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Iron Ore Corporation of Canada (IOC)

Labrador City, Newfoundland and Labrador

Final Report

Wabush 3 – Air Quality Assessment

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SUBMITTED TO

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TABLE OF CONTENTS

Tables

Figures

Appendices

1. INTRODUCTION

This report presents an assessment of the impact of emissions from the operations of Iron Ore Company of Canada (IOC) in Labrador City. The operations include mining activities taking place at the mining areas and all operations at the IOC Plant site. Two emission scenarios, based on 2018 mining operations, were considered for this assessment.

1. Development of the Wabush3 project area (Future Build scenario); and,
2. Mining continues to take place at existing mining pits with additional mining taking place at new work faces (Future No Build).

The operations of the IOC Plant are common to both the scenarios.

The air quality assessment was performed using the CALPUFF air quality dispersion model, based on the Newfoundland & Labrador Department of Environment and Conservation (NLDOEC) Guideline for Plume Dispersion Modelling.

2. METHODS AND DATA

This section provides information on the contaminants considered in this assessment and the respective ambient air quality standards that were selected for comparison. Also detailed are the emission rate development and methodology adopted to complete the air quality modelling component.

2.1 Contaminants and Ambient Air Quality Standards

The contaminants of primary interest emitted from IOC are particulate matter, sulphur dioxide (SO_2), carbon monoxide (CO) and nitrogen dioxide (NO_2).

Airborne particulate matter is often defined in terms of size fractions. Particles less than 40 µm in diameter typically remain suspended in the air for some time, and are referred to as TSP. Suspended particulate matter less than 10 µm in diameter is termed PM_{10}, and particulate matter less than 2.5 µm in diameter is termed $PM_{2.5}$.

Table 2 shows the maximum concentrations over the specified averaging periods that are acceptable in ambient air under Newfoundland and Labrador Regulation 39/04.

Table 2: Ambient Air Quality Standards

Contaminant	Unit of Concentration	Averaging Period	Standard
Total Suspended Particulate (TSP)	µg/m³	24-hour	120.0
	µg/m³	Annual geometric mean	60.0
PM_{10}	µg/m³	24-hour	50.0
$PM_{2.5}$	µg/m³	24-hour	25.0
	µg/m³	24-hour	8.8
SO_2	µg/m³	1-hour	900.0
	µg/m³	3-hour	600.0
	µg/m³	24-hour	300.0
	µg/m³	Annual Arithmetic Mean	60.0
CO	µg/m³	1-hour	35,000.0
	µg/m³	8-hour	15,000.0
NO_2	µg/m³	1-hour	400.0
	µg/m³	24-hour	200.0
	µg/m³	Annual Arithmetic Mean	100.0

2.2 Emissions

Emissions from mining activities at the IOC mine site are generated from: blasting, material handling, crushing of materials, bulldozing, grading of roads, hauling of materials on roads, movement of employee vehicles on the mine access road, and combustion of diesel by the various equipment operating at IOC.

The locations of the sources of emissions from mining activities are shown in Figure 1 for the Future Build scenario and Figure 2 for the Future No Build scenario. It should be noted that the locations of mining activities shown in the figures are representative locations since the location of these sources are subject to change as mining progresses.

This section of the report describes the methodology used to estimate emissions from mining activities at the IOC site, other than blasting, based on predicted mine processing and handling rates for the year 2018.

Blasting is excluded here because it has been addressed in a different manner. The blasts are infrequent events, occurring approximately once per week. They are brief, transient events in which the airborne contaminants pass by a downwind location within the space of a few minutes of the blast occurring. This type of emission source does not lend itself well to dispersion modelling, which is designed primarily for continuous emission sources. As a result, dispersion modelling of blasting was not undertaken. Instead, an assessment of air quality monitoring data, collected downwind of blasts, was performed to compare with NLDOEC Ambient Air Quality Standards. The air quality assessment of blasting emissions can be found in Appendix A of this report.

With respect to emission sources at the IOC Plant site, the methodology and emission rates used in this study are the same as those documented in the 2014 compliance report for the Plant. They are not presented in detail here, with the exception of wind erosion at the tailings area, which was not included in the compliance report.

The following subsections outline the methodology used to estimate emissions from the various sources at the mine as well as the related assumptions.

2.2.1 Material Handling

Fugitive emissions of TSP, PM_{10} and $PM_{2.5}$ were estimated for material handling activities such as loading of haul trucks by shovels, dumping of material from trucks at ore loading pockets (or ore stockpiles) or at waste rock areas, and handling of material by loaders. The fugitive emissions were based on emission factors obtained from the US EPA's AP-42 document, Chapter 13.2.4 "Aggregate Handling and Storage Piles"[1] as follows:

$$E = k * (0.0016) * \frac{(\frac{U}{2.2})^{1.3}}{(\frac{M}{2})^{1.4}} * CE$$

Where:

E = Emission Factor in kg/tonne of Material Handled
k = Particle Size Multiplier, depending on the size fraction of dust
U = Mean Wind Speed (m/s)
M = Material Moisture Content (%)
CE = Control Efficiency (%)

The particulate emission rate is calculated as:

$$Q = E * MH * conversion\ factor$$

Where:

Q = emission Rate (g/s)
E = Emission Factor (kg/tonne)
MH = Material Handled (tonnes/hour)

The particle size multipliers given in US EPA AP-42 Section 13.2.4 were applied in the TSP, PM_{10}, and $PM_{2.5}$ emission estimates. Moisture content of 2% and material handling rates, based on information provided by IOC were used to estimate fugitive dust emissions from the material handling sources. The material handling rates for ore or waste rock loading onto trucks and unloading by the trucks were developed using the number of hours of operation of the shovels and the amount of each type of material (ore or waste rock) extracted annually. The emission estimates for material handling are dependent on wind speed, and hourly CALMET-derived wind speeds at the IOC facility were used for this purpose (see Section 3.1 for a discussion of CALMET). This results in an hourly-varying emission file that was used in the dispersion modelling to account for changing meteorological conditions and, hence, changing magnitudes in fugitive dust emissions. It was assumed that the fugitive dust emissions from the handling sources were not mitigated.

The material handling rates used in the estimation of fugitive dust emissions from the handling sources are shown in Table 2 for the future build scenario and in Table 3 for the future no-build scenario.

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Table 2: Material Handling Processing Rates for Future Build Scenario

Source Description	Source ID [1]	Processing Rate (Mg/h)
Luce shovel 1 ore loading	L_1	2964
Luce shovel 1 waste rock loading	L_1	1186
Luce shovel 2 ore loading	L_2	2075
Luce shovel 2 waste rock loading	L_2	2075
Wabush 3 shovel 1 ore loading	W3_1	2964
Wabush 3 shovel 1 waste rock loading	W3_1	1186
Wabush 3 shovel 2 ore loading	W3_2	2964
Wabush 3 shovel 2 waste rock loading	W3_2	1186
HM shovel 1 ore loading	HM_1	1186
HM shovel 1 waste rock loading	HM_1	2964
HM shovel 2 ore loading	HM_2	1779
HM shovel 2 waste rock loading	HM_2	2371
HS shovel 1 ore loading	HS_1	1186
HS shovel 1 waste rock loading	HS_1	2964
HS shovel 2 ore loading	HS_2	1265
HS shovel 2 waste rock loading	HS_2	2530
Dumping waste rock from Luce shovel 1	WASTE_1	1186
Dumping ore from Luce shovel 1 at stockpile of loading pocket 2 [2]	ORE_1	2964
Dumping waste rock from Luce shovel 2	WASTE_1	2075
Dumping ore from Luce shovel 2 at loading pocket 3	ORE_2	2075
Dumping waste rock from Wabush3 shovel 1	WASTE_2	1186
Dumping ore from Wabush3 shovel 1 at crusher stockpile [3]	ORE_3	2964
Dumping waste rock from Wabush3 shovel 2	WASTE_2	1186
Dumping ore from Wabush3 shovel 2 at crusher stockpile [3]	ORE_3	2964
Dumping waste rock from HM shovel 1	WASTE_5	2964
Dumping ore from HM shovel 1 at loading pocket 1	ORE_4	1186
Dumping waste rock from HM shovel 2	WASTE_1	2371
Dumping ore from HM shovel 2 at stockpile of loading pocket 2 [2]	ORE_1	1779
Dumping waste rock from HS shovel 1	WASTE_3	2964
Dumping ore from HS shovel 1 at stockpile of loading pocket 2 [2]	ORE_1	1186
Dumping waste rock from HS shovel 2	WASTE_4	2530
Dumping ore from HS shovel 2 at stockpile of loading pocket 2 [2]	ORE_1	1265
Front end loader at ore stockpile and loading pocket 2	LOADER1	2100
Front end loader at stockpile and ore crusher	LOADER2	2100

Notes:

[1] This is the source identification used to show the location of the source in Figure 1
[2] The stockpile and loading pocket are assumed to be at the same location.
[3] The stockpile and crusher are assumed to be at the same location.

Table 3: Material handling processing rates for future no-build scenario

Source Description	Source ID [1]	Processing Rate (Mg/h)
Luce shovel 1 ore loading	L_1	2964
Luce shovel 1 waste rock loading	L_1	1186
Luce shovel 2 ore loading	L_2	2371
Luce shovel 2 waste rock loading	L_2	1779
Luce shovel 3 ore loading	L_3	2075
Luce shovel 3 waste rock loading	L_3	2075
HM shovel 1 ore loading	HM_1	1779
HM shovel 1 waste rock loading	HM_1	2371
HM shovel 2 ore loading	HM_2	1482
HM shovel 2 waste rock loading	HM_2	2668
HM shovel 3 ore loading	HM_3	1186
HM shovel 3 waste rock loading	HM_3	2964
HS shovel 1 ore loading	HS_1	1482
HS shovel 1 waste rock loading	HS_1	2668
HS shovel 2 ore loading	HS_2	1265
HS shovel 2 waste rock loading	HS_2	2530
HS shovel 3 ore loading	HS_3	949
HS shovel 3 waste rock loading	HS_3	2846
Dumping waste rock from Luce shovel 1	WASTE_1	1186
Dumping ore from Luce shovel 1 at crusher stockpile [2]	ORE_2	2964
Dumping waste rock from Luce shovel 2	WASTE_1	1779
Dumping ore from Luce shovel 2 at crusher stockpile [2]	ORE_2	2371
Dumping waste rock from Luce shovel 3	WASTE_2	2075
Dumping ore from Luce shovel 3 at crusher stockpile [2]	ORE_2	2075
Dumping waste rock from HM shovel 1	WASTE_5	2371
Dumping ore from HM shovel 1 at loading pocket 1	ORE_3	1779
Dumping waste rock from HM shovel 2	WASTE_1	1428
Dumping ore from HM shovel 2 at loading pocket 2 [3]	ORE_1	2668
Dumping waste rock from HM shovel 3	WASTE_5	2964
Dumping ore from HM shovel 3 at loading pocket 2 [3]	ORE_1	1186
Dumping waste rock from HS shovel 1	WASTE_3	2668
Dumping ore from HS shovel 1 at loading pocket 2	ORE_1	1482
Dumping waste rock from HS shovel 2	WASTE_4	2530
Dumping ore from HS shovel 2 at loading pocket 2	ORE_1	1265
Dumping waste rock from HS shovel 3	WASTE_3	2846

Source Description	Source ID [1]	Processing Rate (Mg/h)
Dumping ore from HS shovel 3 at loading pocket 2 [3]	ORE_1	949
Front end loader at ore stockpile and loading pocket 2	LOADER1	2100
Front end loader at stockpile and ore crusher	LOADER2	2100

Notes:
[1] This is the source identification used to show the location of the source in Figure 2
[2] The stockpile and crusher are assumed to be at the same location.
[3] The stockpile and loading pocket are assumed to be at the same location.

