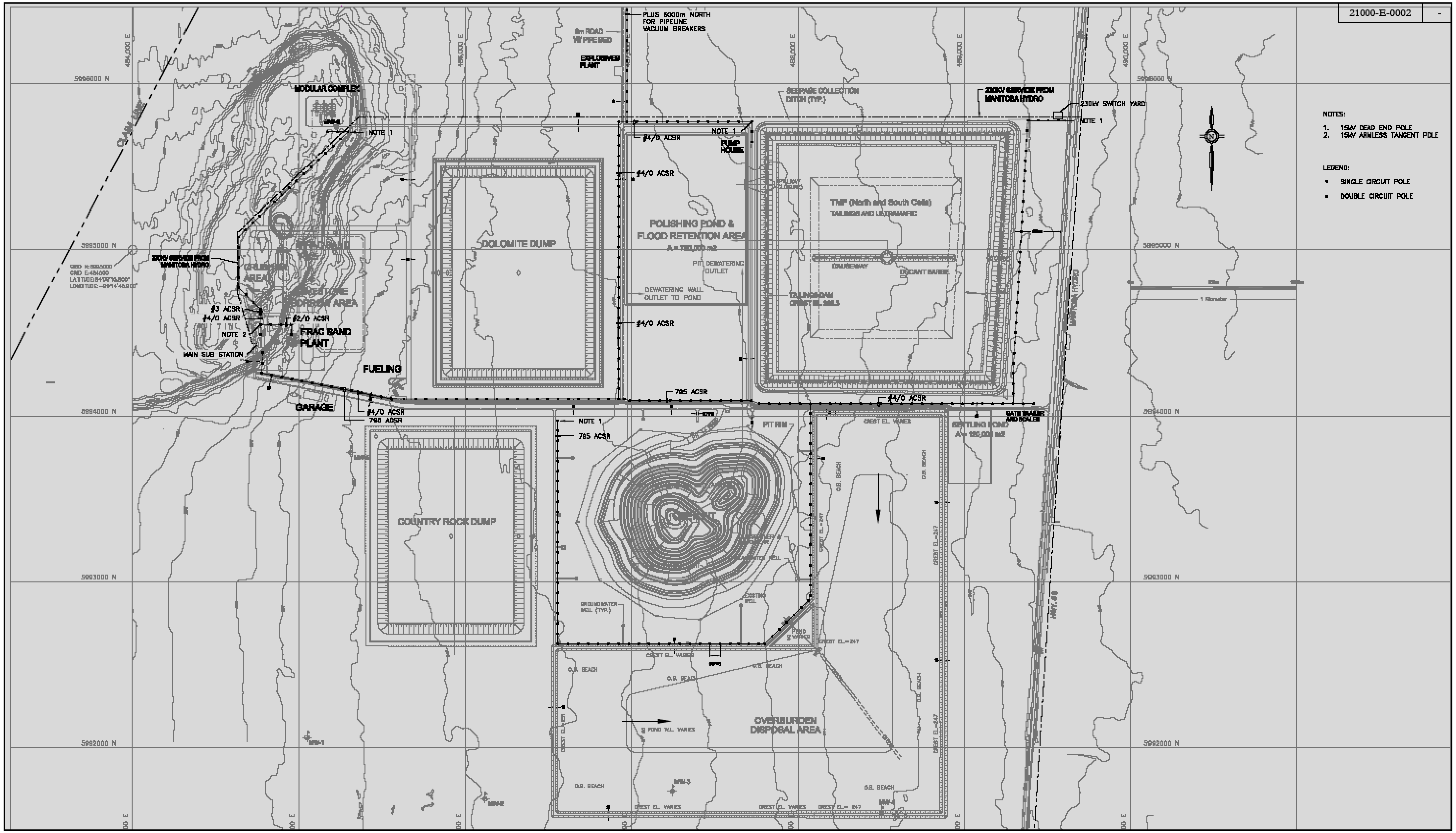
The main substation will consist of two main transformers rated at 50 MVA each capable of supplying the full load. The transformers will transform the power down from 230 kV to 13.8 kV to the main 13.8 kV switch room via metal clad switchgear. The system is sized and configured for full redundancy, allowing the transformers to operate in parallel or individually while maintaining full production. Each transformer must accommodate the full operational loads in the event of a failure of the other. The main substation will be protected by a secure chain link fence surrounding a crushed stone bed for easy maintenance and to ensure effective drainage.

7.15.2.1 Power Distribution

Power from the main switchgear room will be distributed at 13.8 kV via overhead line to the various distribution centres around the site. As necessary, outdoor oil filled transformers will transform the primary 13.8 kV to 6,600 V, 4,160 V and 600 V.

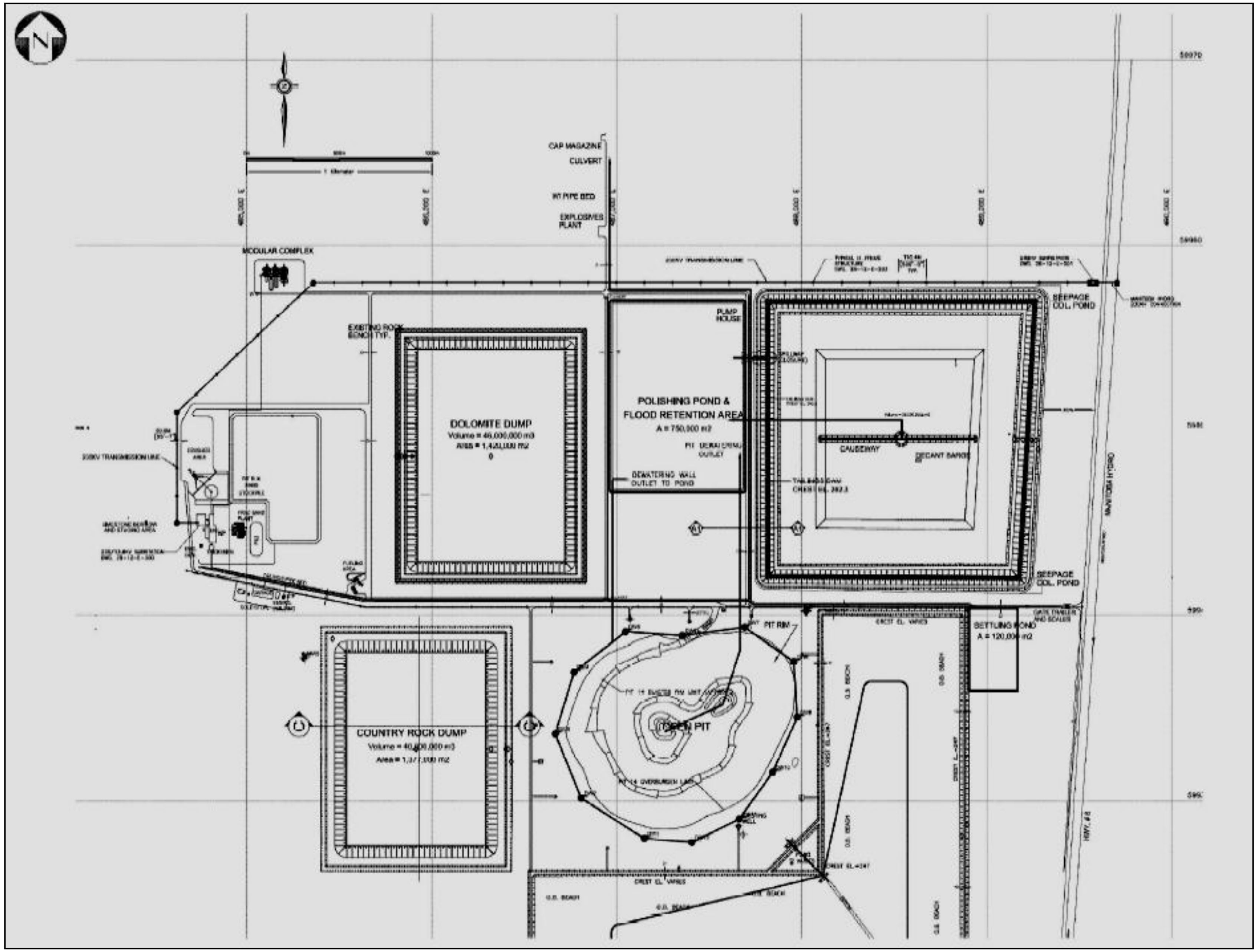
Open Pit Mining

A 13.8 kV overhead distribution line circling the pit will provide power to the pit shovels, drills, dewatering pumps and surface pumps. Outdoor oil-filled transformers on portable substations will transform from 13.8 kV to 6.6 kV to feed the shovels and drills for mining. Within the pit, other portable substations will transform the primary 13.8 kV to 600 V to power the dewatering pumps.



