4.0 ENVIRONMENTAL SETTING

4.1 Physical Environment

4.1.1 Climate

The Project area has a sub-arctic continental taiga climate with severe winters based on 30-year Canadian Climate Normal data obtained from Environment Canada for the Schefferville Airport (1971-2000) (Environment Canada 2008).

4.1.1.1 Temperature

A summary of the daily average, daily maximum and daily minimum temperatures on a monthly basis over the period 1971 to 2000 is presented in Table 4.1. The annual average temperature is -5.3ºC.

Table 4.1 Summary of Average Temperature Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Daily Average (ºC)	-24.1	-22.6	-16	-7.3	1.2	8.5	12.4	11.2	5.4	-1.7	-9.8	-20.6	-5.3
Daily Maximum (ºC)	-19	-16.9	-9.8	-1.5	6	13.7	17.2	15.8	8.9	1.3	-6.1	-15.9	-0.5
Daily Minimum (ºC)	-29.2	-28.1	-22.2	-13.1	-3.6	3.3	7.6	6.5	1.7	-4.6	-13.5	-25.2	-10

4.1.1.2 Precipitation

A summary of the monthly average rainfall, snowfall, total precipitation (as equivalent rainfall based on a conversion factor for snowfall to equivalent rainfall of 0.1) and average snow depth on a monthly basis over the period 1971 to 2000 is presented in Table 4.2. The annual average total precipitation for the area is about 823 millimetres (mm).

Table 4.2 Summary of Average Precipitation Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (mm)	0.2	0.2	1.6	8.4	27.7	65.4	106.8	82.8	85.3	24.4	4.5	0.9	408.1
Snowfall (cm)	57.4	42.6	56.6	54.8	22.9	8	0.5	1.7	12.7	57.2	70.7	55.4	440.5
Precipitation (mm)	53.2	38.7	53.3	61.4	52.1	73.7	107.2	84.5	98.4	80.5	69.4	50.7	822.9
Average Snow Depth (cm)	62	70	71	69	18	0	0	0	0	7	26	49	31

4.1.1.3 Wind Speed and Direction

Climate normal data with respect to wind speed and directionality is presented in Table 4.3. The annual average wind speed for the area is about 17 km/h and the most frequent wind direction, on an annual basis, is from the north-west.

Table 4.3 Summary of Wind Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Speed (km/h)	16.4	16.8	17.4	16.5	16	16.2	15.1	15.6	16.9	17.8	17.3	16	16.5
Most Frequent Direction	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
Maximum Hourly Speed (km/h)	85	97	83	77	66	97	65	61	80	89	84	80	80
Maximum Gust Speed (km/h)	134	148	148	130	101	126	103	117	137	137	142	153	131
Direction of Maximum Gust	W	W	SW	W	W	W	W	W	SW	SW	SW	SW	SW
Days with Winds ≥ 52 km/h	.7	1.4	1.9	1.1	0.9	0.4	0.6	0.4	0.8	1.1	1.8	2.1	13.9
Days with Winds ≥ 63 km/h	0.7	0.5	0.4	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.3	0.6	3.3

4.1.2 Air Quality

An Air Quality Technical Study (Appendix H) was conducted following accepted methodologies to establish existing (baseline) conditions, estimate emissions from the Project and predict the maximum downwind concentrations of the pertinent air contaminants. The methodologies and predictions are summarized in the following sections.

The key components of the Air Quality Technical Study are:

- Existing (Baseline) Conditions – On-site monitoring was conducted to measure and characterize the baseline ambient air quality in the region;
- Emissions Inventory – Maximum emission rates from the Project were estimated based on conceptual engineering design information and published sources of emission factors; and
- Air Quality Modeling – The emission rates in the exhaust and dust plumes were modelled to predict the maximum ground-level concentrations (GLC) due to Project emissions.

In this EIS, the potential environmental effects due to Project-related air contaminant emissions are assessed on the bases of these analyses. Although air quality is not considered a values environmental component or VEC in this assessment, a screening-level analysis considering the potential environmental effects of a change in ambient air quality due to Project-related emissions is provided in Section 4.1.2.2 below.

Emissions estimates and dispersion modeling were used to quantitatively assess the potential change in air quality due to substantive Project-related emissions during operation. The emissions occurring during construction are expected to be less than those occurring during operation.

4.1.2.1 Existing Conditions

An ambient air quality monitoring program was conducted between September and November 2008, specifically monitoring total particulate levels in the area of the Silver Yard. Air samples were obtained during the 2008 field ore crushing and sampling program on a six day schedule. Samples were obtained both on days when ore was being crushed as well as on days when operations were inactive. Results from the program indicated most samples had particulate levels that were below the laboratory detection limit of 0.3 mg, suggesting that the air quality in the region is well within acceptable standards. The highest particulate level sampled was 0.4 mg (28 $\mu g/m^3$), much lower than the NL standard of 120 $\mu g/m^3$. The detailed results of the ambient monitoring program undertaken between September and November 2008 are provided in the Air Quality Technical Study, submitted under separate cover and provided in Appendix H.

A search of the National Air Pollution Surveillance (NAPS) Network data records indicated that there were limited data available to determine background air quality for other air contaminants in the vicinity of the proposed operations (Environment Canada 2008). The nearest available sources of ambient air quality monitoring data are Goose Bay and Labrador City, both of which are more than 200 km from the site location.

For the purposes of air quality dispersion modeling, conservative background air quality estimates were provided by the Provincial Department of Environment and Conservation (Lawrence 2008). The background values considered in the modeling assessment are provided in Appendix H.

4.1.2.2 Emissions Inventory

Emissions of air contaminants from Project-related activities were considered for both the construction (Section 3.2.6) and operation phases (Section 3.3.2). Emissions were estimated for all substantive potential sources based on available literature and preliminary engineering design information. A detailed description of Project emissions estimates, including quantitative estimates and calculation methodologies, are provided in the Air Quality Technical Study, submitted under separate cover, and provided in Appendix H.

For construction, emissions are expected from fuel combustion in road vehicles and non-road equipment (including temporary diesel generators at the workers camp); as well as fugitive particulate matter from railway track installation, rail bed grubbing, clearing/grubbing for the site services area, and the erection of buildings. Project-related emissions during peak construction are expected to be substantively less than emissions during operation.

For operation, emissions are expected from fuel combustion, fugitive dust (particulate matter), standing losses from storage tanks, and on-site vehicle traffic at the primary processing facility. In addition, combustion and fugitive dust emissions are expected to occur due to ore hauling from the mine sites to the processing area, and ore mining activities.

4.1.2.3 Air Quality Modeling Methodology

Air quality dispersion modeling was performed to predict maximum ground-level concentration (GLC) from substantive Project emissions and quantitatively assess potential environmental effects. After consultation with Newfoundland and Labrador Department of Environment and Conservation (NLDEC), the California Puff (CALPUFF) modeling system was chosen (TRC Companies, Inc. 2007). The following subsections provide an overview of the modeling methodology. More details on the model used, inputs, assumptions, and model parameterization are provided in Appendix H.

Model Description

The core components of the CALPUFF modeling system consist of a meteorological model (CALMET), and a transport and dispersion model (CALPUFF).

The CALMET meteorological model is used to provide the meteorological data necessary to initialize the CALPUFF dispersion model. This model is initialized with terrain and land use data describing the region of interest, as well as meteorological input from potentially numerous sources. Various user-defined parameters control both how the input meteorological data is interpolated to the grid, as well as which internal algorithms are applied to these input fields. Output from the CALMET model includes hourly temperature and wind fields on a user-specified three-dimensional domain as well as additional two-dimensional variables used by the CALPUFF dispersion model.