2.2.2 Material Crushing

Fugitive emissions of TSP, PM_{10} and $PM_{2.5}$ from the crushing of rocks at the road maintenance crusher were based on emission factors obtained from the US EPA's AP-42 document, Chapter 11.24 "Metallic Minerals Processing"[2]. The crusher was assumed to be a low moisture primary crusher for the with emission factors of 0.2 kg/Mg for TSP and 0.02 kg/Mg for PM_{10}. Emission factor for $PM_{2.5}$ was obtained by applying a scaling factor of 0.15 on PM_{10} emission factor.

The particulate emission rate is calculated as:

$$Q = E * MH * conversion\ factor$$

Where,

Q = emission Rate (g/s)
E = Emission Factor (kg/tonne)
MH = Material Handled (tonnes/hour)

The crusher processes one million tonnes of rock in a year, in the future build scenario as well as the future no-build scenario. The hourly processing, shown in Table 4, was estimated by conservatively assuming the crusher operates 8 hours a day, 7 days a week. It was also assumed that no emissions controls were applied to the crusher.

Table 4: Road Maintenance Crusher Processing Rate

Source Description	Source ID [1]	Processing Rate (Mg/h)
Road maintenance crusher [2]	CRUSHER2	343

Notes:
[1] This is the source identification used to show the location of the source in Figures 1 and 2
[2] The crusher is assumed to operate 8 hours a day, 7days a week.

2.2.3 Road Dust from Unpaved Roads

Particulate matter emissions from unpaved roads within the IOC facility, due to the movement of haul trucks on haul roads and employee vehicles on the mine access road from the pellet plant to the mine, were estimated using the method described in the US EPA AP-42 chapter 13.2.2 "Unpaved Roads"[3] as follows:

$$E = 281.9\, k * (\frac{s}{12})^{a} * (\frac{W}{3})^{b}$$

Where:

E = Emission Factor (g/VKT);
k, a, and b are empirical constants with values depending on the size of particulate matter, i.e. TSP, PM10 or PM2.5;

s = surface material silt content (%); and
W = mean vehicle weight

The particulate emission rate is calculated as:

$$Q = E * P * D * CE$$

Where:

Q = emission Rate (g/s)
E = Emission Factor (g/VKT)
P = Number of vehicle passes
D = Distance travelled by vehicle (Km)
CE = Control Efficiency (%)

The surface silt content for the unpaved roads was assumed to be 5.8% for ore truck routes, and 4.3% for the mine access road. These values are the mean surface silt content for "taconite mining and processing haul road to/from pit" and "taconite mining and processing service road" as per Table 13.2.2-1 in the US EPA AP-42 chapter 13.2.2, respectively. These values are reasonably consistent with those reported in the same table for Iron and Steel Production and Western Surface Coal Mining, and also consistent with RWDI visual observations during a visit to the site, which indicated the silt loading was likely to be well below 10%. Table 13.2.2-1 of AP-42 does not provide values specifically for iron ore mining.

The hourly traffic passes on the haul roads were determined based on the hourly shovel output of either ore or waste rock and the average payload of each truck. Hourly traffic passes on the mine road were based on information provided by IOC. It was assumed that most of the traffic movements on the mine road took place in three one hour periods in a day. The one hour periods are: 7:00 to 8:00, 16:00 to 17:00 and 19:00 to 20:00.

Particulate matter emissions were estimated by dividing the roads into separate segments. A length of haul road is treated as a separate segment whenever one or more parameters (e.g. number of hourly passes, silt content, etc.) change.

Water is used for dust control on haul roads at the site. The control efficiency for each road section was calculated as per Equation 3-2 of Cowherd et. al.[4] by taking into account the hourly traffic passes, the watering rate of the roads by the water trucks and the average hourly evaporation rate of water as provided in Cowherd et. al.[4]. It was assumed that the water trucks apply water at the same rate on all active sections of haul road. . The mine access road leading from the pellet plant to the mine is subjected to watering, but due to the long length of the road and the high volume of traffic at shift changes, the estimated effectiveness of the watering at those times, calculated using Equation 3-2 of Cowherd et al. was low. Therefore, 0% control efficiency was assumed on the mine access road, from 7:00 to 8:00, and 19:00 to 20:00, and 15% control efficiency was assumed from 16:00 to 17:00 for the purpose of this assessment. Calcium Chloride (CaCl) is applied on the mine access road in spring, summer and fall as a dust control measure. However, due to the lack of information on the quantity and frequency of CaCl application, it was not taken into account for this study. It was assumed that there would be no fugitive dust emissions from the mine access road in the winter months (December to April).

Tables 5 and 6 show the hourly traffic passes, length, and calculated control efficiency for each road segment for the future build and future no-build scenarios, respectively. The location of each road segment is shown in Figure 1 for the future build scenario and Figure 2 for the future no-build scenario.

Table 5: Haul Road Details for the Future Build Scenario

Haul Road [1]	Hourly Passes [2]	Length (m)	Control Efficiency (%)
1	32	973	85%
2	64	1013	69%
3	38	869	82%
4	22	1189	89%
5	32	1162	85%
6	16	876	92%
7	26	1414	88%
8	32	632	85%
9	44	3244	79%
10	20	1505	90%
11	32	506	85%
12	22	894	89%
13	10	753	95%
14	20	447	90%
15	52	354	75%
16	10	4085	95%
17	42	402	80%
18	34	1105	84%
19	32	797	85%
20	18	503	91%
21	30	733	86%
22	20	637	90%

Haul Road [1]	Hourly Passes [2]	Length (m)	Control Efficiency (%)
23	10	1766	95%
24	32	1114	85%
25	22	426	89%
26	10	2327	95%
MINEROAD	820 (from 7:00h to 8:00h)	10200	-
MINEROAD	97 (from 16:00h to 17:00h)	10200	15%
MINEROAD	723 (from 19:00h to 20:00h)	10200	-

Notes:
[1] The location of the haul road segment is shown in Figure 1
[2] The number of passes over specific road segment in a 1-hour period reflects travel in both directions.

Table 6: Haul Road Details for the Future No-Build Scenario

Haul Road [1]	Hourly Passes [2]	Length (m)	Control Efficiency (%)
1	16	571	93%
2	16	2301	93%
3	56	454	76%
4	32	552	87%
5	40	866	83%
6	28	481	88%
7	32	1162	87%
8	24	2427	90%
9	32	933	87%
10	30	136	87%
11	62	181	74%
12	42	426	82%
13	20	2327	92%
14	52	1105	78%
15	30	733	87%
16	20	637	92%
17	10	1766	96%
18	34	447	86%
19	66	354	72%
20	52	402	78%
21	20	503	92%
22	14	4085	94%
23	32	797	87%
24	32	506	87%
25	18	187	92%

Haul Road [1]	Hourly Passes [2]	Length (m)	Control Efficiency (%)
26	40	707	83%
27	22	83	91%
28	32	190	87%
29	10	108	96%
30	14	131	94%
31	24	622	90%
MINEROAD	820 (from 7:00h to 8:00h)	10200	-
MINEROAD	97 (from 16:00h to 17:00h)	10200	15%
MINEROAD	723 (from 19:00h to 20:00h)	10200	-

Notes:
[1] The location of the haul road segment is shown in Figure 2
[2] The number of passes over specific road segment in a 1-hour period reflects travel in both directions.

2.2.4 Wind Erosion of Tailings

Wind erosion of particulate matter from tailings at IOC was determined to take place over 56 dry, un-vegetated hectares. The emissions of wind eroded particulate matter were calculated as per equation 15 of W.G. Nickling et. al[5]. The emission factor is given as:

$$F = 1.59 * 10^{-12} * U^{*2.93}$$

Where:

F = Emission Factor (g/cm² s);
U^* = Friction velocity at tailing surface (cm/s)

This equation is based on two tests of tailings disposal areas in Arizona. Wind erosion of the tailings takes place only when the friction velocity at the surface is above a certain threshold velocity. For this study, the friction velocity was assumed to be 0.2 m/s, which is the average of the threshold velocities for the two tailing sites in W.G. Nickling et. al[5].

The friction velocity at tailing surface can be calculated from Prandtl's equation as follows:

$$U^* = \frac{k * U_{10}}{\ln\left(\frac{z}{z_o}\right)} * conversion\ factors$$

Where:

k Von Karman constant, 0.4;
U_{10} = Velocity at length z. 10 m in this case;
z = 10 m above ground level;
z_o = Roughness length of the tailing surface.

The roughness length of the tailing surface was assumed to be 0.016cm, which is the average roughness length of the two tailing sites in W.G. Nickling et. al[5].

The particulate emission rate is calculated as:

$$Q = F * A * k * conversion\ factors$$

Where,

Q = emission Rate (g/s);
F = Emission Factor (g/cm² s);
A = Area of dry, un-vegetated tailings (56 ha);
k = Particle size multiplier.

The particle size multiplier (to estimate emissions of TSP, PM_{10}, and $PM_{2.5}$) were derived from particle size analysis conducted for the two tailings site study areas in W.G. Nickling et. al[5].

The emission estimates for wind erosion are dependent on hourly CALMET-derived wind speeds at the IOC facility. This results in a variable emission file that was used in the dispersion modelling to account for changing meteorological conditions and, hence, changing magnitudes in fugitive dust emissions. It was assumed that no wind erosion of the tailings took place when there was precipitation or snow cover on the ground.

The tailing area was modeled as a rectangular source with an area equal to 56 ha.

2.2.5 Grading

Fugitive emissions generated from road grading operations were estimated based on emission factors obtained from Table 11.9.2 of the US EPA's AP-42 document, Chapter 11.9 "Western Surface Coal Mining"[##], as follows:

$$EF\ (for\ TSP) = 0.0034S^{2.5}$$
$$EF\ (for\ PM_{10}) = 0.6 * 0.0056S^{2}$$
$$EF\ (for\ PM_{2.5}) = 0.031 * EF\ (for\ TSP)$$

Where:

EF = Emission Factor (kg/vkt);
S = Mean vehicle speed (km/h)

The particulate emission rate is calculated as:

$$Q = EF * S * h * CE * conversion\ factors$$

Where,

Q = emission Rate (g/s);
EF = Emission Factor (g/vkt);
S = Mean vehicle speed (km/h);
CE = Control efficiency (%);
h = Number of hours of operation in a year of each grader (h).

The mean speed of each grader was assumed to be 10 km/h and the annual hours of operation of each grader, 4485, was provided by IOC. It was assumed that watering on the haul roads would be maintained during grading operations, and the control efficiency was assumed to be the weighted average of the haul road watering control efficiencies shown previously in Tables 5 and 6.

The fugitive emissions of grading operations were equally distributed over the entire haul road network.

Although the emission factor was developed for coal mining, it remains reasonably applicable, since grading at a coal mine is analogous to grading at IOC. It has been recommended by the US EPA for other applications besides coal mining (e.g., in Chapter 13.2.3 of AP-42, "Heavy Construction Operations" [6]).