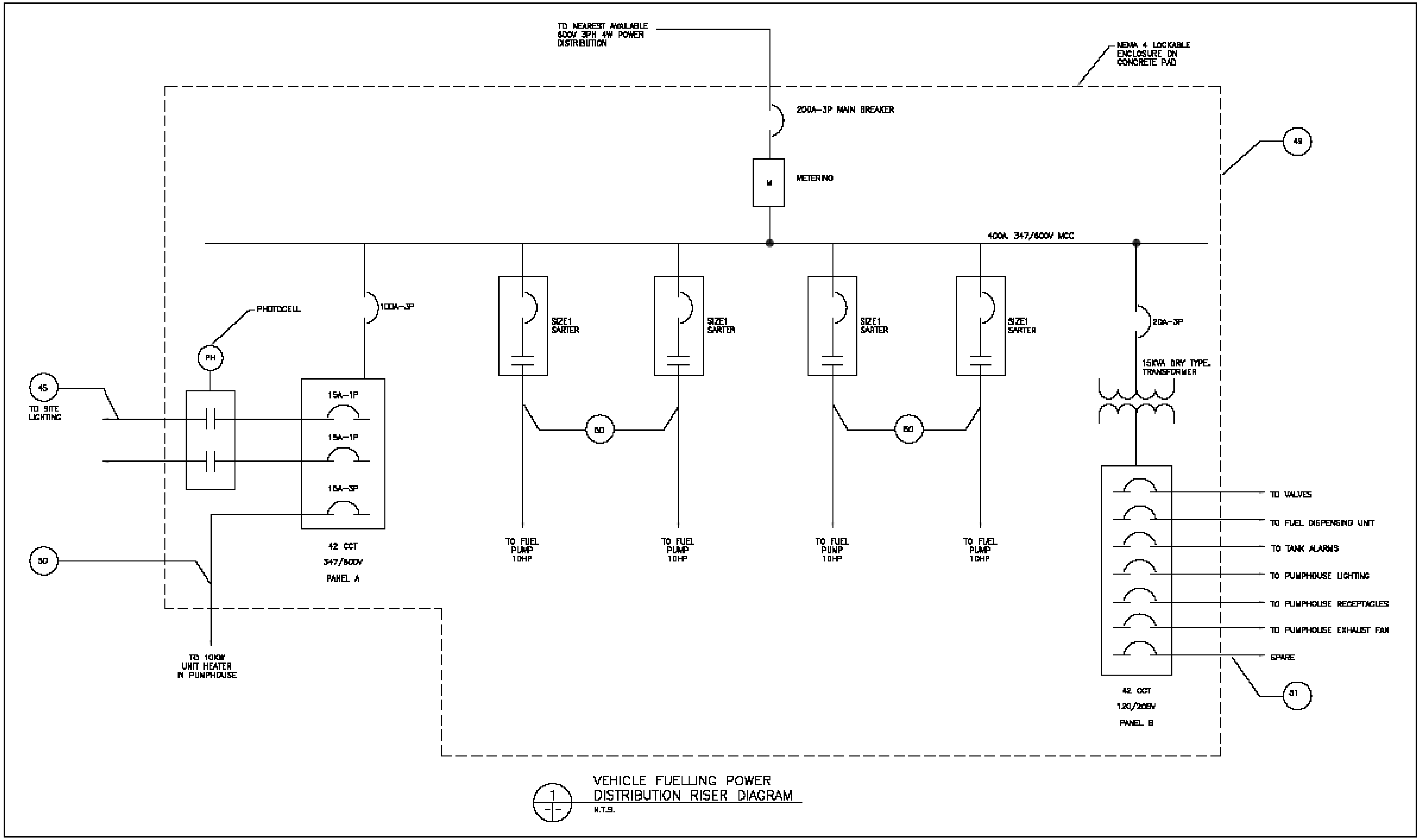
Source: adapted from Wardrop's drawing 0951330400-E0002 (Wardrop, 2009b)

Figure 7.15-1 Location of Power Line and Other Site Infrastructures (Electrical 13.8 kV Site Distribution)



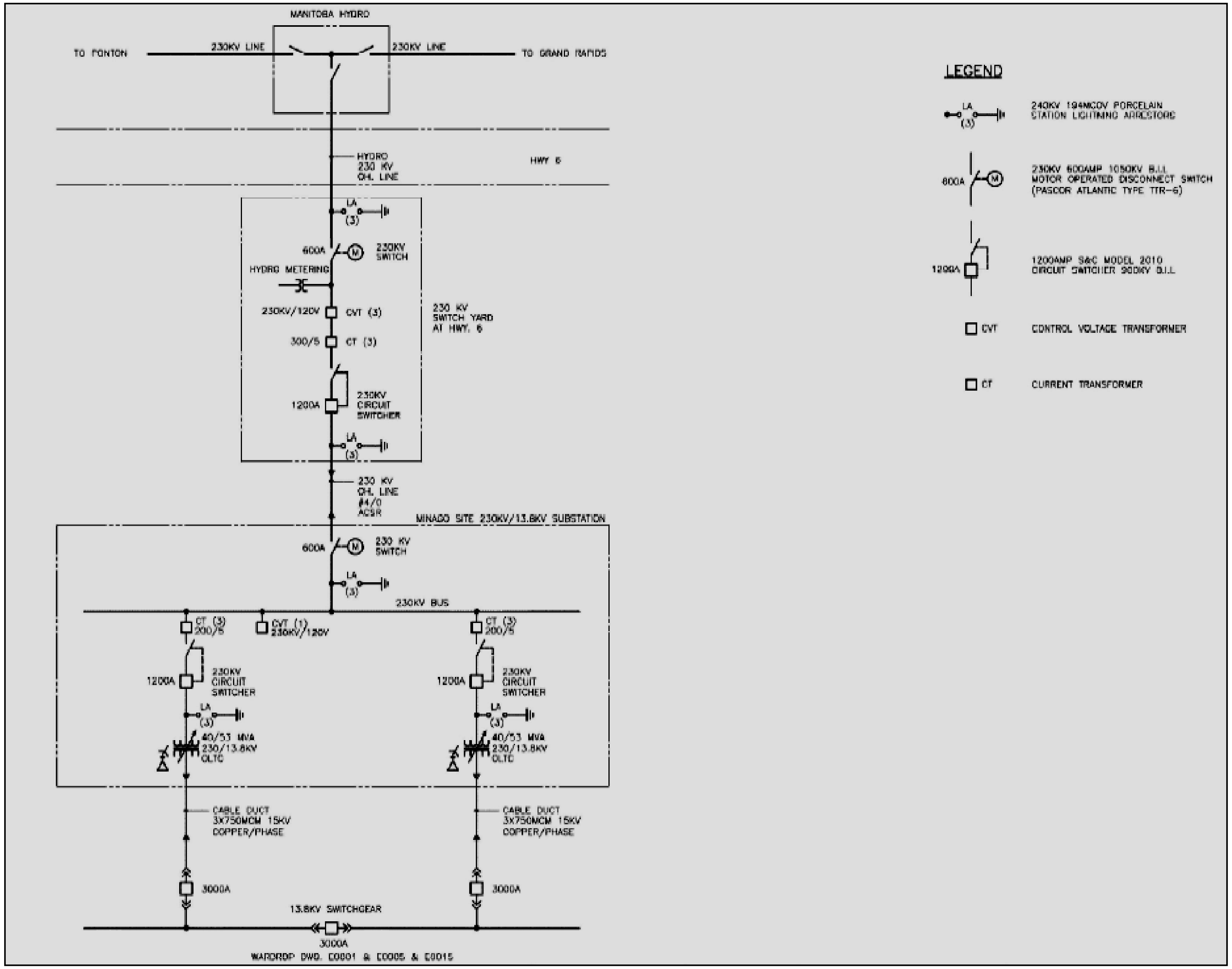
Source: adapted from Wardrop's drawing 0951330400-E0008 (Wardrop, 2009b)