The Department of Environment reviewed and requested changes be made to the CALMET input file for this Project during pre-consultation (November 18, 2008). All these required changes were addressed at that time. However, upon further review of the CALMET inputs, it appears there was a typo in the input file. The time zone for Schefferville was entered as UTC – 4:00 when it should have been UTC – 5:00. All other time zone inputs into CALMET were correctly defined. While this shift may cause the predicted values to change slightly on an hour-by-hour basis, when considered over a five-year period, the CALPUFF maximum predicted concentrations are not expected to change substantively. Therefore, it is not anticipated that the alteration of this CALMET parameter would change the overall non-significance conclusions of the effects analysis.

CALPUFF is a non-steady-state Gaussian puff dispersion model capable of simulating the effects of time and space-varying meteorological conditions on pollutant contaminant transport, transformation, and removal. This model requires time-variant two- and three-dimensional meteorological data output from a model such as CALMET, as well as information regarding the relative location and nature of the sources to be modelled for the application. Output from the CALPUFF model includes ground-level concentrations of the species considered, as well as dry and wet deposition fluxes.

Model Selection

CALPUFF was selected primarily because of its superior ability to characterize atmospheric dispersion in areas with complex, non-steady state meteorological conditions (NLDEC 2006). Atmospheric conditions in the region fit this criterion: areas with complex terrain in the study area create high variability in winds and turbulence. The model has specialized algorithms to deal with calm wind speed conditions and characterize dispersion in regions of complex terrain.

Dispersion Modeling Methodology

Dispersion modeling was used to investigate potential changes in air quality during the operation phase only. Emissions during the construction phase were assessed indirectly by considering the predicted maximum GLC during operation as a worst-case envelope.

The emission sources considered in the dispersion modeling included all substantive sources located at the primary processing during operation such as:

- combustion emissions from fuel oil boilers (note that based on updated design, these units are no longer required) and diesel generators (continuous power); and,
- particulate matter emissions due to crushing, loading/dumping, wind erosion, and dust from conveyors.

To consider a variety of worst-case meteorological events in the dispersion modeling, a five-year simulation period spanning 2002-2006 was selected. As Project operations are expected to cease during the winter months, emissions were not modelled from November to March. Model results were used to help quantitatively assess potential environmental effects due to Project emissions of NO_X, SO_2, CO, PM, PM_{10}, and $PM_{2.5}$. For each source modelled, emissions and other source characteristics were estimated based on preliminary design information and available literature.

As mentioned above, the baseline ambient concentrations considered in the modeling were provided by the NLDEC and are expected to conservatively estimate existing conditions in the region.

The most recent versions of the CALMET (v6.326) and CALPUFF (v6.262) models were used, as requested by the NLDEC.

Dispersion modeling was conducted to predict maximum GLC, which were added to the background concentrations and compared to the relevant air quality standards. A nested grid of receptors covering the Study Area was designed in accordance with the Newfoundland and Labrador Guidance for Plume Dispersion Modeling (NLDEC 2006) to find the maximum off-property GLC occurring over the five year period. In addition, maximum GLC were predicted at discrete sensitive receptors representing cabins, residences, and recreational areas. Figure 4.1 shows the locations of the sensitive receptors relative to the area where Project activities will occur. For all simulations, the model inputs and parameters were selected after consultation with the NLDEC (Lawrence 2008).

For the operation phase, emissions due to standing losses from storage tanks at the primary processing area are not expected to be substantive as the contents will have relatively low vapour pressures (diesel and heavy oil). Similarly, emissions due to on-site vehicle traffic are not expected to be substantive relative to the other combustion and fugitive dust sources in the primary processing area. As these sources are expected to represent only a small fraction of the total emissions from the primary processing facility, neither of the sources was included in the modeling simulations.

Emissions due to fuel combustion and fugitive dust from trucks hauling ore from the deposits to the processing area during operation were also not considered in the modeling. Although fugitive dust emissions will occur due to vehicle traffic along the road, the majority of the fugitive dust will remain in lowest 1-2 meters above ground level and settle within a few hundred meters of the road (DRI 1999). The haul route is an existing dirt road, and although traffic along the route is expected to increase with Project activities, no more than five trucks are expected to pass in a given hour. As such, while changes in air quality may occur due to fugitive dust emissions during certain meteorological conditions when trucks pass, these events will be localized and short in duration.

Emissions due to blasting and on-site traffic at the mine site locations during operation are not expected to cause substantive changes in air quality as they will be emitted inside a pit, mechanical methods will be used where possible, and the distances from the site to the nearest sensitive receptors are relatively far (more than 1.5 km). Therefore, these emissions were excluded from further modeling.

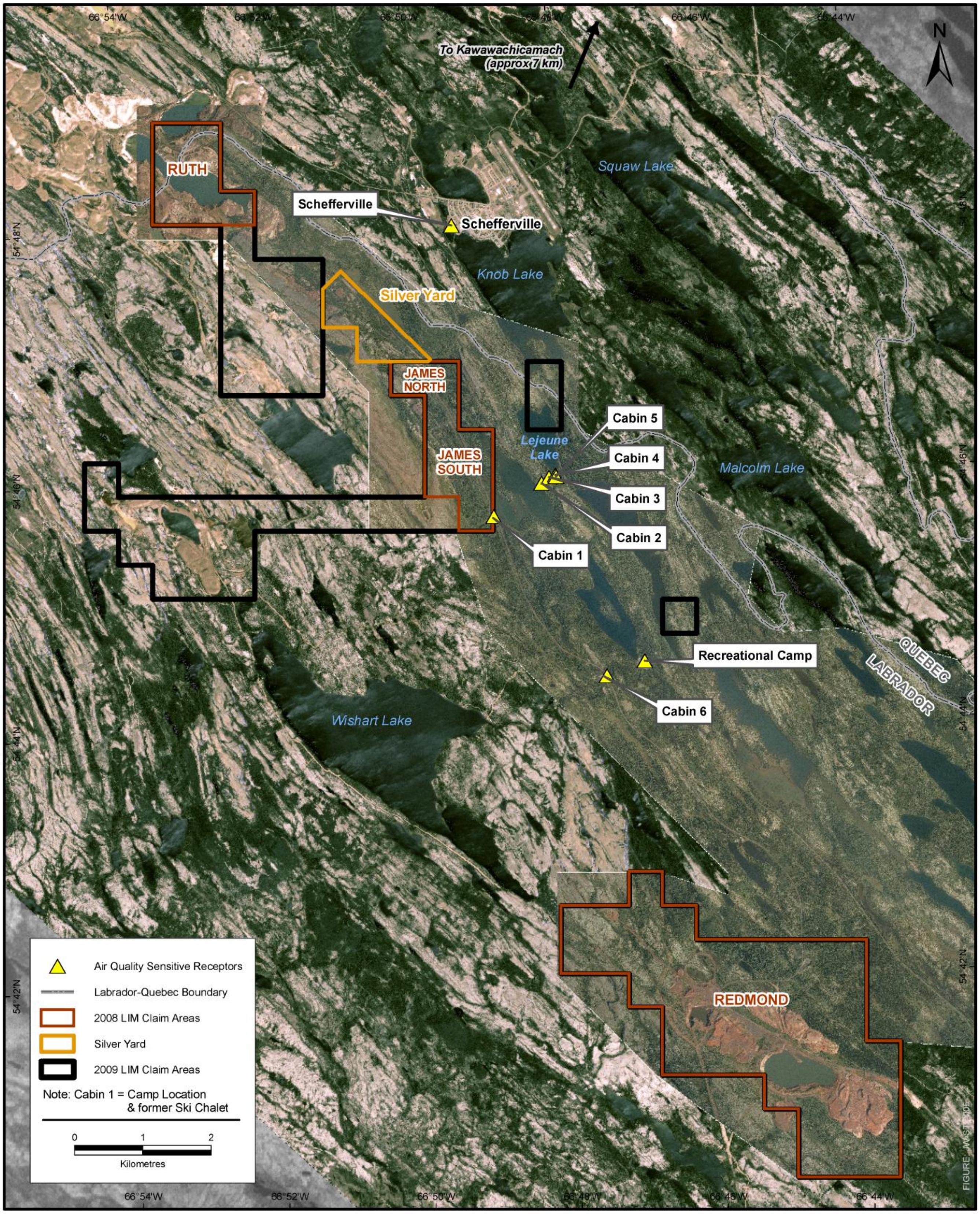


Figure 4.1 Sensitive Receptor Locations

Emissions from the diesel locomotive used for transporting ore from the beneficiation area during operation are not expected to cause substantive changes in air quality as such emissions will be intermittent (one trip per day) and short-term in duration. Therefore, these emissions were not included in the modeling assessment.