2.2.6 Bulldozing

At the IOC mine bulldozing operations take place at the waste rock dumps and at the shovel locations. Fugitive emissions generated from the bulldozing of waste rock and ore IOC were estimated based on emission factors for bulldozing of overburden, obtained from Table 11.9.2 of the US EPA's AP-42 document, Chapter 11.9 "Western Surface Coal Mining"[7] as follows:

$$EF\ (for\ TSP) = 2.6(s)^{1.2}/(M)^{1.3}$$
$$EF\ (for\ PM_{10}) = 0.75 * 0.45(s)^{1.5}/(M)^{1.4}$$
$$EF\ (for\ PM_{2.5}) = 0.105 * EF\ (for\ TSP)$$

Where:

EF = Emission Factor (kg/h);
s = Silt content (%)
M = Moisture content (%)

The particulate emission rate is calculated as:

$$Q = EF * conversion\ factors$$

Where,

Q = emission Rate (g/s);
EF = Emission Factor (kg/h);

The average silt content was assumed to be approximately the same as that occurring on truck haul roads within the site, which was estimated to be 5.8% as per Table 13.2.2-1 in Chapter 13.2.2 "Unpaved Roads" of US EPA's AP-42[3]. The moisture content of waste rocks and ore was estimated by IOC to be 2%.

Similar to that for grading, the emission factor for bulldozing was developed for coal mining, but is applicable here since bulldozing of overburden at a coal mine is analogous to bulldozing at IOC.

The locations of bulldozing activities are shown in Figure 1 and Figure 2 for the future build and future no-build scenarios, respectively.

2.2.7 Baghouse

Particulate matter emissions from the ore crusher baghouse were estimated using the baghouse manufacturer's specification of exhaust flow rate, 100,000 cfm, and the specified in-stack concentration of TSP, 25 mg/m³.

The ratios of TSP to PM_{10} and $PM_{2.5}$ emission rates were assumed to be the same as the ratios of the emissions rates of TSP, PM_{10} and $PM_{2.5}$ at the ore crusher stack at the IOC plant site.

The annual processing rate of the ore crusher was calculated as the sum of the annual processing rates of all the shovels supplying ore to the crusher. Table 7 shows the annual processing rate of the crusher for the future build and future no-build scenarios.

Table 7: Ore Crusher Processing Rate

Processing rate (Mg/y)	Source ID [1]	Scenario
20,000,000 [2]	BAGHOUSE	Future Build
25,000,000 [3]	BAGHOUSE	Future No-Build

Notes:
[1] This is the source identification used to show the location of the source in Figures 1 and 2
[2] Assumed to be the total amount of ore extracted by Wabush3 Shovel 1 and Shovel 2 in a year.
[3] Assumed to be the total amount of ore extracted by Luce Shovel 1, Shovel 2 and Shovel 3 in a year.

2.2.8 Tailpipe Emissions

Emissions of products of combustion were calculated for diesel fuelled non-road equipment such as bulldozers, haul trucks, graders, loaders, shovels, and drills using the methodology in US EPA's 2004 report number NR-009c "Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression Ignition". The calculations are based on equipment horsepower, load factor, model year, and fraction of useful life expended at the start of the year 2018. For each piece of equipment, IOC provided the anticipated year of first use (assumed to correspond to the model year), the expected use (in hours) by the horizon year of 2018, and the expected life span (in hours), the fraction of useful life was calculated from these data. Please refer to Appendix B for further details on the diesel equipment.

The load factor was assumed to be the same as the operation efficiency provided by IOC for each type of off-road diesel equipment. The horse power was obtained from the equipment manufacturer's data sheets. It was also assumed that all the equipment comply with the phase in periods for emission standards[1]

2.2.9 Summary of Emission Estimates

Annual emission rates for all the mine sources for the Future Build and Future Build scenarios are summarized in Table 8 and Table 9, respectively. The utilization rates of equipment and annual hours of operation were taken into consideration when developing the annual emission rates.

It can be seen that the emission of combustion gases is higher from the Future No Build scenario than from the Future Build scenario. This is a result of an increase in the number of diesel powered haul trucks in the Future No Build scenario. At the same time there is a decrease in the emissions of Future No Build scenario particulate matter (TSP, PM_{10} and $PM_{2.5}$) when compared to the Future Build scenario since the total length of haul roads, which is the major source of fugitive emissions, is approximately 15% less.

[1] http://www.dieselnet.com/standards/us/nonroad.php#app

Table 8: Future Build Annual Emission Rates (by source)

Emission Source	Annual Emission Rate (Mg/year) [1]					
	TSP	PM_{10}	$PM_{2.5}$	NO_X	CO	SO_2
Bulk Material Handling and Processing Emissions						
Luce shovel 1 ore loading	27.82	13.16	1.99	N/A	N/A	N/A
Luce shovel 1 waste rock loading	11.13	5.27	0.80	N/A	N/A	N/A
Luce shovel 2 ore loading	19.48	9.21	1.39	N/A	N/A	N/A
Luce shovel 2 waste rock loading	19.48	9.21	1.39	N/A	N/A	N/A
Wabush 3 shovel 1 ore loading	27.82	13.16	1.99	N/A	N/A	N/A
Wabush 3 shovel 1 waste rock loading	11.13	5.27	0.80	N/A	N/A	N/A
Wabush 3 shovel 2 ore loading	27.82	13.16	1.99	N/A	N/A	N/A
Wabush 3 shovel 2 waste rock loading	11.13	5.27	0.80	N/A	N/A	N/A
HM shovel 1 ore loading	11.13	5.27	0.80	N/A	N/A	N/A
HM shovel 1 waste rock loading	27.82	13.16	1.99	N/A	N/A	N/A
HM shovel 2 ore loading	16.70	7.90	1.20	N/A	N/A	N/A
HM shovel 2 waste rock loading	22.25	10.53	1.59	N/A	N/A	N/A
HS shovel 1 ore loading	11.13	5.27	0.80	N/A	N/A	N/A
HS shovel 1 waste rock loading	27.82	13.16	1.99	N/A	N/A	N/A
HS shovel 2 ore loading	11.13	5.27	0.80	N/A	N/A	N/A
HS shovel 2 waste rock loading	22.27	10.53	1.59	N/A	N/A	N/A
Dumping waste rock from Luce shovel 1	15.96	7.55	1.14	N/A	N/A	N/A
Dumping ore from Luce shovel 1 at stockpile of loading pocket 2	39.89	18.87	2.86	N/A	N/A	N/A
Dumping waste rock from Luce shovel 2	27.92	13.21	2.00	N/A	N/A	N/A
Dumping ore from Luce shovel 2 at loading pocket 3	27.92	13.21	2.00	N/A	N/A	N/A
Dumping waste rock from Wabush3 shovel 1	15.96	7.55	1.14	N/A	N/A	N/A
Dumping ore from Wabush3 shovel 1 at crusher stockpile	39.89	18.87	2.86	N/A	N/A	N/A
Dumping waste rock from Wabush3 shovel 2	15.96	7.55	1.14	N/A	N/A	N/A
Dumping ore from Wabush3 shovel 2 at crusher stockpile	39.89	18.87	2.86	N/A	N/A	N/A
Dumping waste rock from HM shovel 1	39.89	18.87	2.86	N/A	N/A	N/A
Dumping ore from HM shovel 1 at loading pocket 1	15.96	7.55	1.14	N/A	N/A	N/A
Dumping waste rock from HM shovel 2	31.91	15.09	2.29	N/A	N/A	N/A
Dumping ore from HM shovel 2 at stockpile of loading pocket 2	23.94	11.32	1.71	N/A	N/A	N/A
Dumping waste rock from HS shovel 1	39.89	18.87	2.86	N/A	N/A	N/A

Emission Source	Annual Emission Rate (Mg/year) [1]					
	TSP	PM_{10}	$PM_{2.5}$	NO_X	CO	SO_2
Dumping ore from HS shovel 1 at stockpile of loading pocket 2	15.96	7.55	1.14	N/A	N/A	N/A
Dumping waste rock from HS shovel 2	34.05	16.10	2.44	N/A	N/A	N/A
Dumping ore from HS shovel 2 at stockpile of loading pocket 2	17.02	8.05	1.22	N/A	N/A	N/A
Front end loader at ore stockpile and loading pocket 2	13.93	6.59	1.00	N/A	N/A	N/A
Front end loader at stockpile and ore crusher	13.93	6.59	1.00	N/A	N/A	N/A
Crusher for road maintenance	200.00	20.00	3.00	N/A	N/A	N/A
Sub Total	**975.92**	**386.99**	**58.57**	**N/A**	**N/A**	**N/A**
Fugitive Road Dust Emissions						
Haul Roads	4000.66	1058.95	105.89	N/A	N/A	N/A
Mine Road	1943.25	484.47	48.44	N/A	N/A	N/A
Sub Total	5943.92	1543.43	154.33	**N/A**	**N/A**	**N/A**
Tail Pipe Emissions						
Haul Trucks	83.44	83.44	80.93	1783.52	327.07	2.07
Graders	2.47	2.47	2.39	23.43	11.17	0.05
Rubber Tired Dozers	1.95	1.95	1.89	20.82	14.40	0.04
Tracked Dozers	2.15	2.15	2.08	46.58	12.89	0.08
Shovels	0.13	0.13	0.13	10.39	0.34	0.02
Loaders	1.48	1.48	1.44	25.28	6.11	0.02
Drills	0.94	0.94	0.91	36.97	1.27	0.05
Sub Total	92.55	92.55	89.78	1947.00	373.24	2.33
Wind Erosion of Tailings						
Wind Erosion of Tailings	284.39	225.09	130.71	N/A	N/A	N/A
Bulldozing						
Bulldozing	480.39	98.59	50.44	N/A	N/A	N/A
Grading						
Grading	52.95	16.55	1.64	N/A	N/A	N/A
Crusher Baghouse						
Crusher Baghouse	14.16	4.11	1.13	N/A	N/A	N/A
Total	**7844.26**	**2367.29**	**486.61**	**1947.00**	**373.24**	**2.33**

Notes:

[1] The annual emission rate is calculated based on equipment utilization percentage or the annual hours of operation of a process.