Figure 7.15-2 Minago Substation 230/13.8 kV Transmission Lines Layout



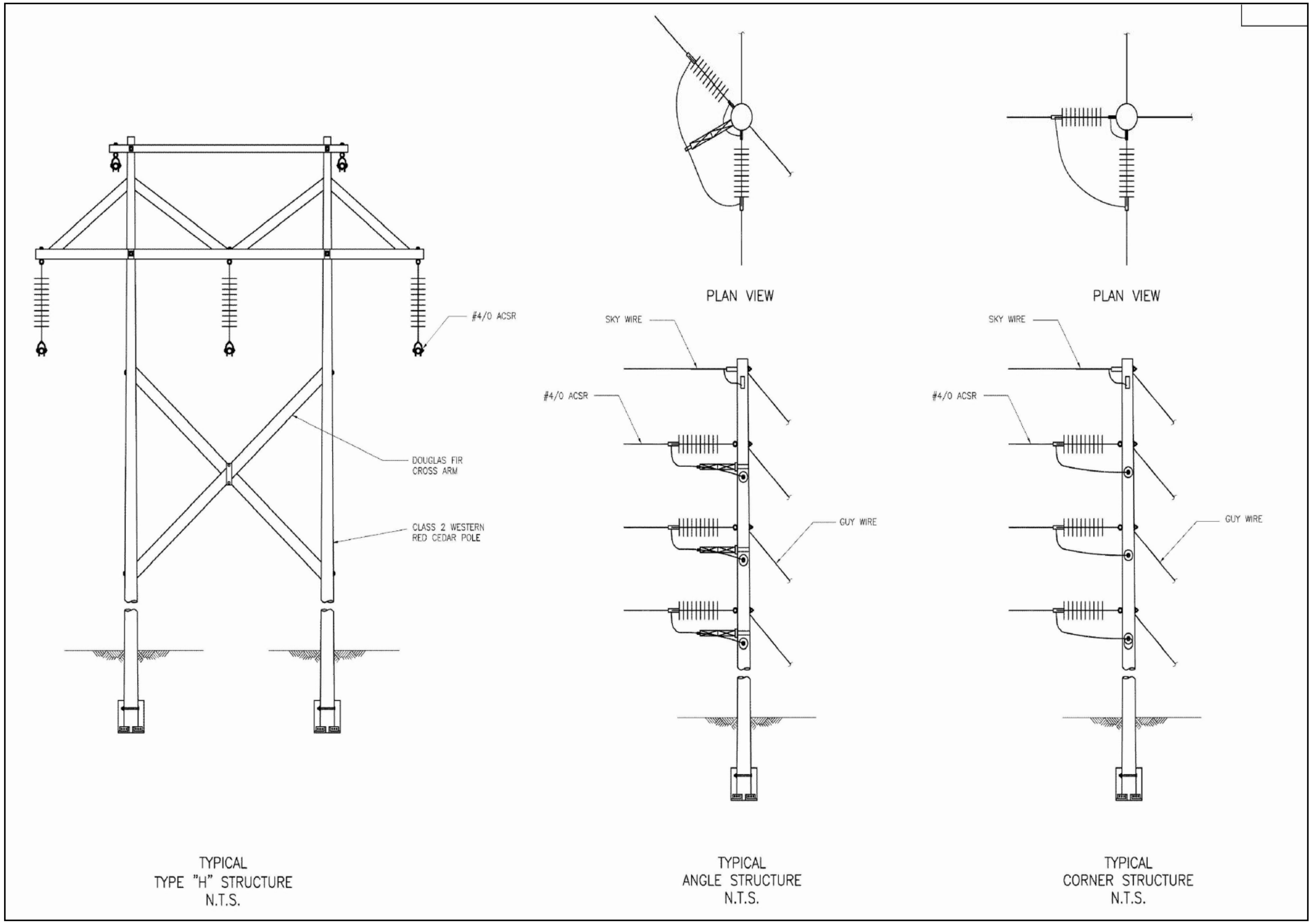
Source: adapted from Wardrop's drawing 0951330400-E0006 (Wardrop, 2009b)

Figure 7.15-3 Vehicle Fuelling – Single Line Drawing



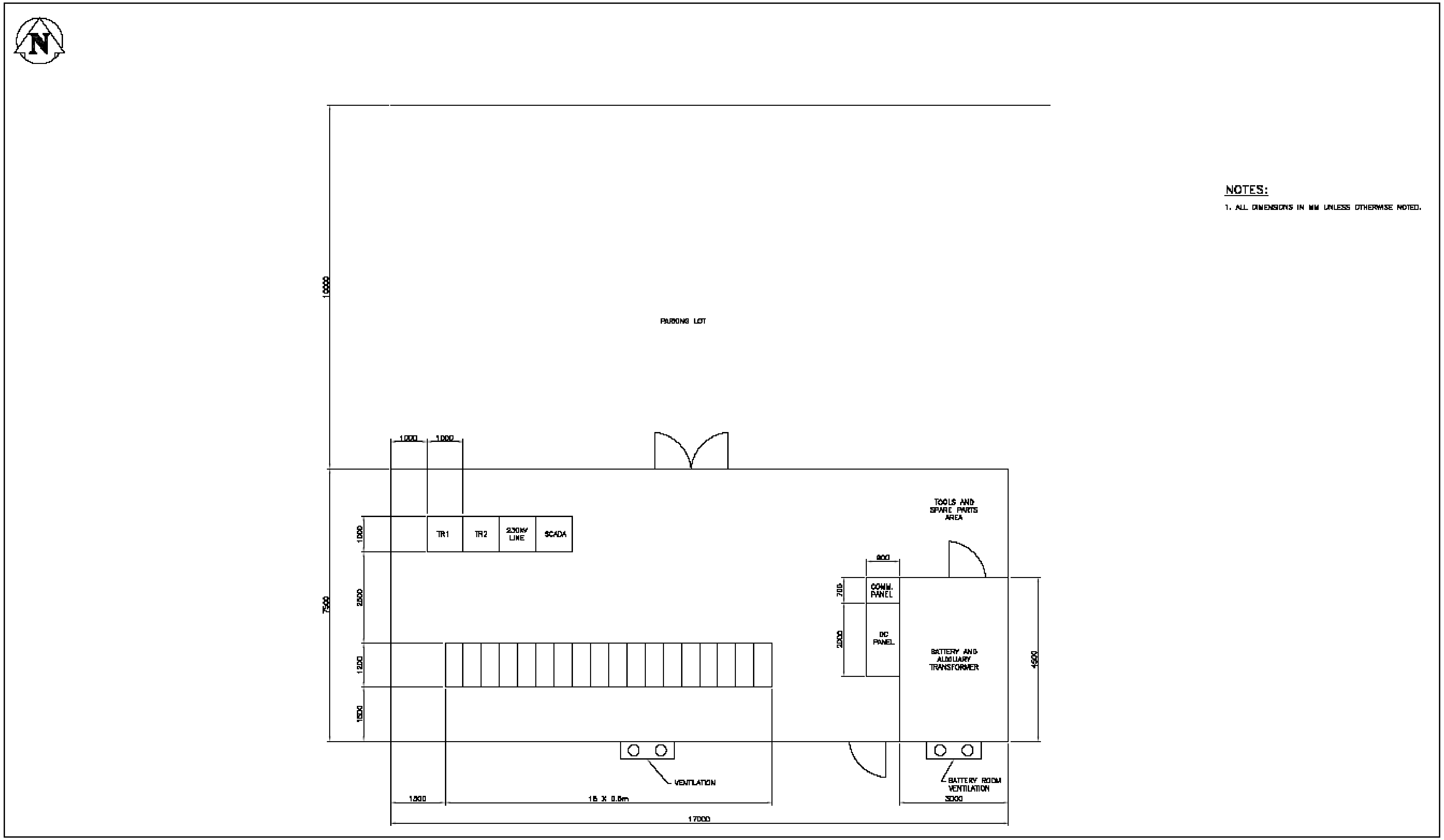
Source: adapted from Wardrop's drawing 0951330400-E0007 (Wardrop, 2009b)

Figure 7.15-4 Substation – 230/13.8 KV Single Line Drawing



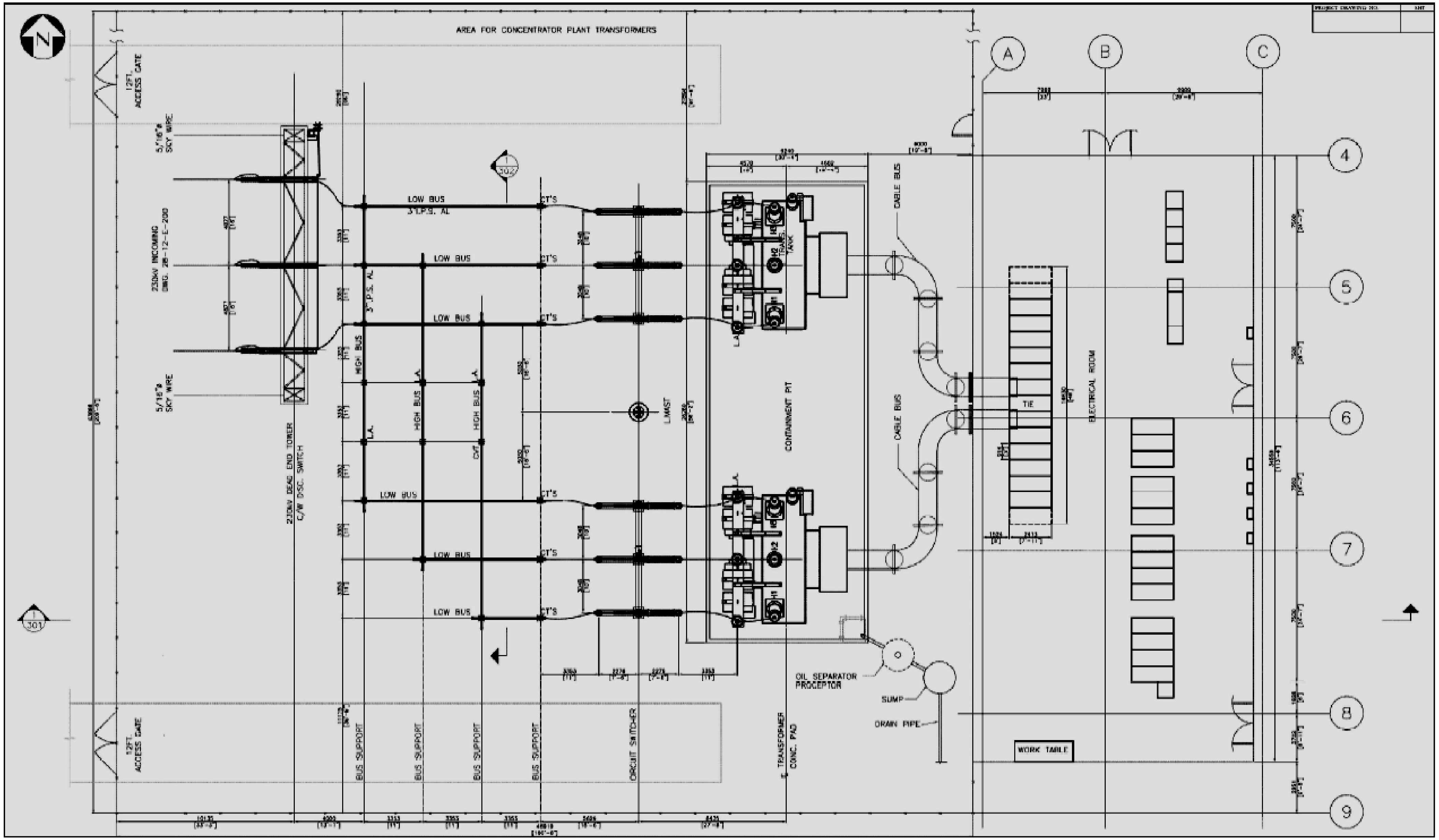
Source: adapted from Wardrop's drawing 0951330400-E0011 (Wardrop, 2009b)