As the diesel generators installed at the worker's camp will be operated in standby mode, any emissions from these units will be intermittent, short-term in duration and negligible compared to other emissions occurring during operation. Therefore, these emissions were excluded from further modeling.

4.1.2.4 Air Quality Modeling Results

Modeling was conducted over all applicable averaging periods, and maximum predicted GLC were compared with applicable regulatory standards. Estimates for background ambient air contaminant concentrations were added to the model predictions to characterize maximum potential changes in air quality. The results of the dispersion modeling assessment are presented in Appendix H.

The maximum predicted concentrations in Appendix H show that during certain rare meteorological conditions, exceedances of the regulatory standards for NO_2, TSP, PM_{10}, and $PM_{2.5}$ could potentially occur near the property line of the facility (within 150 meters of the facility). These higher predicted values are due to emissions from the diesel generators (NO_2) and from fugitive dust sources at the primary processing facility (TSP, PM_{10}, and $PM_{2.5}$). Over the five-year modeling period and including ambient background concentrations, there were 73 predicted exceedances of the 24-hr PM standard, 131 predicted exceedances of the 24-hr PM_{10} standard, 42 exceedances of the 24-hr $PM_{2.5}$ standard, and 1 predicted exceedance of the 1-hr NO_2 standard. The predicted exceedances of NO_2 occur approximately 130 m from the property line (thus not near any residences) and are primarily due to emissions from the diesel generator stacks. The predicted exceedances of particulate matter are primarily due to fugitive dust sources, such as ore loading and storage pile erosion. No exceedances of the regulatory standards for SO_2 or CO were predicted. All predicted GLC near cabins, residences, and recreational areas are well below the regulatory standards. As well, more details are provided in the Air Quality Technical Study, provided under separate cover.

It should be noted that the emissions estimates used as input to the dispersion modeling were based on conservative assumptions and published emissions factors, and do not take into account potential mitigative measures to reduce fugitive dust at the facility. Based on the final design of the facility, mitigative measures will be put in place to minimize emissions and resultant fugitive dust near property limits. These measures, as described in Section 8.1 of the EIS, will include wet suppression of roads and storage piles to minimize fugitive dust. With such mitigation measures in place, fugitive dust emissions (and resultant off-property PM concentrations) would be reduced to below ambient air quality standards LIM will implement mitigation measures efficiently and effectively to ensure that no significant adverse environmental effects occur due to Project-related emissions during operation. Follow-up ambient air monitoring (as discussed in Section 8.3 of the EIS) will confirm Project-related emissions during construction and operation for additional mitigation development and implementation, if appropriate. This approach (mitigation and follow-up monitoring) is a preferable option, and therefore re-modeling of the conservative and theoretical fugitive dust emission from the Project is not required. Furthermore, all model-predicted values represent a conservative worst-case estimate of potential downwind concentrations during adverse meteorological conditions (considering five years of meteorological data).

Contour plots of the predicted maximum ground-level concentrations (including winter months) are shown for NO_2 (1 hr averaging period), and TSP (24 hr averaging period) in Figures 4.2 and 4.3, respectively. The plots show that, as mentioned above, the region of the predicted exceedances is limited to a small area near the property line and more than 1.5 km from any of the sensitive receptor locations. The maximum predicted concentrations at the two sensitive receptor locations nearest to the primary processing facility (Schefferville, Private Cabin) are presented in Appendix H. As mentioned above, the predicted GLC near cabins, residences, and recreational areas are well below the regulatory standards.

Section 5 of the Air Pollution Control Regulations does not apply to the boiler stack or the baghouse stack because the emissions are below the prescribed limits. Based on the methodology used in the emissions inventory and the dispersion modeling, SO_2 and PM emissions from the boiler stack were conservatively estimated to be 5.3 tonnes and 1.3 tonnes respectively, while the PM emissions from the baghouse were estimated to be 6.7 tonnes. These are all below the 20 tonne per year limit described in Section 5 of the Air Pollution Control Regulations. Note that based on updated design information, the boilers are no longer required. However, to be conservative, the potential contributions of these sources are still considered in the air quality assessment.

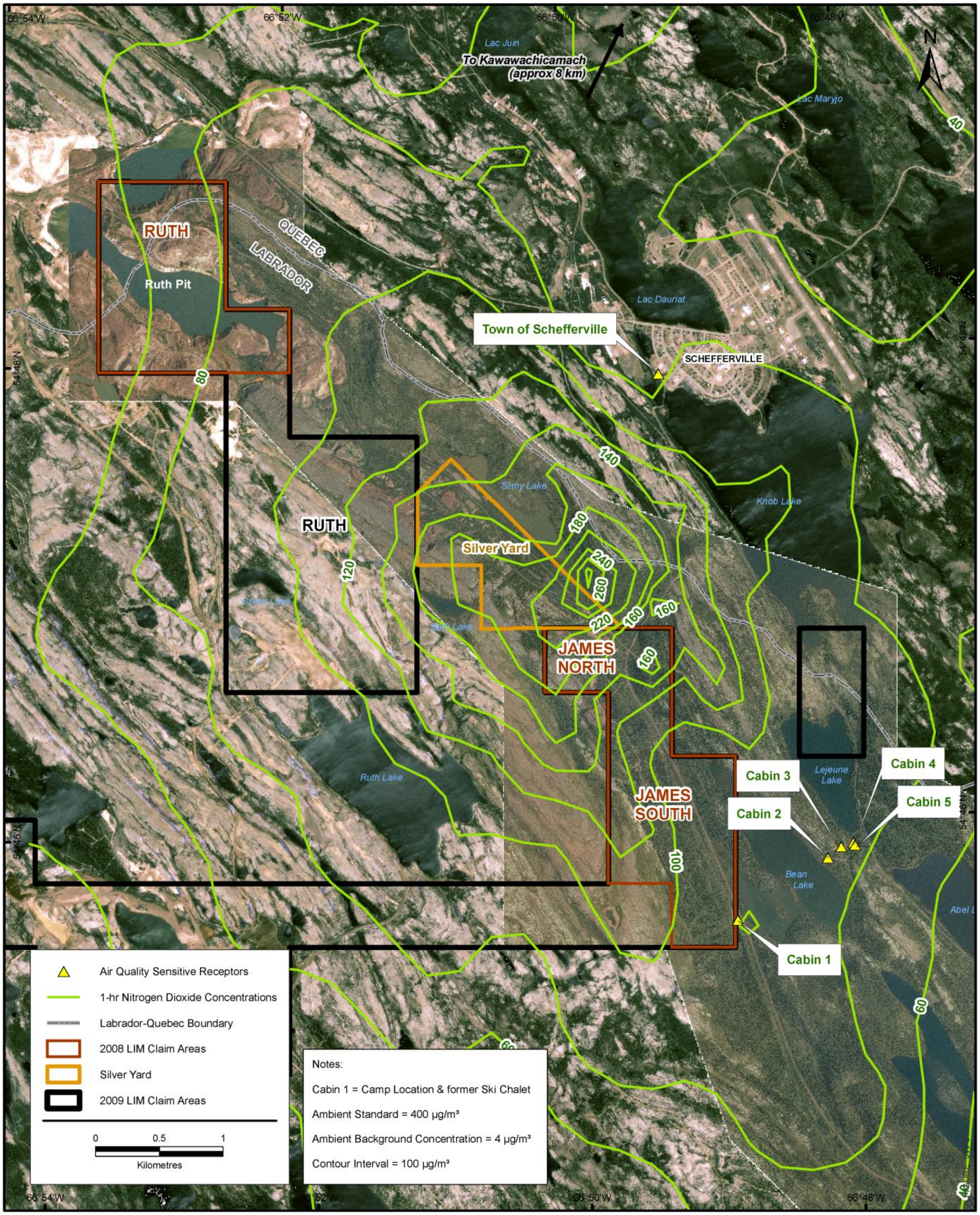
4.1.2.5 Potential Changes in Air Quality due to Project Activities

The Project activities during construction and operation may result in emissions of air contaminants to the atmosphere. These emissions have the potential to cause adverse environmental effects via a change in ambient air quality. In the following sections, the significance of these potential environmental effects is rated for both operation and construction.