Table 9: Future No Build Annual Emission Rates (by source)

Emission Source	Annual Emission Rate (Mg/year) [1]					
	TSP	PM_{10}	$PM_{2.5}$	NO_X	CO	SO_2
Bulk Material Handling and Processing Emissions						
Luce shovel 1 ore extraction	27.82	13.16	1.99	N/A	N/A	N/A
Luce shovel 1 waste rock extraction	11.13	5.27	0.80	N/A	N/A	N/A
Luce shovel 2 ore extraction	22.25	10.53	1.59	N/A	N/A	N/A
Luce shovel 2 waste rock extraction	16.70	7.90	1.20	N/A	N/A	N/A
Luce shovel 3 ore extraction	19.48	9.21	1.39	N/A	N/A	N/A
Luce shovel 3 waste rock extraction	19.48	9.21	1.39	N/A	N/A	N/A
HM shovel 1 ore extraction	16.70	7.90	1.20	N/A	N/A	N/A
HM shovel 1 waste rock extraction	22.25	10.53	1.59	N/A	N/A	N/A
HM shovel 2 ore extraction	13.91	6.58	1.00	N/A	N/A	N/A
HM shovel 2 waste rock extraction	25.04	11.84	1.79	N/A	N/A	N/A
HM shovel 3 ore extraction	11.13	5.27	0.80	N/A	N/A	N/A
HM shovel 3 waste rock extraction	27.82	13.16	1.99	N/A	N/A	N/A
HS shovel 1 ore extraction	13.91	6.58	1.00	N/A	N/A	N/A
HS shovel 1 waste rock extraction	25.04	11.84	1.79	N/A	N/A	N/A
HS shovel 2 ore extraction	11.13	5.27	0.80	N/A	N/A	N/A
HS shovel 2 waste rock extraction	22.27	10.53	1.59	N/A	N/A	N/A
HS shovel 3 ore extraction	8.35	3.95	0.60	N/A	N/A	N/A
HS shovel 3 waste rock extraction	25.05	11.85	1.79	N/A	N/A	N/A
Dumping waste rock from Luce shovel 1 by mine trucks	15.96	7.55	1.14	N/A	N/A	N/A
Dumping ore from Luce shovel 1 at crusher stockpile by mine trucks	39.89	18.87	2.86	N/A	N/A	N/A
Dumping waste rock from Luce shovel 2 by mine trucks	23.94	11.32	1.71	N/A	N/A	N/A
Dumping ore from Luce shovel 2 at crusher stockpile by mine trucks	31.91	15.09	2.29	N/A	N/A	N/A
Dumping waste rock from Luce shovel 3 by mine trucks	27.92	13.21	2.00	N/A	N/A	N/A
Dumping ore from Luce shovel 3 at crusher stockpile by mine trucks	27.92	13.21	2.00	N/A	N/A	N/A
Dumping waste rock from HM shovel 1 by mine trucks	31.91	15.09	2.29	N/A	N/A	N/A
Dumping ore from HM shovel 1 at loading pocket 1 by mine trucks	23.94	11.32	1.71	N/A	N/A	N/A
Dumping waste rock from HM shovel 2 by mine trucks	19.22	9.09	1.38	N/A	N/A	N/A
Dumping ore from HM shovel 2 at loading pocket 2 by mine trucks	35.90	16.98	2.57	N/A	N/A	N/A

Emission Source	Annual Emission Rate (Mg/year) [1]					
	TSP	PM_{10}	$PM_{2.5}$	NO_X	CO	SO_2
Dumping waste rock from HM shovel 3 by mine trucks	39.89	18.87	2.86	N/A	N/A	N/A
Dumping ore from HM shovel 3 at loading pocket 2 by mine trucks	15.96	7.55	1.14	N/A	N/A	N/A
Dumping waste rock from HS shovel 1 by mine trucks	35.90	16.98	2.57	N/A	N/A	N/A
Dumping ore from HS shovel 1 at loading pocket 2 by mine trucks	19.94	9.43	1.43	N/A	N/A	N/A
Dumping waste rock from HS shovel 2 by mine trucks	34.05	16.10	2.44	N/A	N/A	N/A
Dumping ore from HS shovel 2 at loading pocket 2 by mine trucks	17.02	8.05	1.22	N/A	N/A	N/A
Dumping waste rock from HS shovel 3 by mine trucks	38.30	18.11	2.74	N/A	N/A	N/A
Dumping ore from HS shovel 3 at loading pocket 2 by mine trucks	12.77	6.04	0.91	N/A	N/A	N/A
Front end loader at ore stockpile and loading pocket 2	13.93	6.59	1.00	N/A	N/A	N/A
Front end loader at stockpile and ore crusher	13.93	6.59	1.00	N/A	N/A	N/A
Crusher for road maintenance	200.00	20.00	3.00	N/A	N/A	N/A
Sub Total	**1059.66**	**426.60**	**64.57**	**N/A**	**N/A**	**N/A**
Fugitive Road Dust Emissions						
Haul Roads	3085.56	821.72	81.67	N/A	N/A	N/A
Mine Road	1943.25	484.47	48.44	N/A	N/A	N/A
Sub Total	**5028.82**	**1306.20**	**130.12**	**N/A**	**N/A**	**N/A**
Tail Pipe Emissions						
Haul Trucks	90.79	90.79	88.07	1986.82	354.88	2.32
Graders	2.47	2.47	2.39	23.43	11.17	0.05
Rubber Tired Dozers	1.95	1.95	1.89	20.82	14.40	0.04
Tracked Dozers	2.15	2.15	2.08	46.58	12.89	0.08
Shovels	0.13	0.13	0.13	10.39	0.34	0.02
Loaders	1.48	1.48	1.44	25.28	6.11	0.02
Drills	0.94	0.94	0.91	36.97	1.27	0.05
Sub Total	**99.90**	**99.90**	**96.91**	**2150.29**	**401.05**	**2.59**
Wind Erosion of Tailings						
Wind Erosion of Tailings	284.39	225.09	130.71	N/A	N/A	N/A
Bulldozing						
Bulldozing	480.39	98.59	50.44	N/A	N/A	N/A

Emission Source	Annual Emission Rate (Mg/year) [1]					
	TSP	PM_{10}	$PM_{2.5}$	NO_X	CO	SO_2
Grading						
Grading	52.95	16.55	1.64	N/A	N/A	N/A
Crusher Baghouse						
Crusher Baghouse	17.70	5.13	1.42	N/A	N/A	N/A
Total	**7028.58**	**2178.05**	**475.81**	**2150.29**	**401.05**	**2.59**

Notes:
[1] The annual emission rate is calculated based on equipment utilization percentage or the annual hours of operation of a process.

3. DISPERSION MODELLING

Dispersion modelling was conducted using the CALPUFF dispersion model, following the *Guideline for Plume Dispersion Modelling in Newfoundland and Labrador (GD-PPD-019.1)*. All aspects of the dispersion model set-up, including meteorological data (CALMET), study domain, land use data, terrain data, particle density, receptor grid and various other model assumptions were established in close consultation with NLDOEC staff. The main components of the dispersion modeling are discussed below.

3.1 CALMET

Meteorological information is required by the CALPUFF air quality simulation model to provide the transport and dispersion characteristics for the study area. Meteorological characteristics vary with time (*e.g.,* season and time of day), and location (*e.g.,* height, terrain and land use). The CALMET meteorological pre-processing program was used to provide representative temporally and spatially varying meteorological parameters for the CALPUFF model.

3.1.1 RUC Data

The CALMET model requires surface meteorological information as well as profiles of wind and temperature called upper air data. The closest upper air station is Sept-Iles which is about 300 km away from the site and is therefore inadequate. Instead, the upper air and surface meteorological data produced by a mesocale meteorological model called RUC (Rapid Update Cycle) were used for this assessment as an initial guess field (Scire et al.[8]). When included in this way, the prognostic module in CALMET adjusts the initial guess field for kinematic effects of terrain, slope flows and terrain blocking effects using the finer scale CALMET terrain data to produce a modified first guess wind field. The RUC outputs were obtained from TRC with a 20 km grid resolution. This dataset is based on the year 2007-2010. The RUC outputs were processed for input to CALMET using a pre-processor. The RUC data locations (i.e., RUC grid cell centroids) in the vicinity of Labrador City are shown in Figure 3. The surface meteorological data from Wabush Airport was used along with RUC data during the preparation of CALMET output.

3.1.2 Study Period and Model Domain

The modelling for this study was based on four full years of meteorological information covering the period from January 1, 2007 to December 31, 2010. Where an on-site monitoring station was not available the NLDOEC requires a minimum of three years of meteorological data to be used; thus using four years exceeds this. The CALMET study domain adopted for this assessment includes the communities of Labrador City and Wabush near the center of the domain. The domain covers an area of 750 km^2. The UTM (NAD 83) coordinates of the four corners of the domain are provided in Table 10. Figure 3 shows the CALMET domain as well as the terrain (elevation contours).

Table 10: CALMET Domain Coordinates (UTM Zone 19; NAD 83)

Domain Extent	Easting (km)	Northing (km)
Southwest	629.000	5857.100
Northwest	629.000	5887.100
Southeast	654.000	5857.100
Northeast	654.000	5887.100

A horizontal grid spacing of 250 m was adopted for the CALMET modelling, corresponding to a 100 row by a 120-column resolution. With this grid spacing, it was possible to maximize run time and file size efficiencies while still capturing the effect of major terrain features on wind flow patterns.

The terrain information for each 250 m by 250 m grid cell was based on terrain contour data provided by IOC. Terrain data for areas within the CALMET domain not covered by the terrain contours provided by IOC, were based on GeoBase® digital elevation model data files (1:50,000 scale).

To simulate pollutant transport and dispersion accurately, it is important to simulate the vertical profiles of wind speed, temperature, turbulence intensity, and wind direction within the atmospheric boundary layer (i.e., within approximately 2000 m above the Earth's surface). In an effort to limit the size of the CALMET output files and still capture this vertical structure, eight vertical layers were selected. Within CALMET, a vertical layer is defined as the midpoint between two layers or faces (i.e., nine faces = eight layers, with the lowest face always being ground level or zero). The vertical faces used in this study are: 0, 20, 40, 80, 160, 320, 600, 1400, and 2600 m.

3.1.3 Land Use Data

Land use data used for the IOC CALPUFF model were determined based on the "POSTEL" (POSTEL, 2009) land use data set. The modeling domain is characterized by:

- Mixed forest (54.8 %);
- Water (18.1%);
- Shrub land (10.7 %);
- Coniferous forest (8.7 %);
- Barren land (7.0%).
- Other (built-up areas (0.4%)
- deciduous forest (0.3%); and

Figure 4 depicts the land use at 250 m resolution for the study area.

To take advantage of recent studies in the northern regions (e.g., Brook et al.[9], Zhang et. al.[10] and [11]), CALMET was set up using five “seasons”. Winter was defined as two seasons: one associated with frozen, snow-covered water bodies, and the other associated with open water. Gridded fields were produced for terrain and land use (based on the USGS LU/LC - 52 category system), as well as seasonally specific parameters of surface roughness (Z_0), leaf area index, albedo, Bowen ratio, soil heat flux, and anthropogenic heat flux.

Table 11 indicates the temporal definition of each “season”, while Tables 12a and 12b gives the specific parameters used for each land-use type for the five seasons. Anthropogenic heat flux was excluded from Tables 12a and 12b, since all values were set to zero given the low population density.

3.1.4 Summary of CALMET Model Results

Since the meteorological data were compiled from various sources, CALMET predicts meteorological conditions based on the combination of the sources of meteorological observations. Predictions for wind conditions at Wabush Airport (Figure 5) showed similar wind patterns to those observed at the same location (Figure 6). Figure 7 shows the wind rose predicted by the model for a location at the center of the mine.

CALMET output of Pasquill-Gifford (PG) stability classes were examined by frequency of stability class and hour of day. The PG stability class scheme represents six levels of turbulence that can occur in the atmosphere. PG classes A, B and C are referred to as “unstable” and represent day-time periods when atmospheric turbulence is enhanced due to solar heating. PG classes E and F are referred to as “stable” and represent night-time periods when turbulence is suppressed due to surface cooling. PG class D (referred to as neutral) represents day- or night-time periods that are either overcast or characterized by high wind speed, mechanically-dominated conditions. Figure 8 shows the PG stability class frequency distribution as predicted by CALMET at the IOC plant facility. As expected, stability classes A, B and C are limited to day-time periods, and classes E and F occur mainly during nighttime periods. PG classes D and F are the most frequently occurring classes.

A box plot of mixing heights is given in Figure 9. As expected, mixing heights are greater during the day (i.e., those associated with PG classes A, B and C) and lower during the night (i.e., those associated with PG classes E and F).