Figure 7.15-5 Substation – 230 KV & 15 KV Transmission Line Details



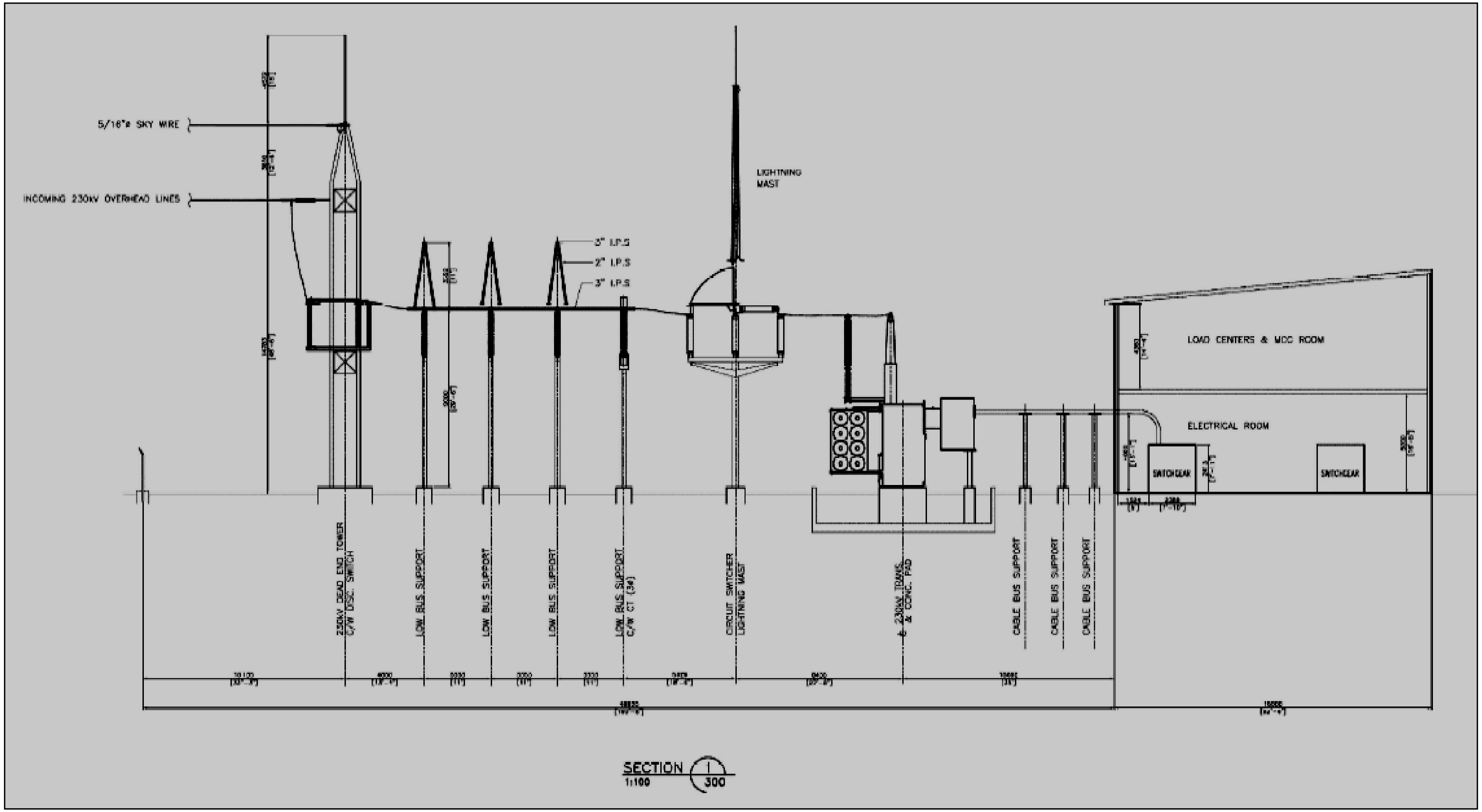
Source: adapted from Wardrop's drawing 0951330400-E0004 (Wardrop, 2009b)

Figure 7.15-6 Substation – 230 kV Layout



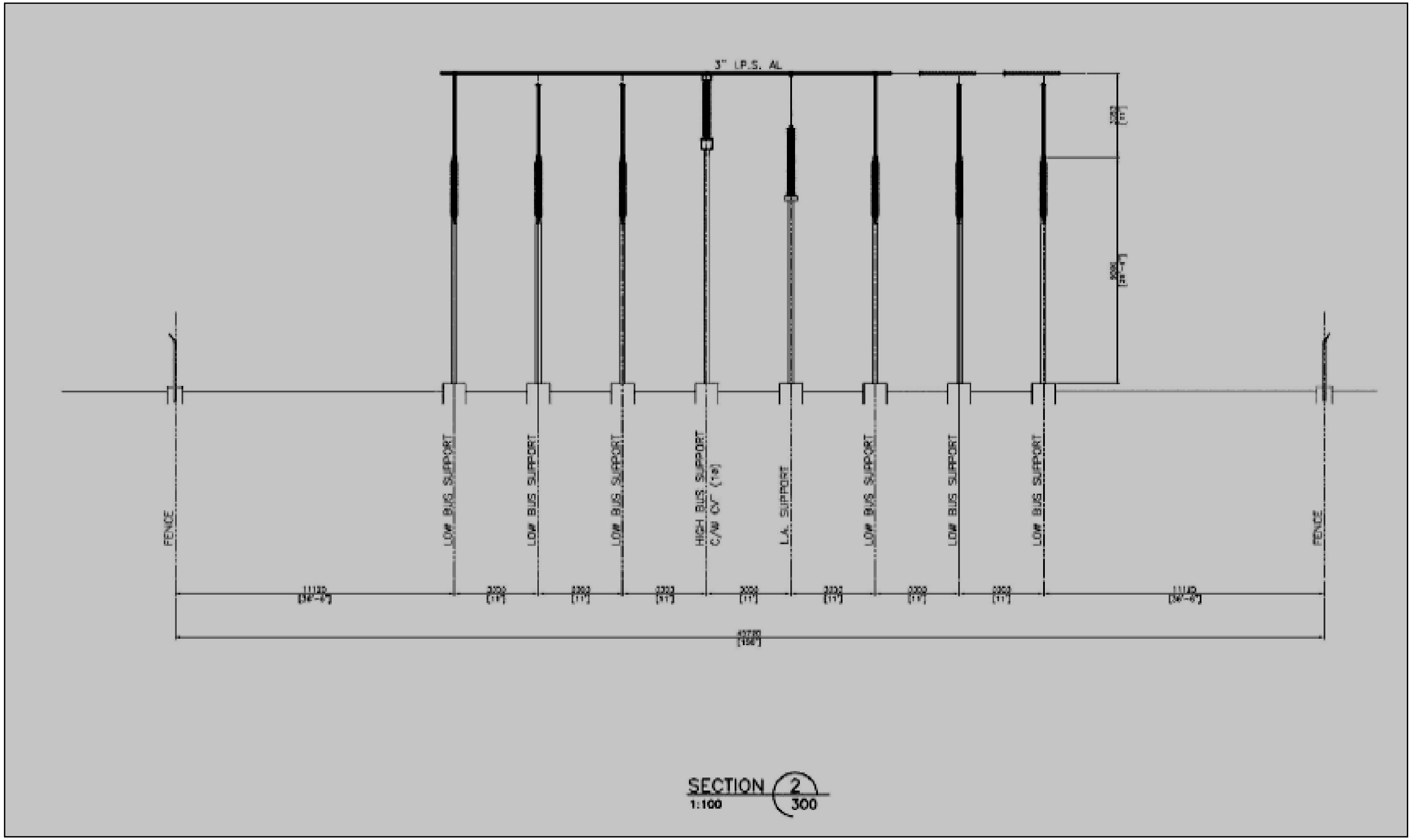
Source: adapted from Wardrop's drawing 0951330400-E0012 (Wardrop, 2009b)