Operation

Emissions estimates for the Project during operation were developed for all potentially substantive sources using the list of potential sources provided in the guidelines as a basis. Where emission sources identified in the guideline were found to be not substantive or not applicable, emissions were not estimated. All source screening and emissions estimates were based on preliminary data for the Project. The potentially substantive emission sources during operation can be broadly grouped as either combustion emissions or fugitive dust emissions. Emissions were estimated for numerous non-negligible sources including boilers (note that based on updated design, these units are not required), generators, on-site vehicles, ore loading, ore crushing, stockpile erosion, and on-site conveyor systems. The final emissions inventory (with more detailed estimates and methodology) is provided in the Air Quality Technical Study which is submitted under separate cover and provided in Appendix H. The emission sources during operation can be categorized into three groups:

- emissions from the primary processing facility;
- emissions due to trucks hauling ore from the mines to the processing area; and,
- emissions due to blasting and on-site traffic at the mine site locations.



Notes:

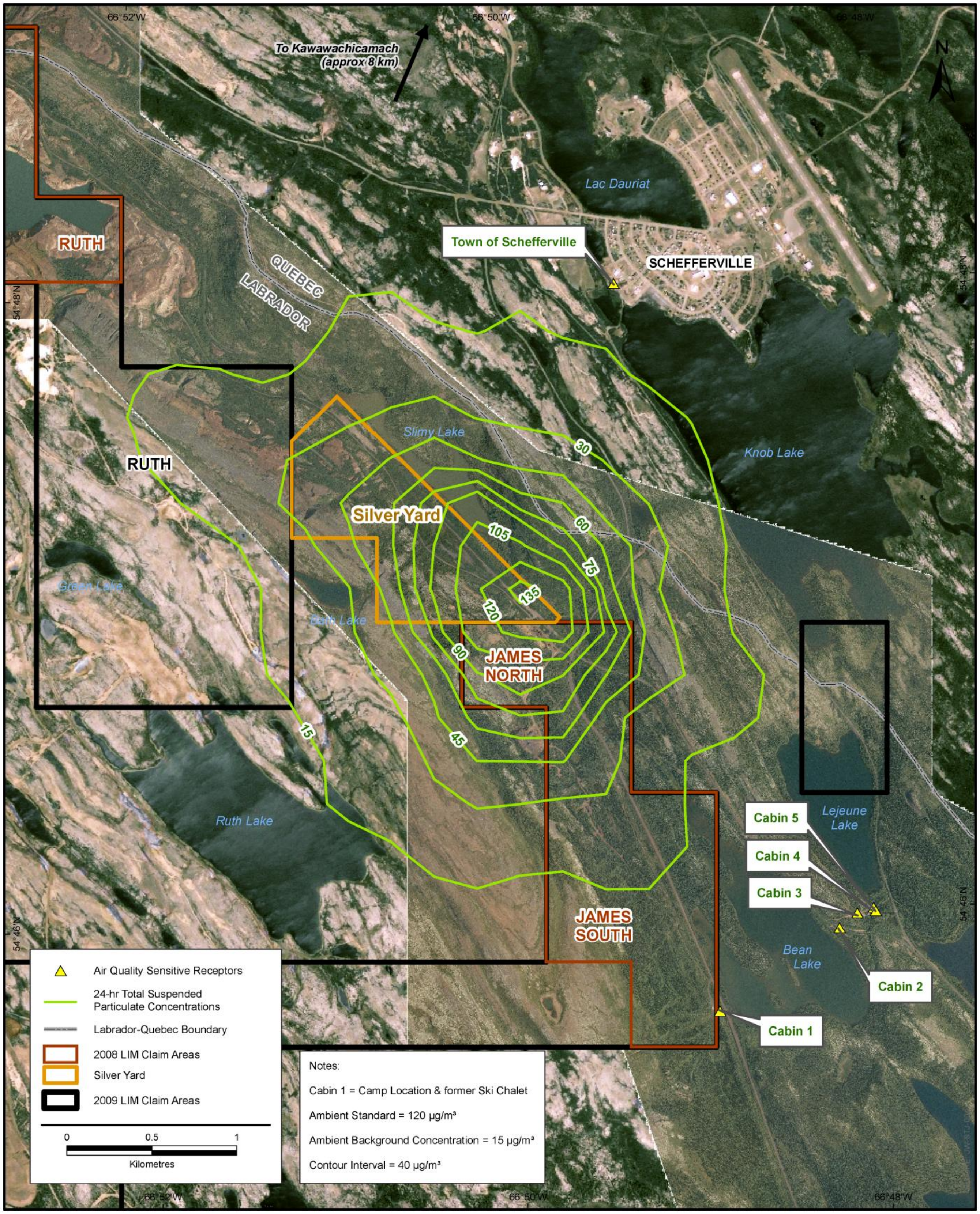
Cabin 1 = Camp Location & former Ski Chalet

Ambient Standard = 400 µg/m³

Ambient Background Concentration = 4 µg/m³

Contour Interval = 100 µg/m³

Figure 4.2 Maximum Predicted 1-hr NO_X Ground-level Concentrations



Notes:

Cabin 1 = Camp Location & former Ski Chalet

Ambient Standard = 120 µg/m³

Ambient Background Concentration = 15 µg/m³

Contour Interval = 40 µg/m³

Figure 4.3 Maximum Predicted 24-hr TSP Ground-level Concentrations

As shown in the dispersion modeling of emissions from the primary processing facility presented above, although there may be exceedances of regulatory standards at locations near the property line during adverse meteorological conditions, these higher values are limited to within 150 m of the property line. As this region is far from any of the sensitive receptor locations, it is unlikely that prolonged human exposure to air contaminant concentrations at these levels will occur. Therefore, as the predicted exceedances represent worst-case meteorological conditions, are limited in spatial extent, and are short-term in duration, no substantive changes in air quality are expected due to emissions from the primary processing facility.

Although fugitive dust emissions will occur due to vehicle traffic along the road during operations, the majority of the fugitive dust will remain in lowest 1-2 meters above ground level and settle within a few hundred meters of the road (DRI 1999). The haul route is an existing dirt road, and although traffic along the route is expected to increase with Project activities, no more than five trucks are expected to pass in a given hour. As such, while some dusting of vegetation may occur due to vehicle traffic during certain meteorological conditions, no substantive environmental effects are expected due to such emissions as they will be localized in extent and short-term in duration.

Emissions due to blasting and on-site traffic at the mine site locations are not expected to cause substantive environmental effects as will be emitted inside a pit and the transport distances to the nearest sensitive receptors are relatively far (greater than 1.5 km).

Emissions from the diesel locomotive used for transporting ore from the beneficiation area are not expected to cause substantive environmental effects as these emissions will be intermittent (one trip per day) and short-term in duration.