Table 11: Definition of CALMET "Seasons"

Season	Winter 1	Spring	Summer	Fall	Winter 2
Description	Snow Cover (Water Frozen)	Partial Vegetation	Lush Vegetation	Prior to Snow Cover	No Snow Cover (Open Water)
Julian Day	305 to 120	121 to 151	152 to 212	213 to 273	274 to 304
Month	November to April	May	June to July	August to September	October

Table 12a: Season-specific Land Use Parameters (1)

Land use	Surface Roughness (Z_0) (m)				Albedo (Fraction)				Bowen Ratio			
	Winter 1 & 2	Spring	Summer	Fall	Winter 1 & 2	Spring	Summer	Fall	Winter 1 & 2	Spring	Summer	Fall
Deciduous	0.5/ 0.6	1.00	1.3	1.3	0.5 /0.017	0.16	0.16	0.16	0.5 / 1.0	0.7	0.3	1.0
Coniferous	1.3	1.3	1.3	1.3	0.35 /0.12	0.12	0.12	0.12	0.5 / 0.8	0.7	0.3	0.8
Mixed	0.9/ 0.95	1.15	1.3	1.3	0.42 /0.14	0.14	0.14	0.14	0.5 / 0.9	0.7	0.3	0.9
Barren land	0.05/ 0.05	0.05	0.05	0.05	0.2/0.6	0.2	0.2	0.2	1.5/0.5	1.5	1.5	1.5
Built-up	0.5/0.5	0.52	0.54	0.54	0.18/ 0.45	0.16	0.16	0.16	1.0/0.5	0.8	0.8	1.0
Shrubland	0.3/0.15	0.3	0.3	0.3	0.18/0.5	0.18	0.18	0.18	1.5/0.5	1.0	1.0	1.5
Water	0.002 /0.001	0.001	0.001	0.001	0.7 / 0.1	0.10	0.10	0.10	0.5 / 0.1	0.1	0.1	0.1

Table 12b: Season-specific Land Use Parameters (2)

Land use	Soil Heat Flux (Fraction)				Leaf Area Index			
	Winter 1 & 2	Spring	Summer	Fall	Winter 1 & 2	Spring	Summer	Fall
Deciduous	0.15	0.15	0.15	0.15	0.0 / 0.1	0.8	3.4	1.9
Coniferous	0.15	0.15	0.15	0.15	5.0	5.0	5.0	5.0
Mixed	0.15	0.15	0.15	0.15	2.3	3.3	4.5	3.5
Barren land	0.15/0.15	0.15	0.15	0.15	0.0/0.0	0.0	0.0	0.0
Built-up	0.25/0.15	0.25	0.25	0.25	0.1/0.0	0.2	0.3	0.2
Shrubland	0.15/0.15	0.15	0.15	0.15	0.0/0.0	0.0	0.0	0.0
Water	0.15 / 1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0

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3.2 CALPUFF Model

The CALPUFF dispersion model was used with the three-dimensional CALMET meteorological field to predict the maximum expected pollutant concentrations due to emissions from IOC operations. CALPUFF (Scire et al.[12]) is a multi-layer, multi-species, non-steady-state puff dispersion model that can simulate the effects of time and space-varying meteorological conditions on pollutant transport, transformation, and deposition.

3.2.1 Model Set-up

The CALPUFF dispersion model was used with the resulting three-dimensional CALMET meteorological field to predict the maximum expected pollutant concentrations due to emissions from IOC operations.

The CALPUFF computational grid domain was set at 20 km by 24 km, which is completely within the CALMET model domain boundary and encompasses the area where noticeable air quality effects from the IOC operations can to occur.

3.2.2 CALPUFF Model Switches

In general, the diagnostic model options were chosen in accordance with the *Guidelines for Plume Dispersion Modelling*. Unless there was a specific reason to the contrary, model options outlined in the *Guidelines for Plume Dispersion Modelling* and default model options were used. Where a model switch differed from the guideline, permission was granted from the NLDOEC to do so. The model switches used are presented in Table 13.

Table 13: CALPUFF Model Switch Settings

Parameter	Default	Project	Comments
MGAUSS	1	1	Gaussian distribution used in near field
MCTADJ	3	3	Partial plume path terrain adjustment
MCTSG	0	0	Scale-scale complex terrain not modelled
MSLUG	0	0	Near-field puffs not modelled as elongated
MTRANS	1	1	Transitional plume rise modelled
MTIP	1	1	Stack tip downwash used
MBDW	1	2	PRIME method building downwash used
MSHEAR	0	0	Vertical wind shear modelled
MSPLIT	0	1	Puffs are split
MCHEM [1]	1	3	Chemical transformation modelled
MAQCHEM	0	0	Aqueous phase transformation not modelled
MWET	1	1	Wet removal modelled
MDRY	1	1	Dry deposition modelled
MDISP	3	2	Near-field dispersion coefficients internally calculated from sigma-v, sigma-w using micrometeorological variables

Parameter	Default	Project	Comments
MTURBVW	3	3	Use both σ_v and σ_w from PROFILE.DAT to compute σ_y and σ_z (n/a)
MDISP2	3	2	This variable is not used for MDISP = 2
MROUGH	0	0	PG σ_y and σ_z not adjusted for roughness
MPARTL	1	1	No partial plume penetration of elevated inversion
MTINV	0	0	Strength of temperature inversion computed from default gradients
MPDF	0	1	PDF used for dispersion under convective conditions as recommended for MDISP = 2
MSGTIBL	0	0	Sub-grid TIBL module not used for shoreline
MBCON	0	0	Boundary concentration conditions not modelled
MFOG	0	0	Do not configure for FOG model output
MREG	1	0	Do not test options specified to see if they conform to regulatory values

Notes:

[1] To save processing time, chemical transformations were not modelled in CALPUFF when sources did not emit NOx or SO_2. Therefore, MCHEM was set to 3 when modelling sources that emitted NOx and SO_2 and set to zero for sources that did not emit NOx and SO_2 (e.g. PM only).

3.2.3 Receptor Locations

As can be seen in Figure 10, a Cartesian grid of discrete receptors contained within the CALPUFF model boundaries was applied with the following receptor spacing:

- 100-m spacing from 500 m (from the center of IOC plant site operations) out to 1000 m;
- 200-m spacing from 1000 m out to 2000 m;
- 50-m spacing within residential areas that are located within 1000 m of the permitted IOC Plant administrative boundary;
- 100-m spacing within residential areas that are located beyond 1000 m but within 2000 m of the IOC Plant administrative boundary;
- 50-m spacing over recreational areas around Dumbell Lake;
- 200-m spacing over the mining area and extending out to 2 km beyond area of mining activities; and,
- 500-m everywhere else.

This receptor grid was approved by the NLDOEC. There were no receptors placed within the approved IOC Plant administrative boundary as areas within this boundary are not a concern from an environmental compliance perspective. An administrative boundary around the mining operations has not been defined at this point in time and, consequently, receptors were included within the mining area.

3.2.4 Meteorology

The CALMET diagnostic wind field module was used to provide representative wind, temperature and turbulence fields (see Section 3.1).

3.2.5 Terrain Coefficients

When an elevated plume of emissions (e.g., from the pellet plant stacks) approaches a hill, ridge or mountain, it has the potential to move closer to the local ground surface. The plume path coefficient (PPC) method can be used to account for this potential decrease in plume height above the ground. A PPC of 1.0 assumes that the plume trajectory is parallel to the terrain features. Lott (1984) recommends PPC values of 0.8, 0.7, 0.6, 0.5, 0.4, and 0.3 for PG stability categories A, B, C, D, E and F, respectively. The default CALPUFF values are 0.5, 0.5, 0.5, 0.5, 0.35, and 0.35 for PG stability categories A, B, C, D, E and F, respectively. These default values were applied for this assessment.

3.2.6 Building Downwash

Point sources at the IOC Plant were subject to building downwash. Please refer to the 2014 compliance report for details on building downwash.

4. DISPERSION MODELLING RESULTS

4.1 Model Outputs

Dispersion model results are presented as concentration contour plots for the Future Build scenario (Figures 11 to 26) and for the Future No Build scenario (Figures 27 to 42). High resolution contour plots covering the downhill and cross-country ski recreation areas are provided for selected contaminants in the Future Build scenario (Figures 43 to 45) to enable closer examination of potential future impacts in that area.

As discussed previously in Section 2.2, the contour plots show the impact of emissions from daily mining operations and do not include the impact of blasts, which occur approximately once per week. Emissions from blasting were assessed separately, as described in Appendix A.

The following section provides a general interpretation of the contour plots, with particular attention paid to the recreation areas, which are relatively close to the proposed mining operations. Predicted impacts within the built-up area of Labrador City can be seen in the figures but are not discussed in detail here. They are dominated by emissions from the IOC Plant operations, which are much closer to the town site than the mining operations. The impacts there are not significantly affected by the proposed Wabush 3 project. More information on the impacts from the Plant operations can be found in the 2014 compliance report.

4.2 Interpretation of Results

4.2.1 Particulate Matter (TSP, PM_{10} and $PM_{2.5}$)

Levels of airborne particulate matter in the downhill and cross-country ski recreation areas are generally higher in the Future Build scenario than in the Future No-Build scenario. Long-term exposure levels (i.e., annual average concentrations) remain within the applicable standards (NLDOEC has annual average standards for TSP and $PM_{2.5}$). Maximum short-term exposure levels (24-hour concentrations) exceed their applicable standards under worst-case meteorological conditions over the upper portion of the downhill ski trails and some sections of cross-country ski trail north of Dumbell Lake. In the case of TSP, maximum 24-hour concentrations exceed the standard south of Dumbell Lake as well, due to emissions from the IOC Plant site in both the Build and No-Build scenario.

4.2.2 Combustion Gases (NO_2, SO_2 and CO)

Predicted concentrations of SO_2 and CO for all averaging periods are below their respective NLDOEC standards at all locations outside the Plant administrative boundary for both the Future Build and Future No Build scenarios. Predicted maximum short-term concentrations of NO_2 (1-hr and 24-hr averages) exceed the applicable standards under worst-case meteorological conditions at locations in close proximity to mining operations, but are within the standards throughout the recreation area in both scenarios.

5. CONCLUSIONS

The impacts of emissions from mining and processing plant operations at IOC, excluding emissions from blasting, were assessed using the CALPUFF dispersion modelling system and the model configuration was developed in close consultation with NLDOEC. The following points summarize the findings:

- The proposed Wabush 3 project has no significant impact on contaminant levels in populated areas of Labrador, due to the large separation distance. Contaminant levels there are dominated by emissions from IOC Plant site and are virtually unchanged between the Future Build and Future No-Build scenarios.

- The proposed Wabush 3 project results in higher levels of contaminants in the downhill and cross-country ski recreation areas near Dumbell Lake than without the project. The levels remain within the applicable standards throughout the recreation area, with the exception of maximum short-term levels of particulate matter (maximum 24-hr concentrations of TSP, PM_{10} and $PM_{2.5}$ under worst-case meteorological conditions).

Emissions from blasting were assessed using data from a blast monitoring program that was conducted by IOC. The following points summarize the findings from that assessment:

- The 1200m safety clearance zone that IOC adopts during blasts adequately addresses short-term pollutant levels. Concentrations of relevant contaminants are estimated to remain below NLDOEC 1-hour standards beyond this distance.

- The principal exception is hydrogen sulphide (H_2S). During the worst-case blast, the standard was estimated to be exceeded to a distance of 2700m from the blast. However, blasts generally occur only once per week and,are expected to occur only approximately twice per month in the Wabush 3 mining area. Also, the monitoring data indicated that most events had measured H_2S levels that were much lower than those of the worst-case event. Taking these factors into consideration, the potential for 1-hr H2S levels to be exceeded outside the 1200m safety clearance zone in the recreation areas is considered to be low.