Figure 7.15-7 Substation – 230/13.8 kV Layout



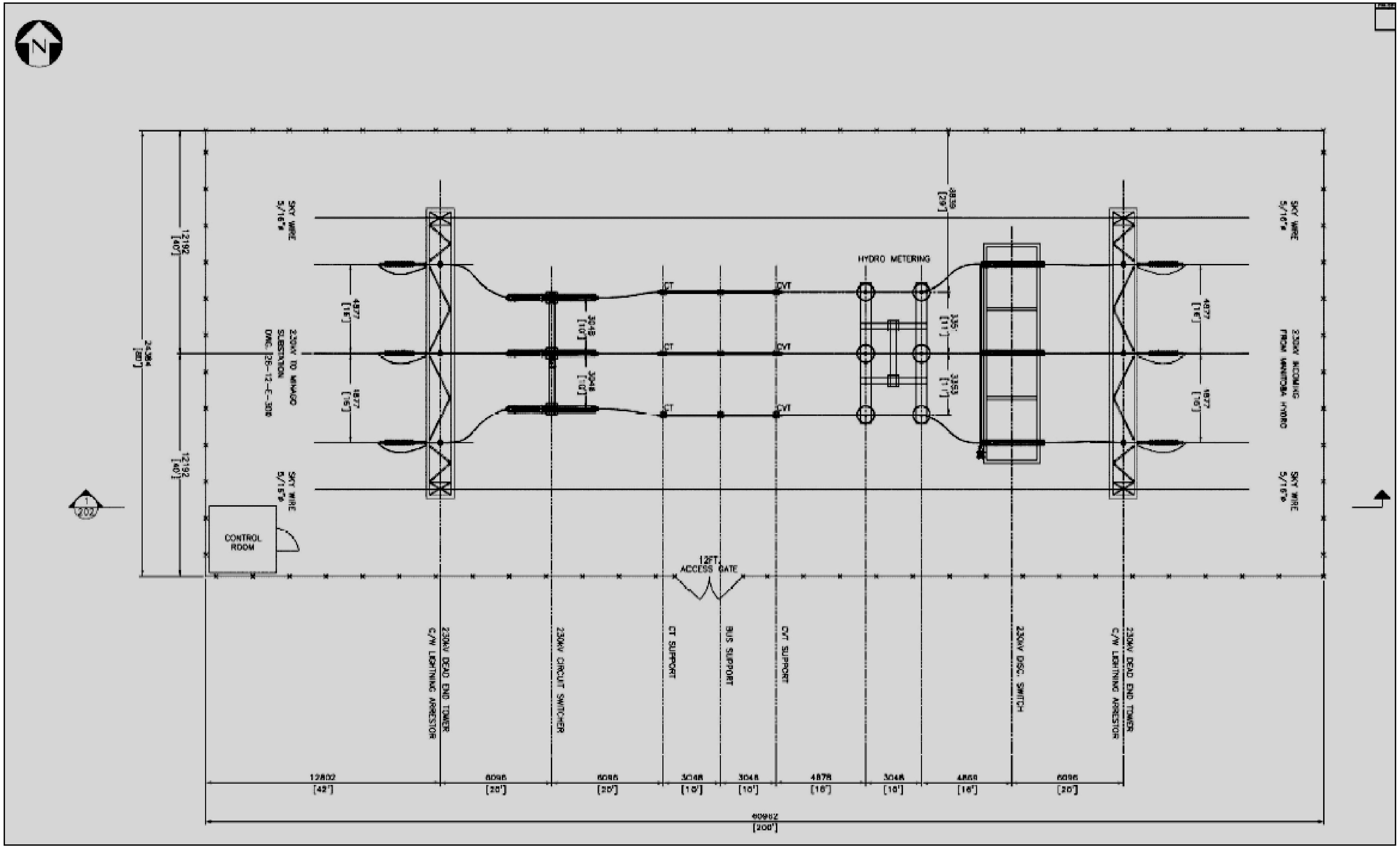
Source: adapted from Wardrop's drawing 0951330400-E0013 (Wardrop, 2009b)

Figure 7.15-8 Substation – 230/13.8 kV Section



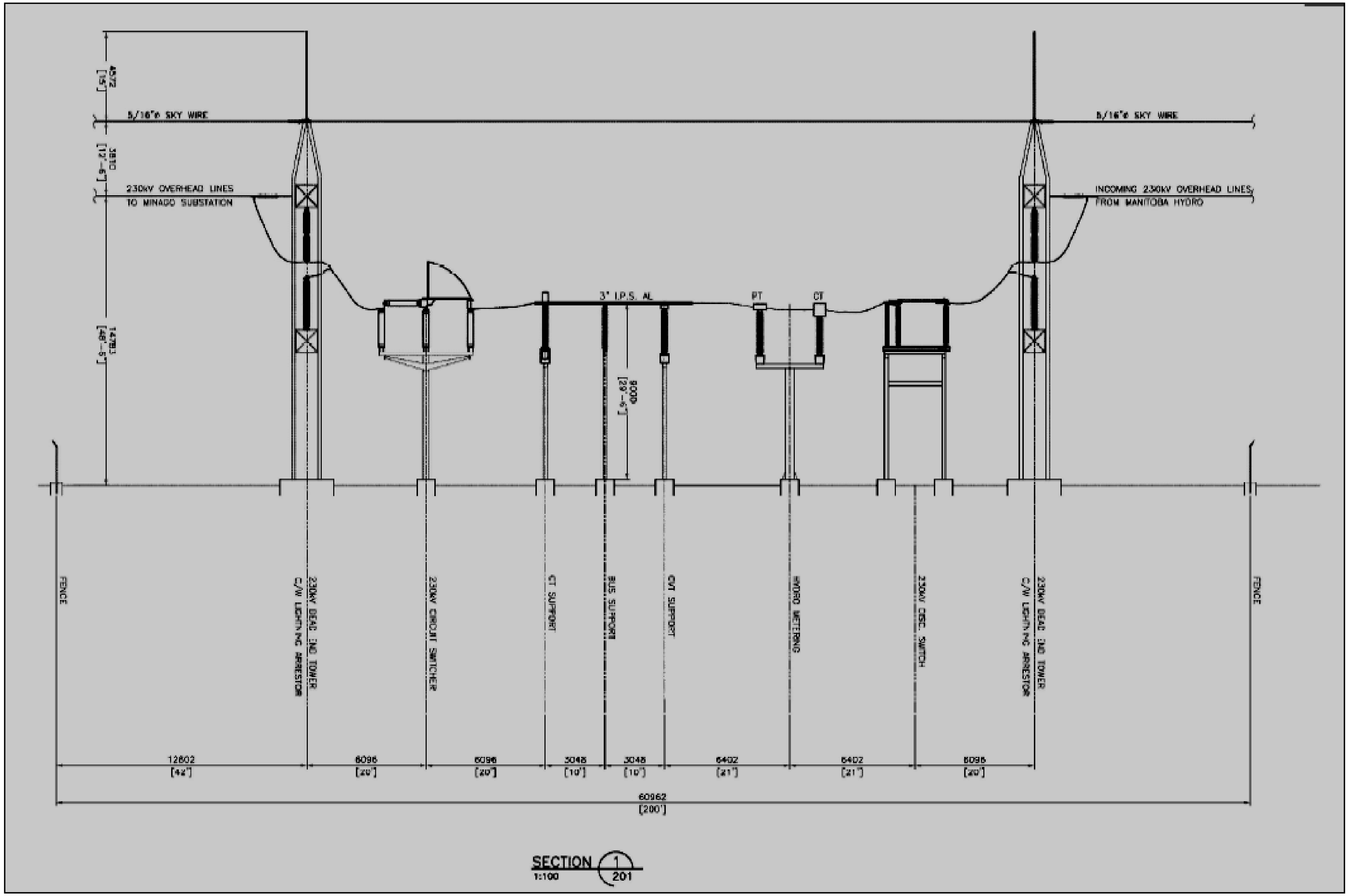
Source: adapted from Wardrop's drawing 0951330400-E0014 (Wardrop, 2009b)