Similarly, emissions from the standby diesel generators installed at the worker’s camp will be intermittent, short-term in duration, and negligible relative to other emissions during operation. Therefore, such emissions are not expected to cause substantive environmental effects.

Therefore, no significant adverse environmental effects due to Project-related emissions are anticipated during operation.

Construction

As outlined in Section 3.2.6, emissions to the atmosphere may occur during construction activities such as railway track installation, rail bed grubbing, clearing/grubbing for site services area, and the erection of buildings at the primary processing facility location. Fuel combustion and fugitive dust from the movement of soil and vehicles are expected to contribute most substantively to emissions during this phase. In addition, combustion emissions are expected from the temporary diesel generators installed at the worker’s camp.

As the emissions occurring during construction are expected to be fractionally small compared to those occurring during operation, the potential effects to air quality during this Phase can be assessed indirectly by considering the model-predicted concentrations using the operation phase as a worst-case envelope. Since no significant adverse environmental effects are anticipated due to a change in air quality during operation, it follows the same conclusion will apply for construction.

Therefore, no significant adverse environmental effects due to Project-related emissions are anticipated during construction.

Summary

Based on the above rationales, the environmental effect of a change in air quality due to emissions from Project-related activities, through all phases, is rated not significant.

4.1.3 Landscape

4.1.3.1 Regional Geology

At least 45 hematite-goethite ore deposits have been discovered in an area 20 km wide that extends 100 km northwest of Astray Lake, referred to as the Knob Lake Iron Range, which consists of tightly folded and faulted iron-formation. The iron deposits occur in deformed segments of iron-formation, and the ore content of single deposits varies from one million to more than 50 million tonnes.

The Knob Lake properties are located on the western margin of the Labrador Trough adjacent to Archean basement gneisses. The Labrador Trough, known as the Labrador-Québec Fold Belt, extends for more than 1,000 km along the eastern margin of the Superior craton from Ungava Bay to Lake Pletipi, Québec. The belt is about 100 km wide in its central part and narrows considerably to the north and south.

The western half of the Labrador Trough can be divided into three sections based on changes in lithology and metamorphism (North, Central and South). The Trough is comprised of a sequence of Proterozoic sedimentary rocks including iron formation, volcanic rocks and mafic intrusions known as the Kaniapiskau Supergroup (Gross, 1968). The Kaniapiskau Supergroup consists of the Knob Lake Group in the western part of the Trough and the Doublet Group, which is primarily volcanic, in the eastern part.

The Central or Knob Lake Range section extends for 550 km south from the Koksoak River to the Grenville Front located 30 km north of Wabush Lake. The principal iron formation unit, the Sokoman Formation, forms a continuous stratigraphic unit that thickens and thins from sub-basin to sub-basin throughout the fold belt.

The southern part of the Trough is crossed by the Grenville Front. Trough rocks in the Grenville Province to the south are highly metamorphosed and complexly folded, which has caused recrystallization of both iron oxides and silica in the primary iron formation to meta-taconites.

Geological conditions throughout the central division of the Labrador Trough are generally similar to those in the Knob Lake Range.

A geological map of the Project area is shown in Figure 4.4.

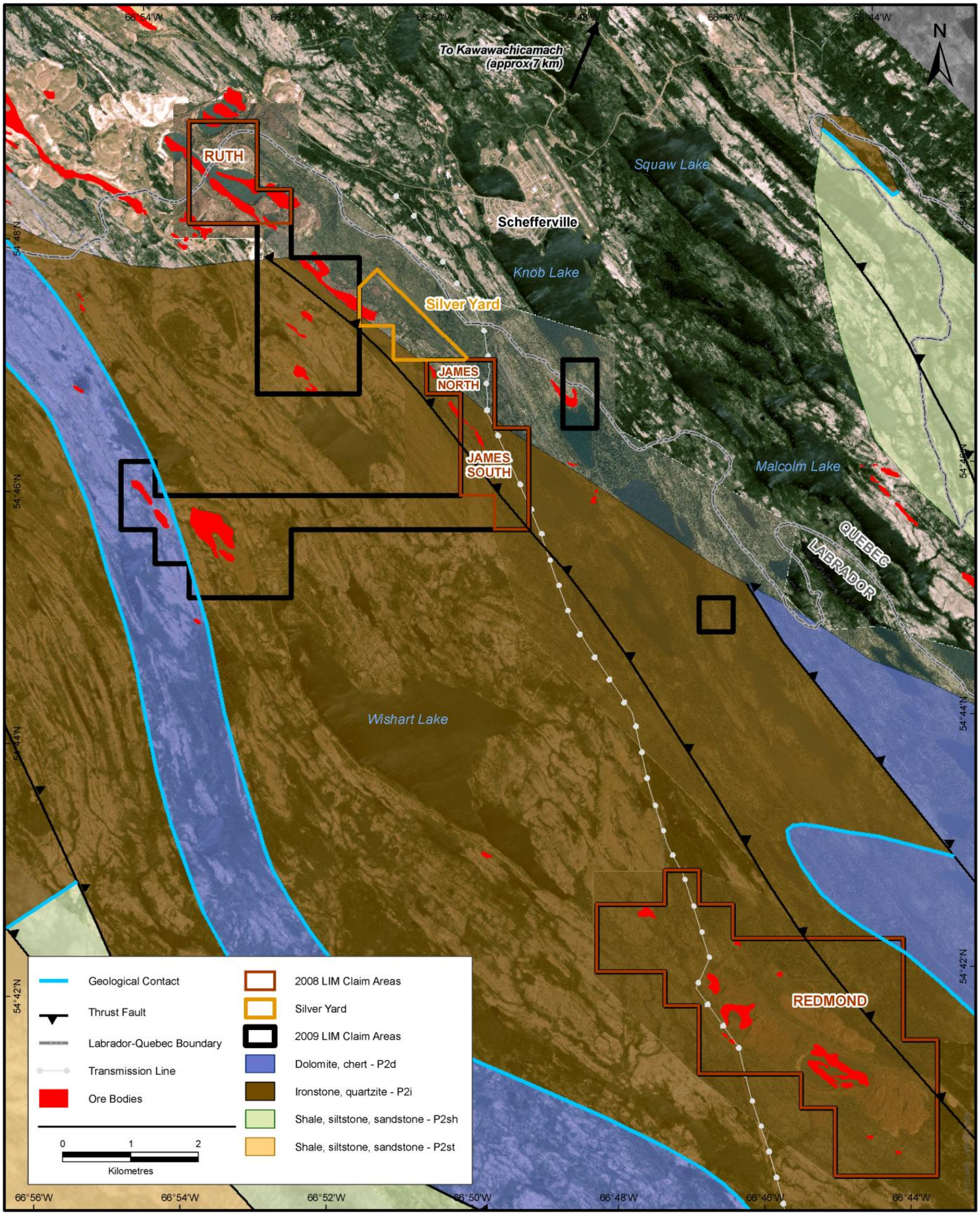


Figure 4.4 Geological Map (Project Area)

4.1.3.2 Knob Lake Range Geology

The general stratigraphy of the Knob Lake area is representative of most of the range, except that the Denault dolomite and Fleming Formation (described below) are not uniformly distributed. The Knob Lake Range occupies an area 100 km long by 8 km wide. The sedimentary rocks including the cherty iron formation of this area are weakly metamorphosed to greenschist facies. In the structurally complex areas, leaching and secondary enrichment have produced earthy textured iron deposits. Unaltered banded magnetite iron formation (taconite) occurs as gently dipping beds west of Schefferville in the Howells River deposits.

Most of the secondary earthy textured iron deposits occur in canoe-shaped synclines with some as tabular bodies. In the western part of the Knob Range, the iron formation dips gently eastward over the Archean basement rocks for about 10 km to the east, then forms an imbricate fault structure with bands of iron formation.