- Blasts also contribute along with other emission sources to 24-hour average concentrations of some contaminants. The data indicate, however, that the contribution is small compared to that of other sources and generally not significant.

6. REFERENCES

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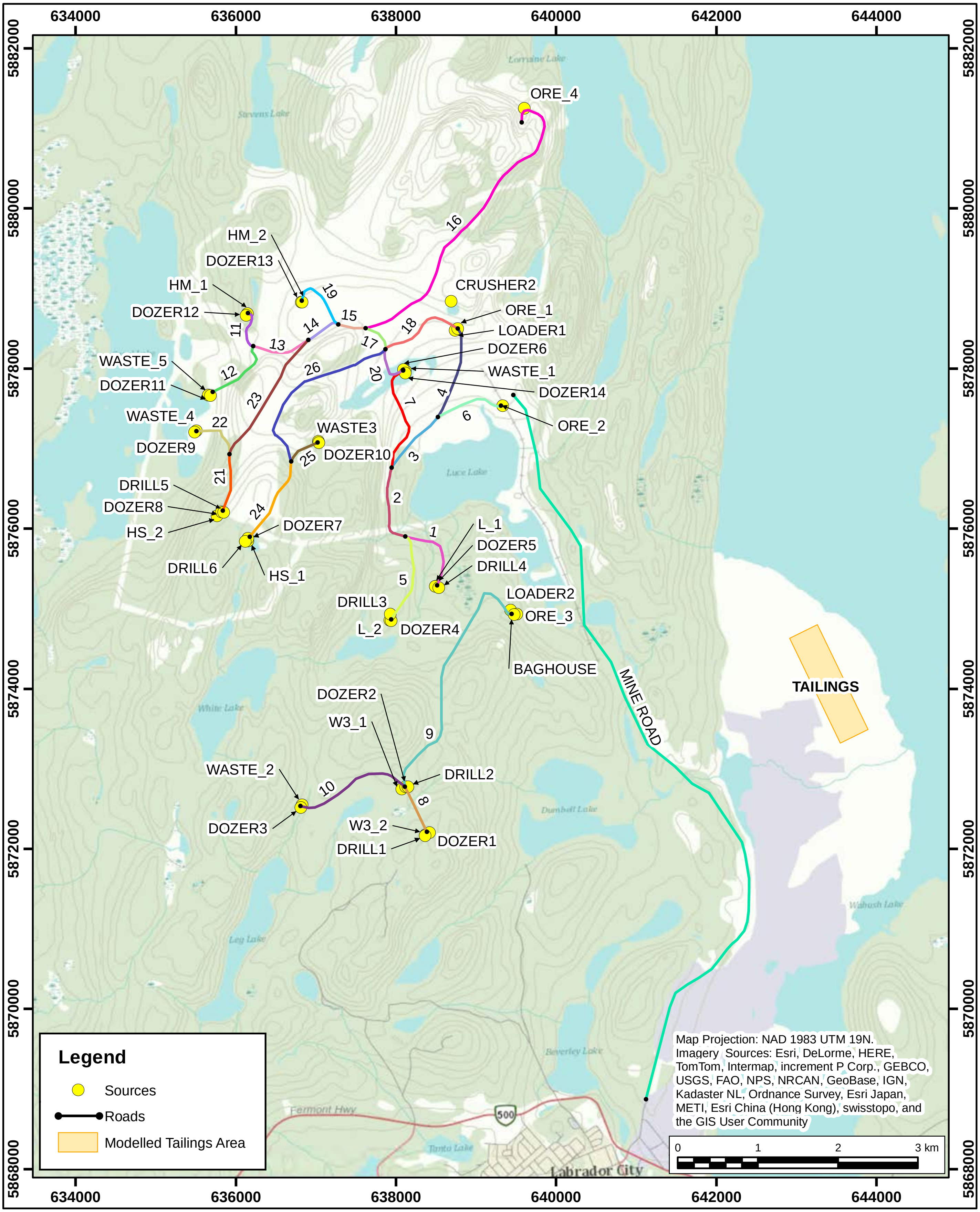
12. Scire J.S., F.R. Robe, M. E. Ferneau, and R.J. Yamartino.2000, A User's Guide for the CALPUFF Dispersion Model. Earth Tech Inc., Jan. 2000.

FIGURES



Locations of Sources

Future Build Scenario

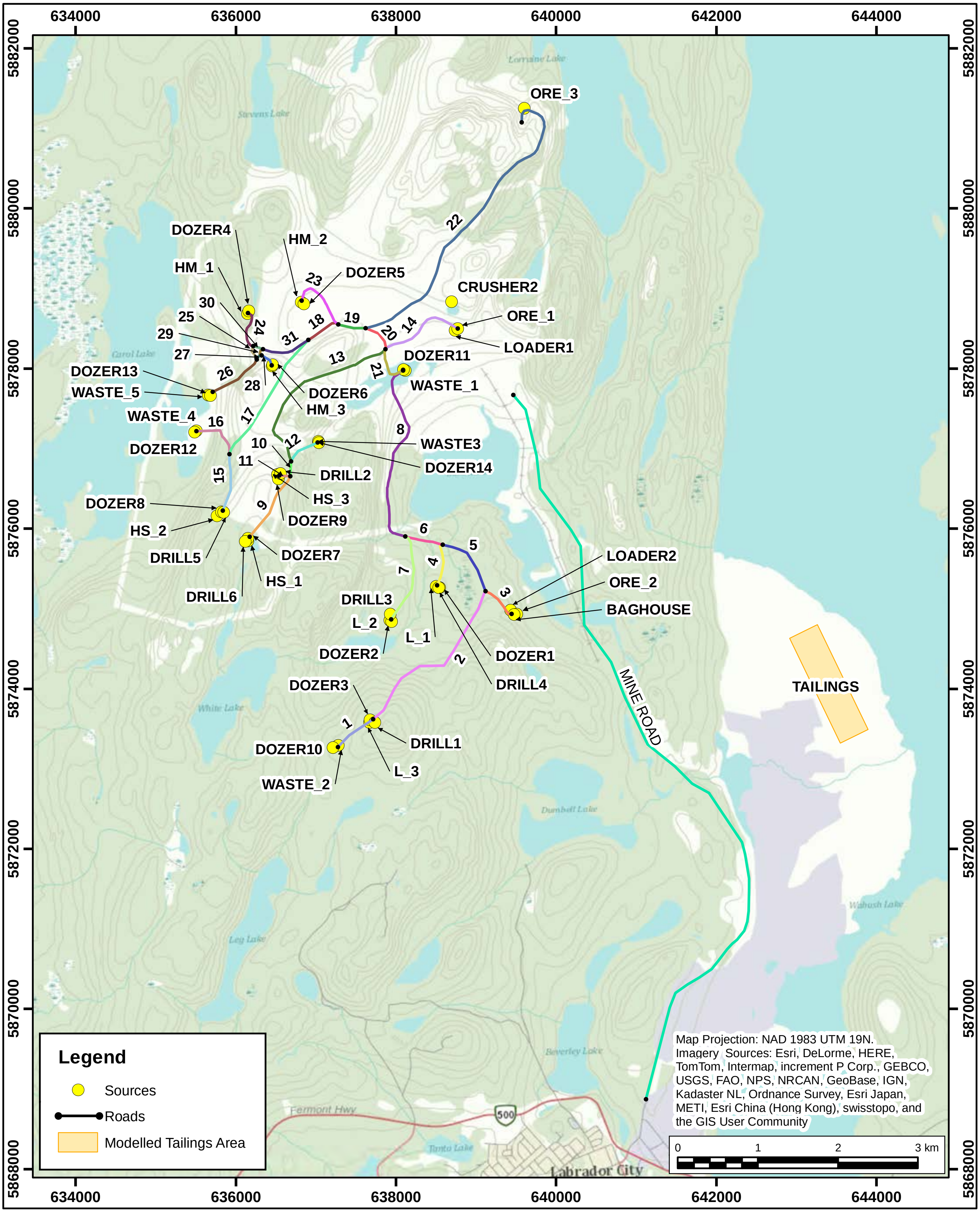
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 1
Approx. Scale:	1:65,000
Date Revised:	Apr. 3, 2014