Figure 7.15-9 Substation – 230/13.8 kV Section



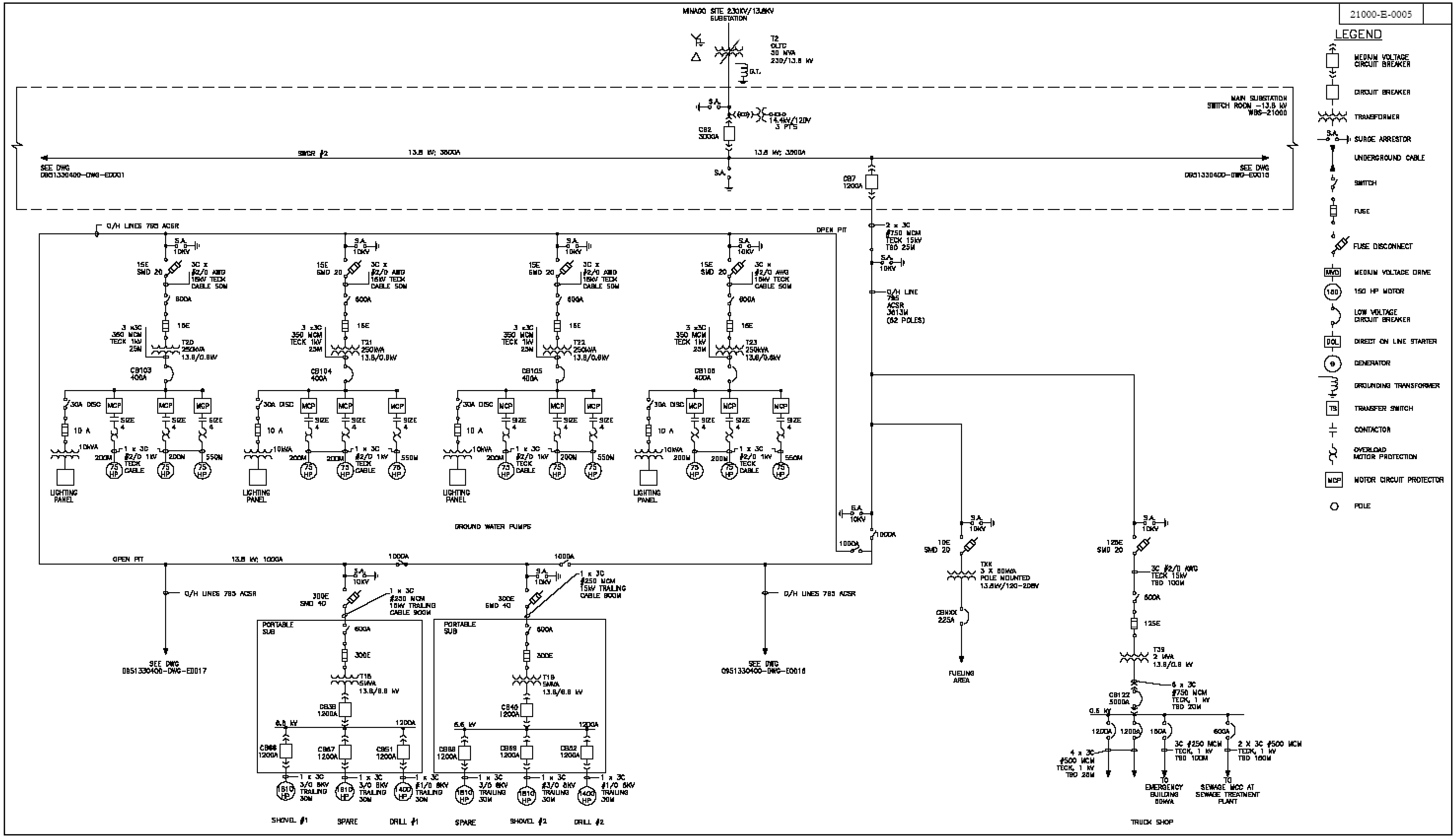
Source: adapted from Wardrop's drawing 0951330400-E0009 (Wardrop, 2009b)

Figure 7.15-10 Switchyard at Highway 6 – Layout



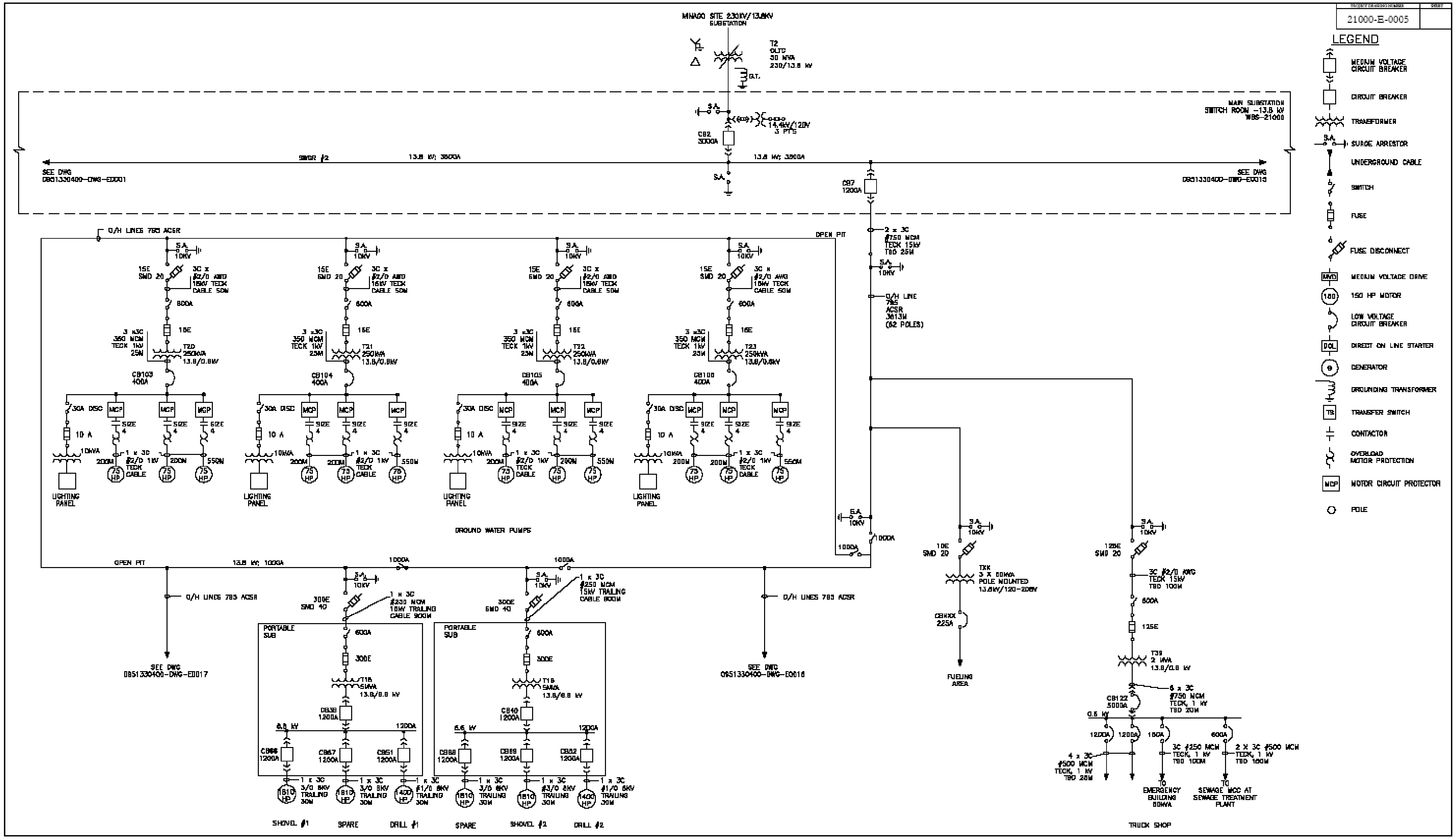
Source: adapted from Wardrop's drawing 0951330400-E0010 (Wardrop, 2009b)

Figure 7.15-11 Switchyard at Highway 6 – Section



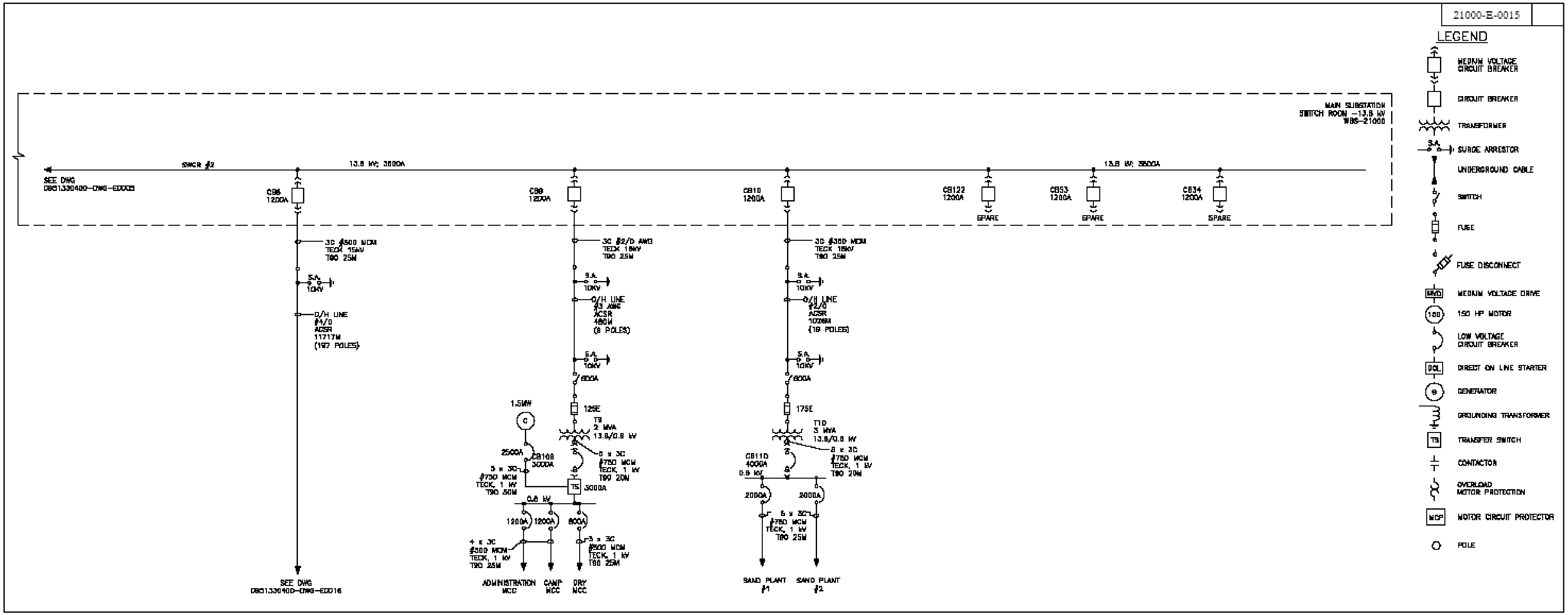
Source: adapted from Wardrop's drawing 0951330400-E0001 (Wardrop, 2009b)