Subsequent supergene processes converted some of the iron formations into high-grade ores, preferentially in synclinal depressions and/or down-faulted blocks. Original sedimentary textures are commonly preserved by selected leaching and replacement of the original deposits. Jumbled breccias of enriched ore and altered iron formations, locally called rubble ores, are also present.

The stratigraphy of the Schefferville area is represented by the following formations.

Attikamagen Formation. It consists of argillaceous material that is thinly bedded, fine grained, greyish green, dark grey to black, or reddish grey. Calcareous or arenaceous lenses occur locally interbedded with the argillite and slate, and lenses of chert are common.

Denault Formation. The Denault Formation consists primarily of dolomite being more clastic at its base and cherty at its top. Leached and altered beds near the iron deposits are rubbly, brown or cream coloured.

Fleming Formation. It occurs a few kilometres southwest of Knob Lake and only above dolomite beds of the Denault Formation. It consists of rectangular fragments of chert and quartz within a matrix of fine chert.

Wishart Formation. The Wishart Formation is a sandstone formation (quartzite and arkose) cemented by quartz and minor amounts of hematite and other iron oxides. It is well differentiated from the iron ore bearing overlaying formations by its texture and color.

Ruth Formation. It is a black, grey-green or maroon ferruginous slate, 3 to 36 metres thick. This thinly banded material contains lenses of black chert and various amounts of iron ore.

Sokoman Formation. More than 80 percent of the ore in the Knob Lake Range occurs within this formation. Lithologically, the iron formation varies in detail in different parts of the range and the thickness of individual members is not consistent.

A thinly bedded, slatey facies at the base of the formation consists largely of fine chert with an abundance of iron silicates and disseminated magnetite and siderite. Fresh surfaces are grey to olive green, and weathered surfaces brownish yellow to bright orange. Thin-banded oxide facies of iron formation occurs above the silicate-carbonate facies in nearly all parts of the area. The thin (<1.25cm) jasper bands are mostly deep red, but in some places are greenish yellow to grey, and are interbanded with hard, blue layers of fine-grained hematite and a minor magnetite.

The thin jasper beds are located underneath thick massive beds of grey to pinkish chert and beds that are very rich in blue and black iron oxides, and make up most of the Sokoman Formation. The upper part of the Sokoman Formation comprises discontinuous beds of dull green to grey or black massive chert.

Menihek Formation. A thin-banded, grey to black argillaceous slate conformably overlies the Sokoman Formation in the Knob Lake area. Thicknesses are unknown since the slate is found in faulted blocks in the main ore zone.

4.1.3.3 Regional Mineralization

The earthy bedded iron deposits are a residually enriched type within the Sokoman iron formation that formed after two periods of intense folding and faulting, followed by the circulation of meteoric waters in the fractured rocks. The enrichment process was caused largely by leaching and the loss of silica, resulting in a strong increase in porosity. This produced a friable, granular and earthy-textured iron ore. The siderite and silica minerals were altered to hydrated oxides of goethite and limonite. The second stage of enrichment included the addition of secondary iron and manganese which appear to have moved in solution and filled pore spaces with limonite-goethite. Secondary manganese minerals, i.e., pyrolusite and manganite, form veinlets and vuggy pockets. The types of iron ores developed in the deposits are directly related to the original mineral facies. The predominant blue granular ore was formed from the oxide facies of the middle iron formation. The yellowish-brown ore, composed of limonite-goethite, formed from the carbonate-silicate facies, and the red painty hematite ore originated from mixed facies in the argillaceous slaty members. The overall ratio of blue to yellow to red ore is approximately 70:15:15. The proportion of each varies widely within the deposits.

Only the direct shipping ore is considered beneficial to produce lumps and sinter feed and will be part of the resources for the LIM Project. The direct shipping ore was classified by IOC in six categories based on their chemical, mineralogical and textural compositions. This classification is still used in the evaluation of the mineralization. The following ore categories and other mineralization categories not part of the potential economic mineralization, are:

- High Non-Bessemer (HNB);
- Lean Non Bessemer (LNB);
- High Silica (HiSiO2) (waste); and
- Treat Rock (TRX) (waste but previously stockpiled for possible later treatment).

The blue ores, which are composed mainly of the minerals hematite and martite, are generally coarse grained and friable. They are usually found in the middle section of the iron formation.

The yellow ores, which are made up of the minerals limonite and goethite, are located in the lower section of the iron formation. These ores have the unfavourable characteristic of retaining high moisture content.

The red ore is predominantly a red earthy hematite. It forms the basal layer that underlies the lower section of the iron formation. Red ore is characterized by its clay and slate-like texture.

Direct shipping ores and lean ores mined in the Schefferville area during the period 1954-1982 amounted to some 150 million tons. Based on the original ore definition of IOC (+50% Fe <18% SiO2 dry basis), approximately 200 million tonnes of iron resources remain in the area, exclusive of magnetite taconite. LIM has acquired rights to approximately 50 percent of this remaining iron resource.

4.1.3.4 Deposit Types

The Labrador Trough contains four main types of iron deposits:

- soft iron ores formed by supergene leaching and enrichment of the weakly metamorphosed cherty iron formation; they are composed mainly of friable fine-grained secondary iron oxides (hematite, goethite, limonite);
- taconites, the fine-grained, weakly metamorphosed iron formations with above average magnetite content and which are also commonly called magnetite iron formation;
- more intensely metamorphosed, coarser-grained iron formations, termed metataconites which contain specular hematite and subordinate amounts of magnetite as the dominant iron minerals; and
- minor occurrences of hard high-grade hematite ore occur southeast of Schefferville at Sawyer Lake, Astray Lake and in some of the Houston deposits.

The Labrador Iron Mountain deposits are composed of iron formations of the Lake Superior-type. The Lake Superior-type iron formation consists of banded sedimentary rocks composed principally of bands of iron oxides, magnetite and hematite within quartz (chert)-rich rock, with variable amounts of silicate, carbonate and sulphide lithofacies. Such iron formations have been the principal sources of iron throughout the world.

The Sokoman iron formation was formed as chemical sediment under varied conditions of oxidation-reduction potential (Eh) and hydrogen ion concentrations (pH) in varied depth of seawater. The resulting irregularly bedded, jasper-bearing, granular, oolite and locally conglomeratic sediments are typical of the predominant oxide facies of the Superior-type iron formations, and the Labrador Trough is the largest example of this type.

The facies changes consist commonly of carbonate, silicate and oxide facies. Typical sulphide facies are poorly developed. The mineralogy of the rocks is related to the change in facies during deposition, which reflects changes from shallow to deep-water environments of sedimentation. In general, the oxide facies are irregularly bedded, and locally conglomeratic, having formed in oxidizing shallow-water conditions. Most carbonate facies show deep-water features, except for the presence of minor amounts of granules. The silicate facies are present in between the oxide and carbonate facies, with some textural features indicating deep-water formation.

Each facies contains typical primary minerals, ranging from siderite, minnesotaite, and magnetite-hematite in the carbonate, silicate and oxide facies, respectively. The most common mineral in the Sokoman Formation is chert, which is closely associated with all facies, although it occurs in minor quantities with the silicate facies. Carbonate and silicate lithofacies are present in varying amounts in the oxide members.

The sediments of the Labrador Trough were initially deposited in a stable basin which was subsequently modified by penecontemporaneous tectonic and volcanic activity. Deposition of the iron formation indicates intraformational erosion, redistribution of sediments, and local contamination by volcanic and related clastic material derived from the volcanic centers in the Dyke-Astray area.

The consolidation of the sediments into cherty banded iron formation is due to diagenesis and low grade metamorphism, which only reached the greenschist rank. The iron may be a product of erosion. It is unlikely that the Nimish volcanism made a significant contribution.