RWDI



Locations of Sources

Future No Build Scenario

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

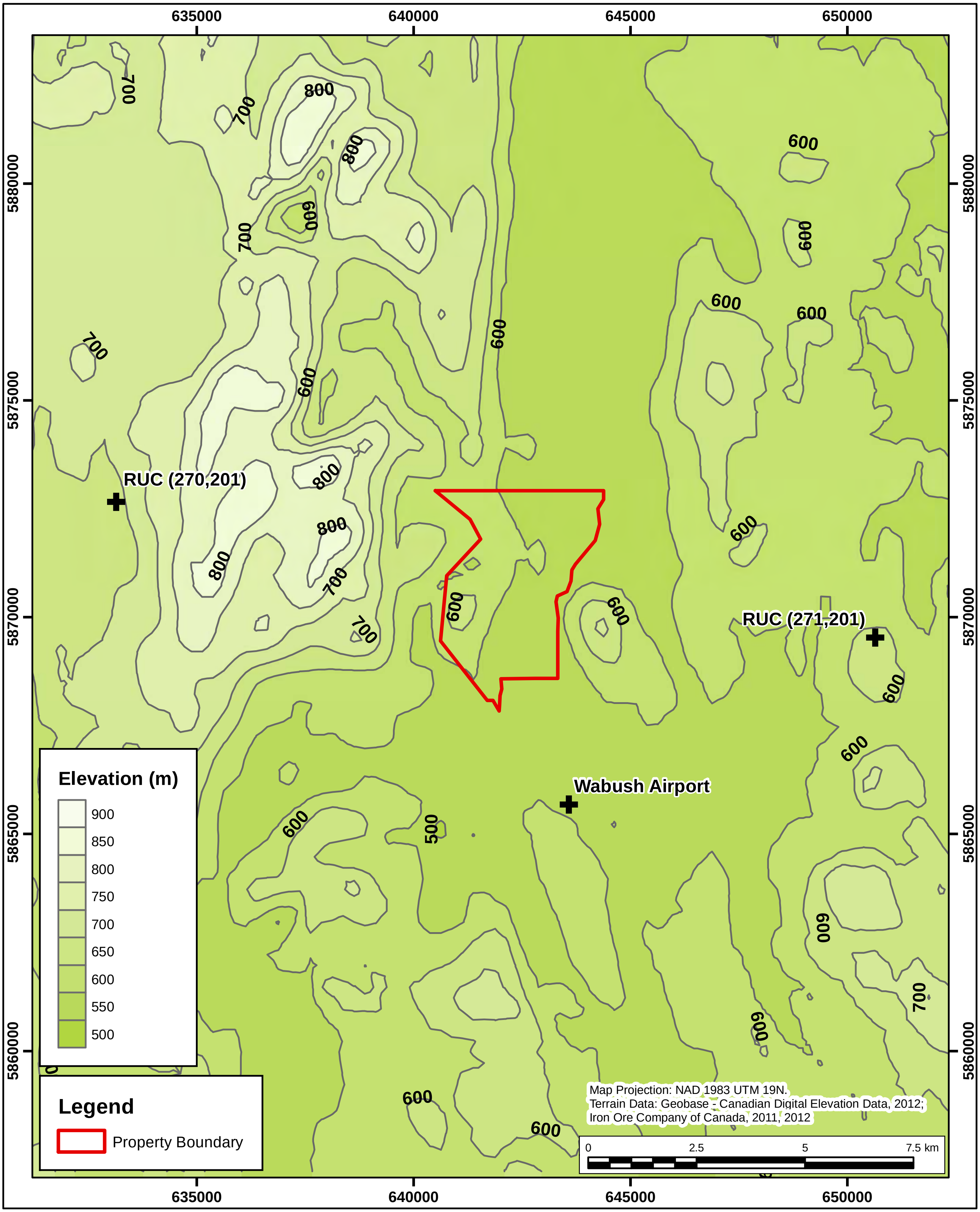
Project #1400675

Drawn by: NBN

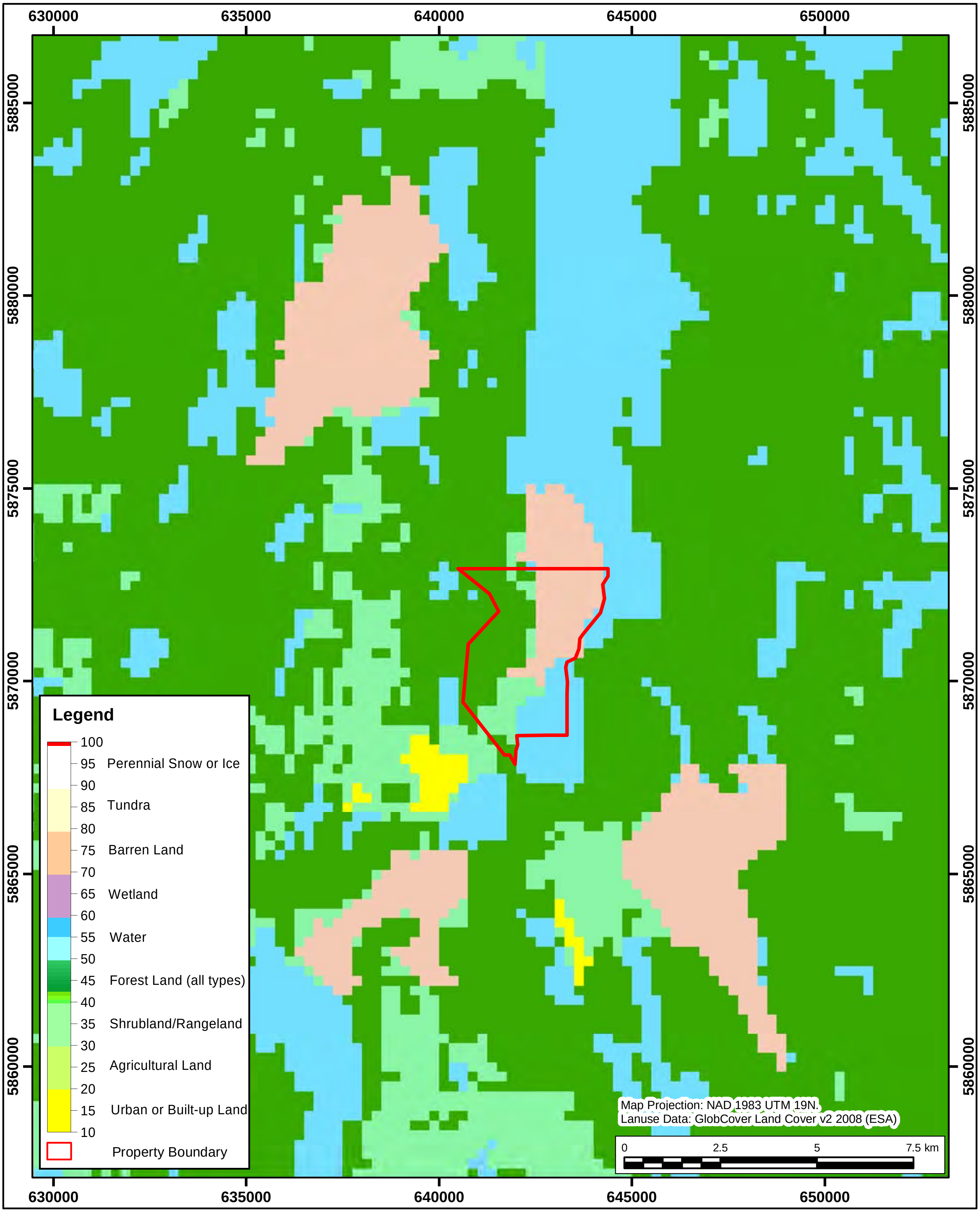
Figure: 2

Approx. Scale: 1:65,000

Date Revised: Apr. 3, 2014



Surface Meteorological Station and RUC Output Locations	True North	Drawn by: NBN	Figure: 3
		Approx. Scale: 1:120,000	
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador	Project #1401221	Date Revised: Apr. 1, 2014	



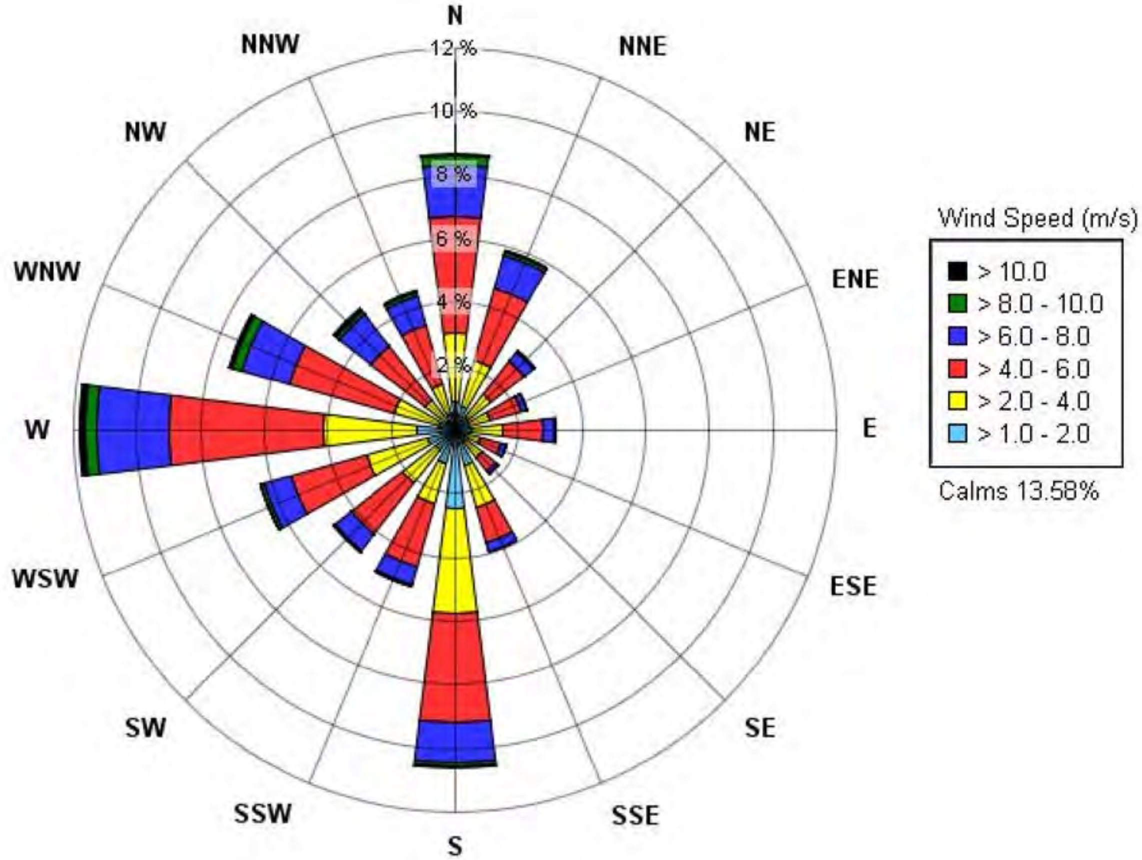
Gridded Land-Use Classes in the CALMET Modeling Domain

True North

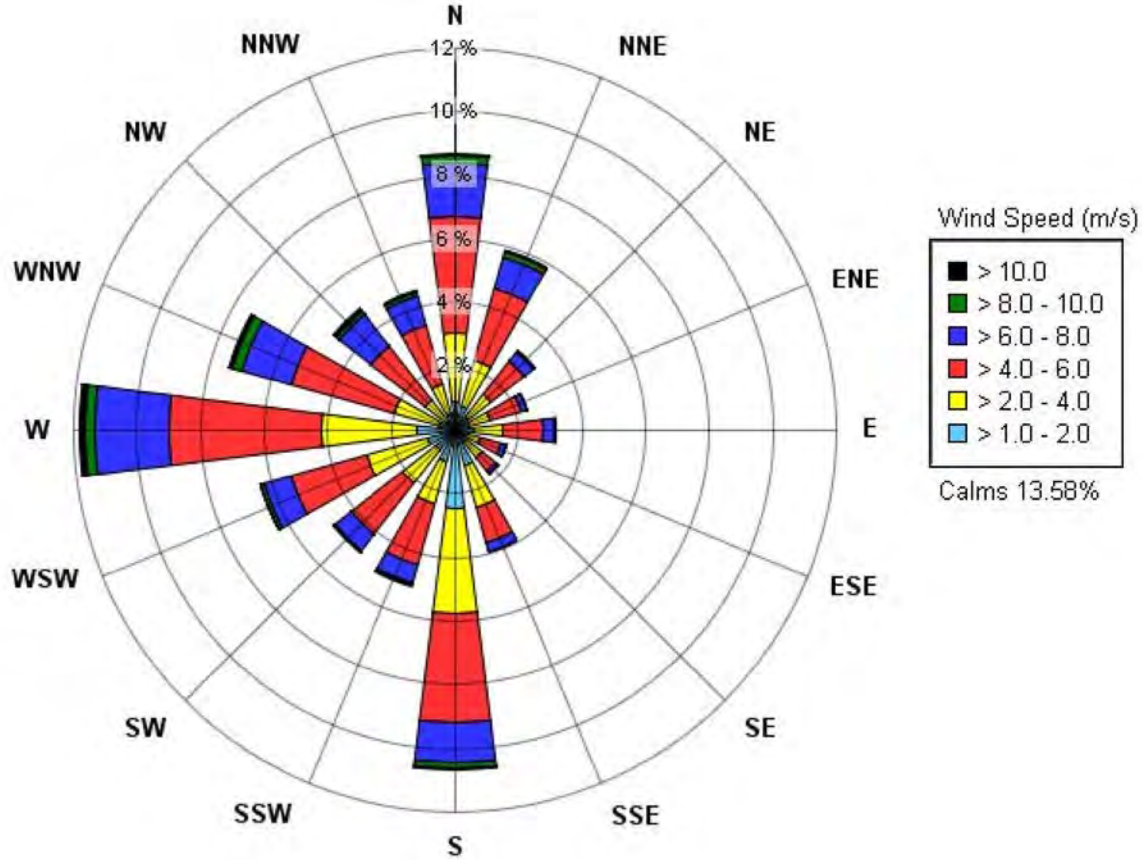
Drawn by: NBN	Figure: 4	RWDI
Approx. Scale:	1:135,000	
Date Revised:	Apr. 1, 2014	

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

Project #1401221



CALMET 2007 to 2010 Predicted Wind Rose at Wabush Airport	Drawn by: NBN	Figure: 5
	Approx. Scale: N/A	
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador — Project #1401221	Date Revised: Apr. 1, 2014	