Figure 7.15-12 Single Line Drawing – 1/5



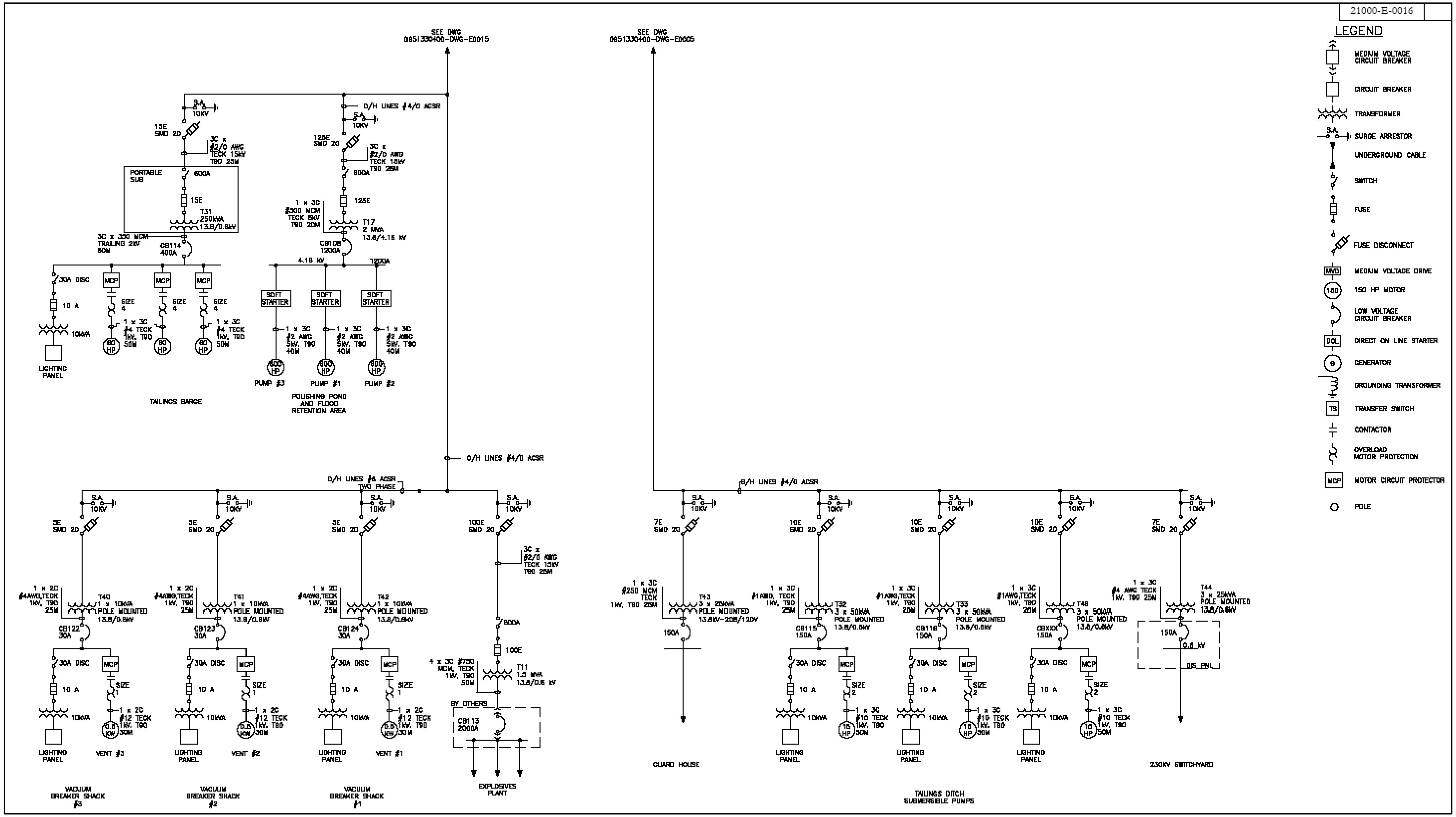
Source: adapted from Wardrop’s drawing 0951330400-E0005 (Wardrop, 2009b)

Figure 7.15-13 Single Line Drawing – 2/5



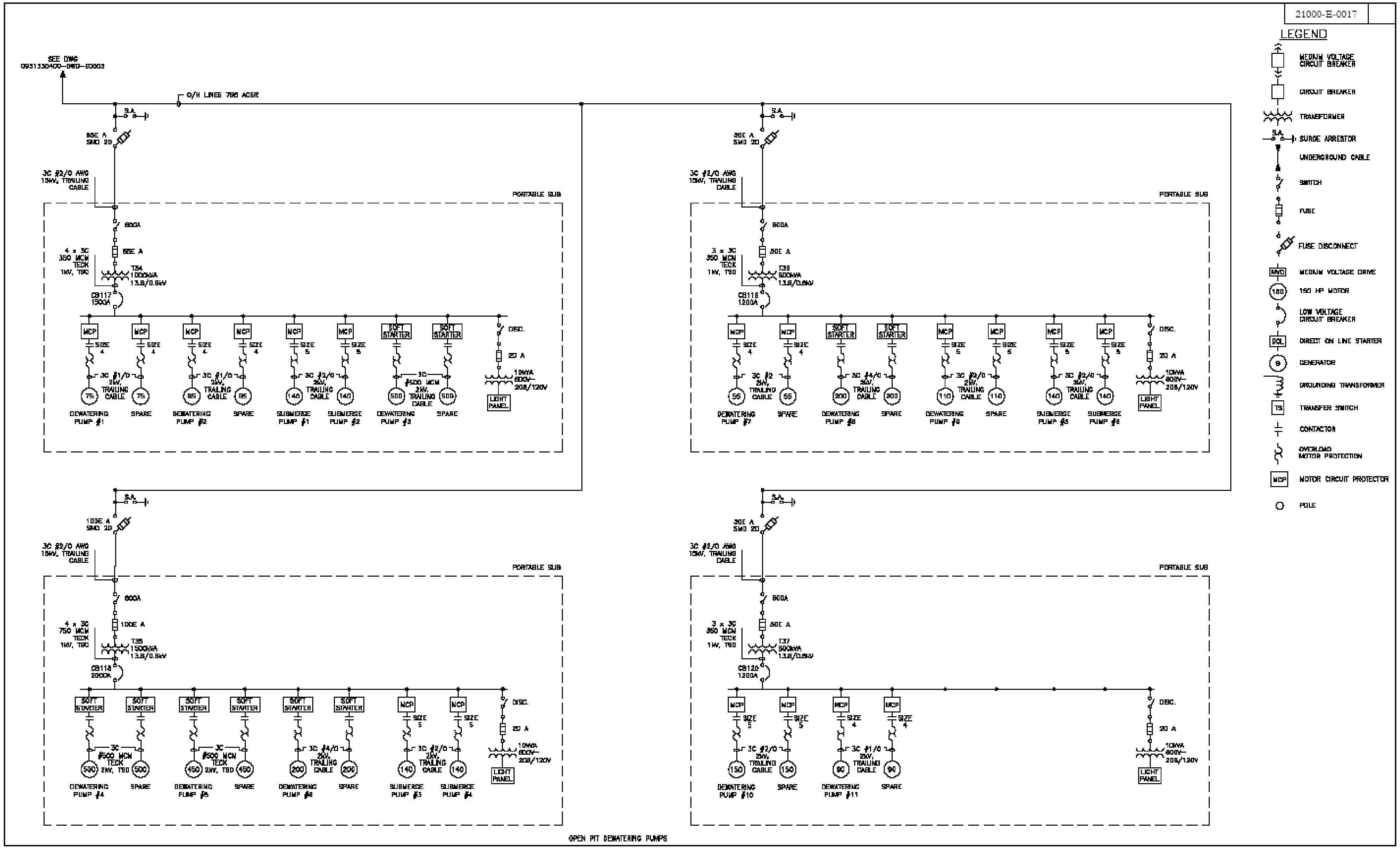
Source: adapted from Wardrop's drawing 0951330400-E0015 (Wardrop, 2009b)

Figure 7.15-14 Single Line Drawing – 3/5



Source: adapted from Wardrop's drawing 0951330400-E0016 (Wardrop, 2009b)

Figure 7.15-15 Single Line Drawing – 4/5



Source: adapted from Wardrop's drawing 0951330400-E0017 (Wardrop, 2009b)

Figure 7.15-16 Single Line Drawing – 5/5

Ore Processing Plant

The ore processing plant, including crushing and grinding, will be provided with separate electrical rooms to support the motor control centres (MCCs) for the facility. The ball mill and SAG mill will operate at 4,160 V and will be provided with liquid rheostat starters. The primary crusher, cyclopack pump with VFD and process water pumps, which will operate at 4,160 V, will be provided with soft starters to reduce inrush current. Motor control centers will be housed in two electrical rooms, one above the other. The upper room will house the low voltage switchgear and the lower room will be dedicated to the medium voltage equipment. A separate MCC will be installed in the gyratory crushing plant to house 4,160 V and 600 V switchgear associated with this building.

Frac Sand Processing Plant

The frac sand plant will be powered from the main switchgear by its own overhead 13.8 kV line. Outdoor oil-filled transformers will transform from 13.8 kV to 600 V to feed the various loads. From a separate room, the motor control centers and 600 V panel boards will distribute power in each area.