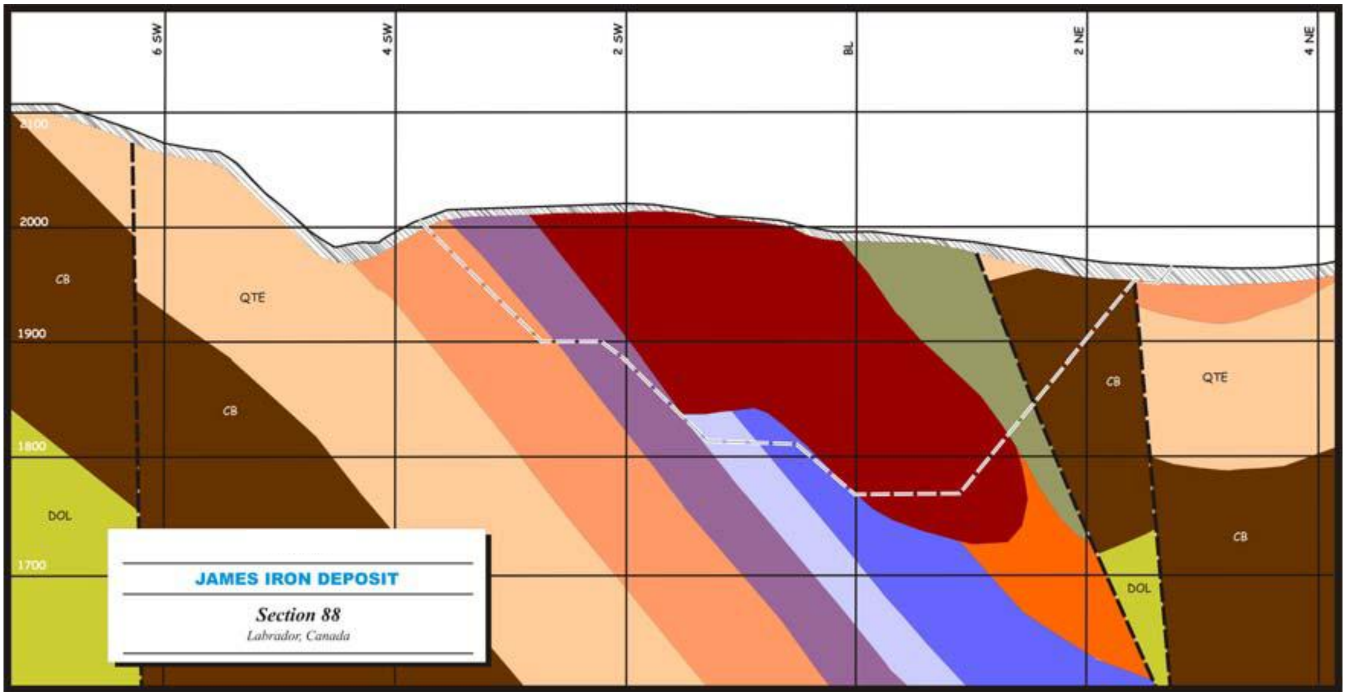
The Project currently involves the James North, James South and Redmond Deposits.

James Deposit

The James deposit is a northeast dipping elongated iron deposit with a direction of N330° in its main axis and it appears to be structurally and stratigraphically controlled. The stratigraphic units recorded in James area go from the Denault Formation to the Menihek Formation. The main volume of the mineralization is developed in the Middle Iron Formation (MIF) and lower portion of the Upper Iron Formation (UIF) both part of the Sokoman Formation.

The iron mineralization in the James deposit consist of thin layers (<10 cm thick) of fine to medium grained steel blue hematite intercalated with minor cherty silica bands <5 cm thick dipping 30° to 45° to the northeast. The James mine mineralization has been affected by strong alteration which removed most of the cementing silica giving it a sandy friable texture.

A typical section developed by IOC is shown in Figure 4.5.



Source: Labrador Iron Mines Limited

Figure 4.5 Generalized Cross Section-James Deposits

Redmond Deposit

The Redmond deposits are developed along a northwest trending synclinal that extends to the south to the Redmond No.1 deposit and to the north to the Wishart mine. The Redmond deposits enclosed in license 016291M are small rounded medium Fe grade mineralized bodies.

4.1.3.5 Geomorphology, Surficial Geology, Soils and Permafrost

There are dominant surficial materials within the area surrounding the Project deposits of drift-poor areas, glacial till and other surficial deposits (undifferentiated), with occasional areas of glaciofluvial deposits.

The till and other surficial deposits (undifferentiated), are predominantly nonstratified, poorly sorted, silty to sandy diamicton, gravel, and sandy gravel, deposited either directly from ice or by meltout during ablation and includes glaciofluvial, glaciolacutrine, marine, and fluvial deposits of either minor areal extent or thin (less than two m) and discontinuous.

The drift-poor areas are described as greater than 80 percent bedrock; including areas of till and other surficial materials generally < 1 m thick and discontinuous.

The glaciofluvial deposits are classified as proglacial or ice contact sand and gravel, forming ice contact fans and deltas, outwash plains and terraces, pitted outwash, crevasse fillings, kames and kame terraces, commonly associated with eskers and including areas of extensive, thick fluvial sediments derived from pre-existing glaciofluvial deposits.

The areas in and surrounding the deposits associated with the Project being predominantly greater than 80 percent bedrock, and a previously mined area, do not possess a high number of identifiable landforms. There is evidence of striae, indicating direction of flow known and unknown, as well as identified eskers (esker ridge; kame or splay deposit) in the area (R.A. Klassen et al. 1992).

Permafrost

There have been observations of permafrost of 120 m in thickness in the Schefferville region (Brown 1979). The Schefferville area has been previously identified as the “tentative southern limit of continuous permafrost”, Jenness (1949), then later as the “approximate southern limit of permafrost”, Thomas (1953). It was later concluded that there were no continuous zones of permafrost in the Labrador-Ungava and boundaries of discontinuous and sporadic zones were specified (Black 1951). An area 160 km north of Schefferville was indicated as the southern limit of discontinuous permafrost and extending to within 80 km of the Gulf of St. Lawrence was the sporadic zone (Pryer 1966).

Permafrost was determined to be more widespread than thought once IOC began mining near Schefferville in 1954. As described by Brown (1979), the southern limit of the discontinuous permafrost zone approximately extends along the 51st parallel of latitude from the southern end of James Bay to the Strait of Belle-Isle, 1500 km to the east (Figure 4.6). The western extremity of the northern limit of the discontinuous zone begins at Hudson Bay in the vicinity of Post-de-la-Baleine, 55oN latitude. The eastern extremity of this zone ends in the vicinity of Hopedale. Schefferville is situated at the northern margin of the permafrost. The permafrost occurs as scattered islands which increase in size and number from south to north. Although permafrost is present within the Fleming-Timmins group of deposits, 25 km northwest of Schefferville (Garg 1982), permafrost has not been identified within the current project area.

Various studies on permafrost refer to vegetation and snow cover as having correlation with permafrost presence and thickness. Snow depth and density changes with relief, weather and vegetation (Thom 1969). Thom suggests thick permafrost (up to 60 m) is likely in areas where snow cover is less than 0.4 m during the winter months of January and February.