General

The modular complex building, water treatment plant, maintenance building, fuelling area, emergency building and sewage treatment plant will be provided with power via an overhead 13.8 kV line. At these locations, outdoor oil-filled transformers will transform primary power at 13.8 kV to 600 V to feed the various loads. From a centrally-located room, motor control centers and 600 V panel boards will distribute power in each of these areas.

Site Facilities

Another 13.8 kV overhead distribution line will feed the Polishing Pond pumping station, the water discharge line, the Explosive Plant, and the Tailings and Ultramafic Waste Rock Management Facility (TWRMF). An extension from the open pit 13.8 kV overhead line will service the guardhouse and scalehouse located at the site entrance. Each plant and pumping station will have the necessary transformation and motor control centers for their application.

7.15.3 Emergency Power

Two diesel generator sets rated at 1.5 MW, 13.8 kV with associated switchgear will be housed in a dedicated building located near the main electrical substation.

The system will be designed to provide power during the construction phase and then emergency power during the operations phase for life-sustaining and critical process equipment. The emergency power system will feed the entire plant grid with operators isolating non-emergency switchgears to direct the standby power to the critical services. The emergency power will provide critical power to the dewatering pumps in the event of a utility power failure.

7.15.4 Estimated Load

The peak connected load is estimated to be 42.4 MW (50 MVA), based upon the power requirements of operations and auxiliary equipment on the site and an average power factor of 0.85. The operational load was estimated by analyzing load characteristics and applying a load factor of 0.75 and a utilization factor of 0.8 to the connected load. The effects of seasonal variation in load were analyzed and determined to be negligible. The estimated operating load for the five cost centres including future growth is 30 MVA. Estimated electrical loads are given in Table 7.15-1.

Table 7.15-1 Estimated Electrical Loads

	Cost Centre	Connected Load (MVA)	Operational Load (MVA)
1	Open Pit Mining	14.3	8.6
2	Frac Sand Processing Plant	2.5	1.5
3	Ore Processing Plant	23.4	14.0
4	Site Facilities/General & Admin	5.2	3.1
5	Future Growth	4.6	2.8
	TOTAL	**50.0**	**30.0**

7.15.5 Effects Assessment

The 230 kV power transmission line will go through about 6.3 km of muskegs to get to the Minago substation. That area has already been partially disturbed as part of the mining exploration program and will be disturbed more during the planned mining activities. A maintenance road for the power line will also have to be constructed along the future power line in such a way that a 20-m wide strip will have to be cleared, for a total of about 12.6 ha without accounting for historical exploration and future mining related disturbances. Some areas within this 20-m wide strip have already been cleared during the exploration program so that these 12.6 ha do not all represent newly cleared surfaces. Moreover, such an area represents less than 1 % of the entire surface, which will have to be cleared as part of the Minago project.

Section 7.9: Vegetation provides a description of the baseline data gathered in 2007 and 2008 which was used to characterize the Minago Project Area. Plant communities and species in the Project Area are quite abundant and common both at the regional and local levels; they are not of conservation concern. Moreover, no special-status plant species were observed in the vicinity of the Project Area.

Wildlife species identified as Valued Ecosystem and Cultural Components (VECCs) are provided in Section 7.10. Wildlife that was identified to include, but not be limited to, woodland caribou, moose, black bear, beaver, lynx, American marten and the song bird community. Potential impacts on wildlife from the implementation of the power line may occur from changes to habitat availability associated with minor site clearance, minor landscape disturbance creating disruptions to animal movement patterns, and population declines related to increased mortality risk along the maintenance road. These potential effects were assessed for the seven VECCs and are detailed in Section 7.10: Wildlife.

The greatest direct loss of habitat will occur during construction as a result of isolated clearing for the construction of the power line and its maintenance road. The majority of the maintenance road will be located in an area that has been disturbed during the exploration activities and also the planned mining activities. New disturbances will be insignificant. One of the most important effects is the potential for increased rates of wildlife mortality resulting from human access provided by the proposed maintenance road that will be also used for mining activities. The power line maintenance road will turn into a multi-purpose road. In the past, the project area has not been accessible by vehicle, but as of March, 2010 an access road has been constructed and the power line will run almost along the access road and as such there will be no significant loss of terrestrial habitat. The power line will not cross any water streams. With the road comes noise and traffic flow, causing behavioural disturbance and increased mortality from collisions, as well as increased access for legal hunters and poachers.

Most of those VECCs wildlife species have been observed to cross high-use roads less frequently than low use roads (see Section 7.10: Wildlife for more precise information), implying that movement disruptions will not be significant along the maintenance road since even with its multiple use status. Such a multi-use road and the fact that it will not be open to the public will also help to minimize the number of incidents related to collisions with wildlife. It has also been shown that most wildlife species tend to avoid project footprints during actual construction, but will not significantly shift their territorial distributions in response to rights-of-way activities (see Section 7.10: Wildlife for more precise information). As the density of disturbance due to the power line construction is low in the project area, impacts resulting in habitat fragmentation and isolation are unlikely. A Wildlife Protection Plan (Section 9.5) will also be implemented to mitigate the effects of the project on wildlife.

No rivers or creeks will be crossed by the power line and thus implementation will not impact any stream habitats. Road construction and the implementation of the power line could however have potential effects on erosion and sediment input into the Oakley Creek watershed. However, the area is surrounded by wetlands (treed bogs), which act as natural filter and therefore, limits the runoff of sediments towards the Oakley Creek. Moreover, an Erosion and Sediment Control Plan and a Site Water Management Plan will be implemented during all project phases.

Also, since the eletrical power infrastructures will be built at the surface and no underground works will be needed to do so, impacts on groundwater and hydrogeology is considered to be not significant.

The construction phase will have the greatest incremental impact on the terrain, surficial geology, and soils in the project area. Effects in this phase include road building processes such as land consumption, movement and alteration of surficial materials and corresponding reductions in soil capability. This includes alteration of the road, as well as impacts caused by the removal of aggregate from borrow pits for use in surfacing the roads. Aggregate from borrow pits will also be used for construction material and to stabilize sites underlain by soft soils where required. Reduction of soil capability can be caused by a number of factors including loss of topsoil, creation of impermeable layers during overburden replacement, and soil compaction (e.g., bottom of borrow pits).

Erosion control is a critical aspect of the construction phase. VNI will incorporate into the construction program provisions requiring that during all phases of construction best management practices (BMPs) are implemented to reduce and eliminate soil erosion

Various mitigation measures will be employed to minimize these effects, including topsoil salvage and stockpiling for use during reclamation, limiting soil compaction where applicable, by limiting clearing and site disturbance to periods when the soil is dry or frozen, and progressive reclamation of disturbed areas during construction. Progressive reclamation throughout the life of the project will provide the opportunity to test reclamation approaches and modify them as required to optimize productive capacity of reclaimed areas.

Consequently, the effects of the implementation of a power line and its maintenance road on vegetation, wildlife, surface water and soil quality are considered to be adverse, low magnitude, site-specific and long-term, as detailed in Table 7.15-2. The likelihood of those effects to occur as predicted is high given the baseline data that has been gathered as part of this project. These effects are considered to be reversible since a Reclamation Plan will be implemented and disturbed surfaces will be re-vegetated with indigenous species (green alder, willows). Since road surfaces will be reclaimed at closure, there will not be any additional access to the area provided in the far future.

VNI will decommission the power line and revegetate the disturbed areas with green alders or any other suitable local species. The Closure Plan will provide for rehabilitation of the site to a condition that is safe, environmentally stable and compatible with surrounding lands. The overall Closure Plan for the powerline is detailed in a separate report.

Table 7.15-2 Effects of the Installation of a Power Line and its Maintenance Road

Environmental Components	Potential Effect	Level of Effect						Effect Rating	
		Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effective
Construction									
Vegetation	Site clearing	Adverse	Low	Local	Long term	Reversible	High	Not significant	Not significant
Wildlife	Reduction in seasonal habitat availability due to clearing and sensory disturbance	Adverse	Low	Local	Long term	Reversible	High	Not significant	Not significant
	Disruption to movement patterns due to sensory disturbance	Adverse	Low	Regional	Long term	Reversible	High	Not significant	Not significant
	Increase mortality risk from collisions	Adverse	Low	Regional	Long term	Irreversible	High	Not significant	Not significant
Surface Water Quality	Changes in water quality in Oakley Creek from construction site runoff	Adverse	Low	Local	Long term	Reversible	High	Not significant	Not significant
Soil Quality	Damage to key terrain features	Adverse	Low	Local	Long term	Reversible	High	Not significant	Not significant
	Modification of surficial materials and reduction in soil capability	Adverse	Low	Local	Long term	Reversible	High	Not significant	Not significant
	Increased soil erosion	Adverse	Low	Local	Long term	Reversible	High	Not significant	Not significant
Operation									
Wildlife	Reduction in seasonal habitat availability due to clearing and sensory disturbance	Adverse	Low	Local	Long term	Reversible	High	Not significant	Not significant
	Disruption to movement patterns due to sensory disturbance	Adverse	Low	Regional	Long term	Reversible	High	Not significant	Not significant
	Increase mortality risk from collisions	Adverse	Low	Regional	Long term	Irreversible	High	Not significant	Not significant
Surface Water Quality	Changes in water quality in Oakley Creek from construction site runoff	Adverse	Low	Local	Long term	Reversible	High	Not significant	Not significant