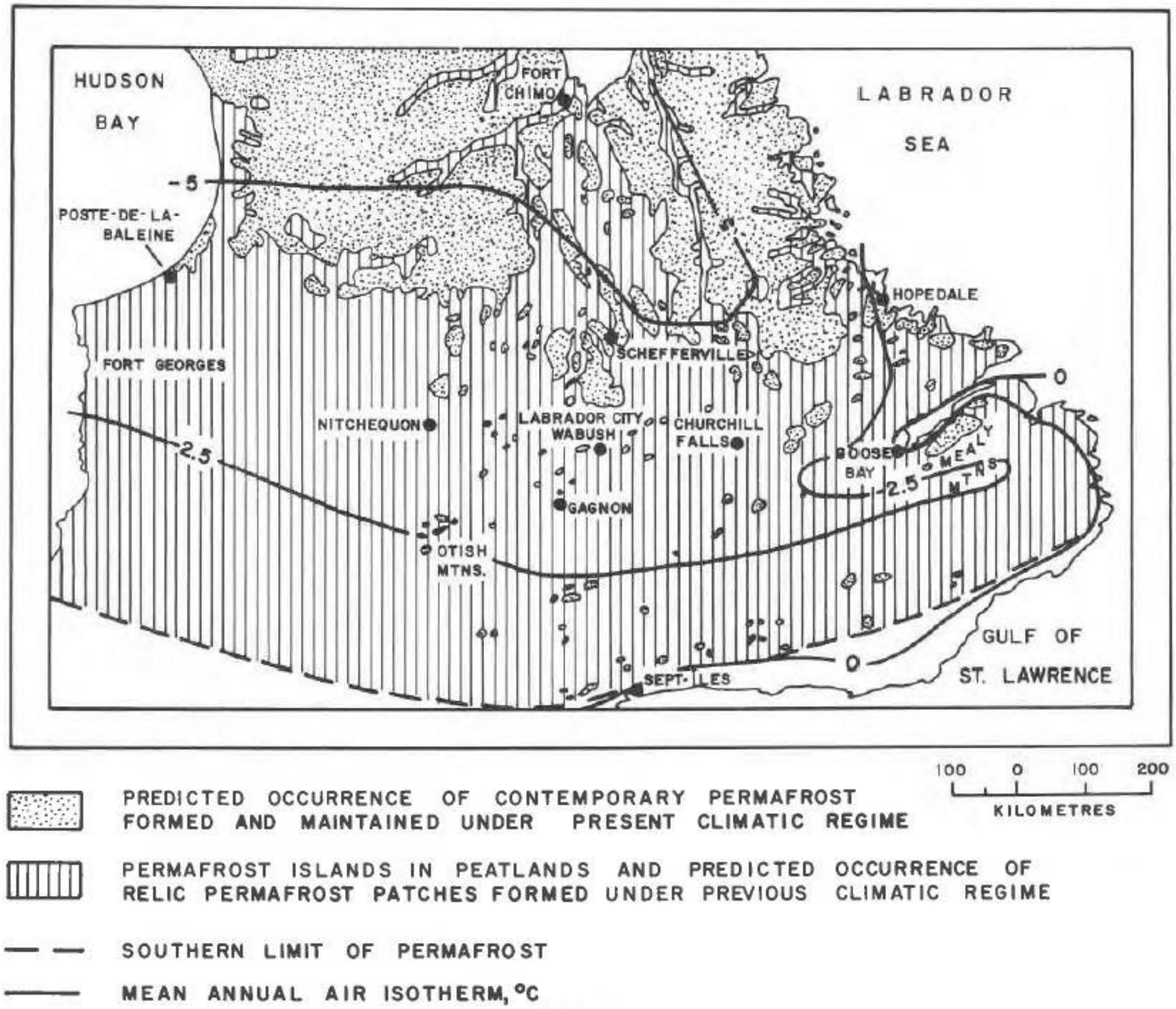


Figure 4.6 Permafrost Distribution in Nouveau-Québec and Labrador (Source Brown, 1979)

Research on permafrost distribution at numerous sites in the Schefferville area has been conducted by Nicholson (February 1978). Two sites north of the Project included Timmins 4 and Fleming 7, at an elevation of 700 m, between 1973 and 1975. It was determined that deep permafrost underlies areas of high elevation, which were exposed and vegetation cover consisted of tundra. The permafrost ranged from 60 to 100 m in depth, and entirely unfrozen areas occurred in valleys on the edge of these sites. No permafrost was present on less exposed and low-lying wood covered ground surfaces (Nicholson and Lewis 1976). Permafrost is expected to be absent beneath water bodies in the area that are so deep they do not freeze solid during winter, due to the water bodies' ability to produce higher ground temperatures. Permafrost is not expected to occur within 30 m from permanently covered shoreline (Nicholson February 1978).

Permafrost has not been observed in the Project Area and therefore it is not anticipated that permafrost will interfere with mining at the James and Redmond deposit areas.

4.1.3.6 Acid Rock Drainage

Based on the geology associated with iron ore deposits and specifically the deposits associated with the James and Redmond Properties that form the Project, the geological materials to be excavated, exposed and processed during mining of the James and Redmond deposits have low to no potential for Acid Rock Drainage (ARD). However, due diligence requires that ARD potential for any new mine site be fully evaluated and LIM is committed to ensuring the long term chemical stability of the Project through all stages of the mine life.

To date, sufficient historical and baseline data, as well as current laboratory test work, exists to suggest that ARD potential is extremely low for this Project. The following sections summarize the available data and the ongoing test work that will be completed.

Historical and Baseline Water Quality

Exploration and mining activities have occurred at the Project site dating back to the 1950s. IOC excavated large open pits and stockpiled considerable waste rock, low grade ore and other materials around the site. These materials have been exposed to both water and air (both required conditions for acid generation from rock) for decades and to date there is no evidence of poor or deteriorating water quality (lowered pH, elevated metals) in the flooded pits, stockpile drainage areas, or the surrounding natural water bodies.

Water quality monitoring on and around the James and Redmond Properties completed by AECOM in 2007 and 2008 (see Appendix I) indicates generally good water quality with pH ranging from 6.5 to 8.5 and normal metal concentrations.

ARD Sampling and Testing Program

A phased ARD sampling and testing program has been initiated to investigate and confirm the ARD potential for all geological materials (ore and waste) to be exposed at this site. To date, preliminary ‘static’ ARD test work has commenced on geological materials available from LIM’s 2008 sampling (trenching and boreholes) program.

The results of the acid base accounting test work completed to date are compiled in Table 4.4. These samples contain very low concentrations of sulphur and the NP/AP ratios for these samples tested range from 37 to 44 over seven samples. Based on the static ARD test results available to date, it is not anticipated that any of the ore or waste materials for this Project will be acid generating.

Bulk metals analysis was completed on seven samples by strong acid digestion (4 Acid) for trace metals (ICP-AES and ICP-MS). These results are shown in Table 4.4 and show generally typical element composition with the exception of iron, as would be expected.

Additional ARD test work will be completed as additional samples from LIM’s 2008 sampling (trenching and boreholes) program become available. Additional test work will be designed to provide coverage of all geological materials and spatial extents of the planned mine workings.

Table 4.4 Acid Base Accounting (ABA) Results

Deposit	Sample Method	Material Type	Paste pH	Total Sulphur	Acid Leachable SO_4-S	Sulphide -S	Total Carbon	Carbonate	NP (t $CaCO_3$/ 1000t)	AP (t $CaCO_3$/ 1000t)	Net NP (t $CaCO_3$/ 1000t)	NP/AP Ratio
			(units)	(%)	(%)	(%)	(%)	(%)				
James	Bulk	HGO	6.98	< 0.005	< 0.1	< 0.01	0.040	0.127	12.5	0.31	12.2	40.3
James	Bulk	LGO	7.10	< 0.005	< 0.1	< 0.01	0.091	0.024	12.5	0.31	12.2	40.3
Redmond 2	Bulk	LGO	7.55	< 0.005	< 0.1	< 0.01	0.048	0.029	13.0	0.31	12.7	41.9
Redmond 2	Bulk	Waste	6.95	< 0.005	< 0.1	< 0.01	0.047	0.119	11.6	0.31	11.3	37.4
Redmond 2B	Bulk	HGO	7.04	< 0.005	< 0.1	< 0.01	0.141	0.228	13.4	0.31	13.1	43.2
Redmond 5	Bulk	HGO	7.41	< 0.005	< 0.1	< 0.01	0.081	0.017	13.7	0.31	13.4	44.2
Ruth	Bulk	Waste	8.03	0.121	0.3	< 0.01	0.026	0.031	12.1	0.31	11.8	39.0