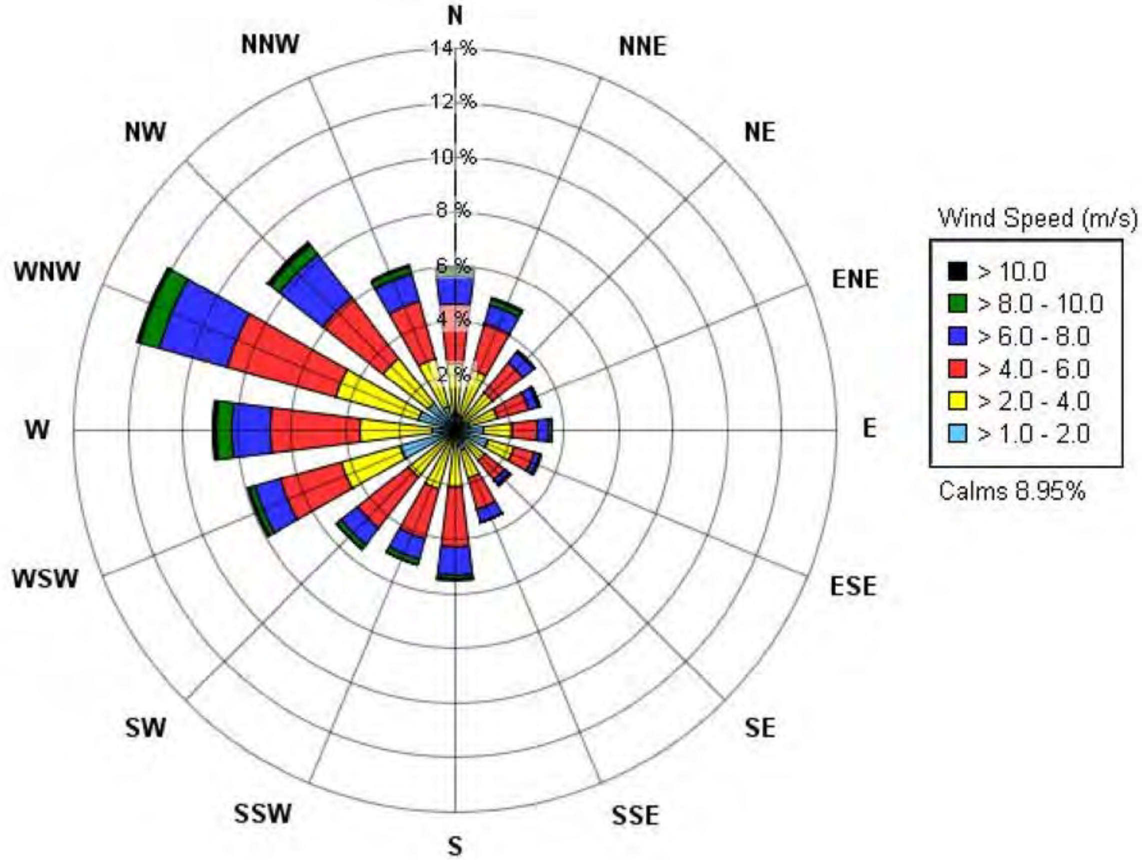
CALMET 2007 to 2010 Observed Wind Rose at Wabush Airport

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

Project #1401221

Drawn by: NBN	Figure: 6
Approx. Scale:	N/A
Date Revised:	Apr. 1, 2014

RWDI



CALMET 2007 to 2010 Predicted Wind Rose at Mine Site

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

Project #1400675

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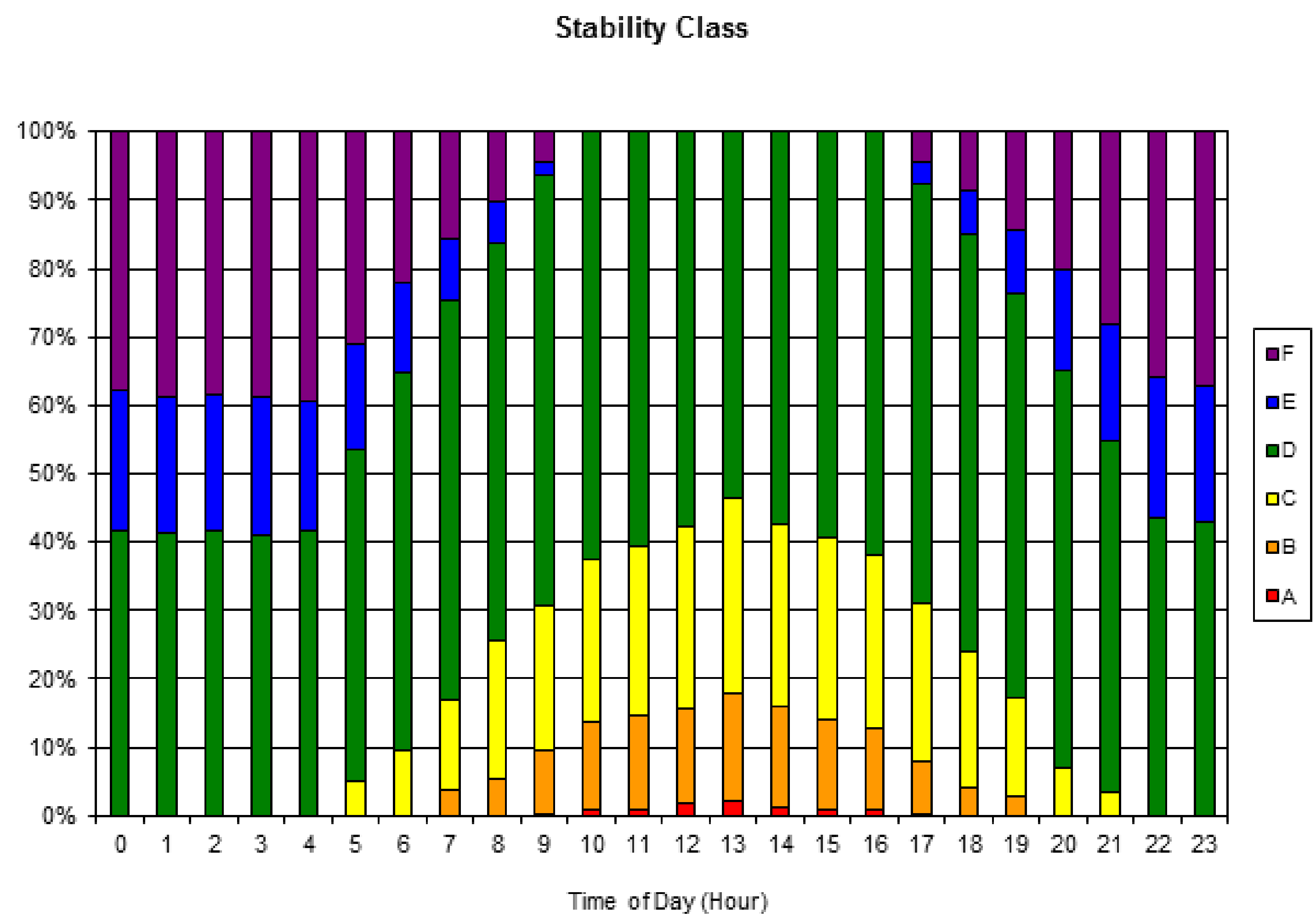
Date Revised: May 14, 2014	



Frequency of Stability Class for Time of Day as Modelled By CALMET at the Project Site (Years 2007-2010)

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

Project #1401221

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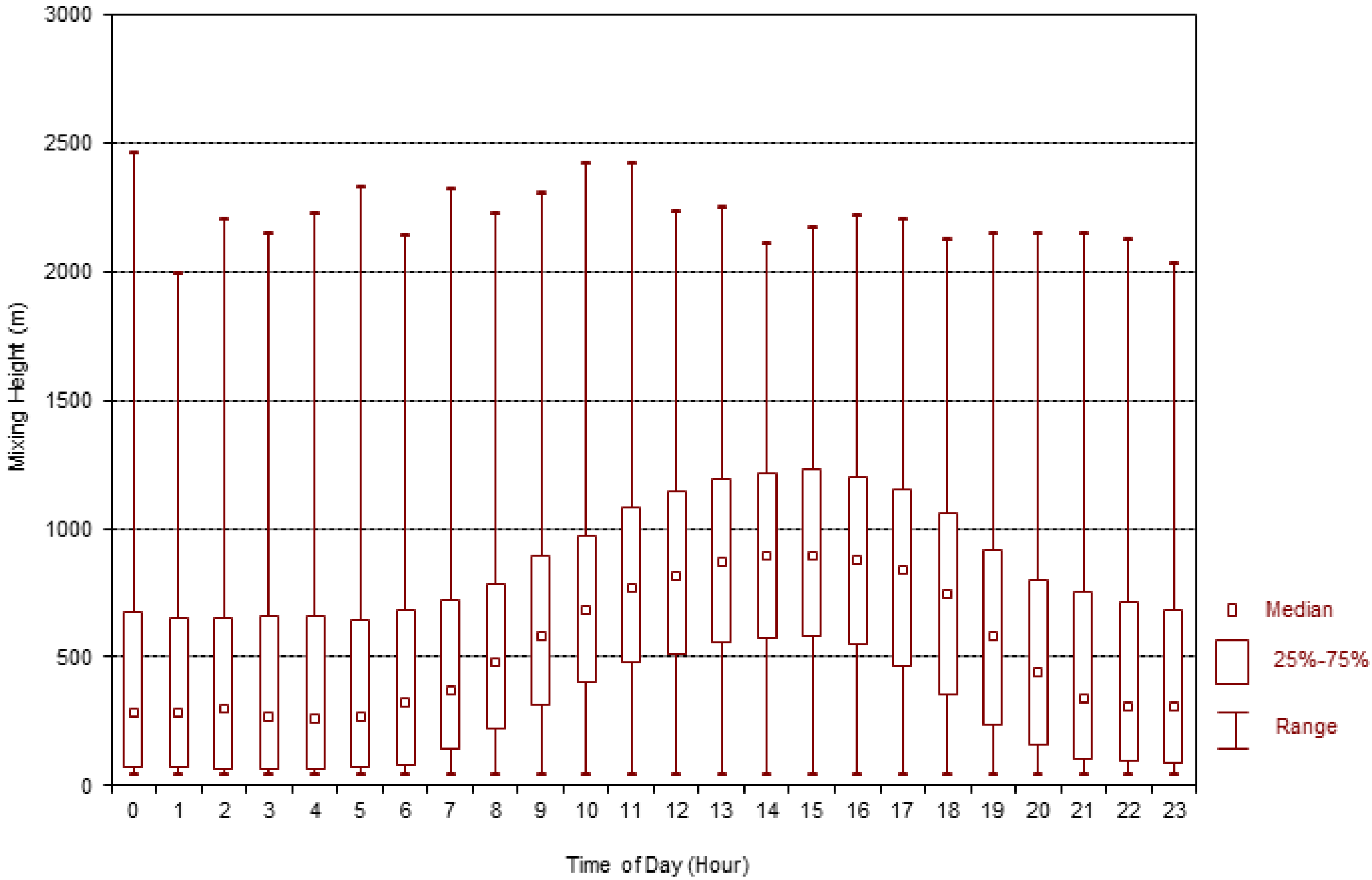
Approx. Scale:	N/A
Date Revised:	Mar. 28, 2014



Mixing Height and Time of Day as Modelled By CALMET at the Project Site (Years 2007-2010)

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

Project #1401221

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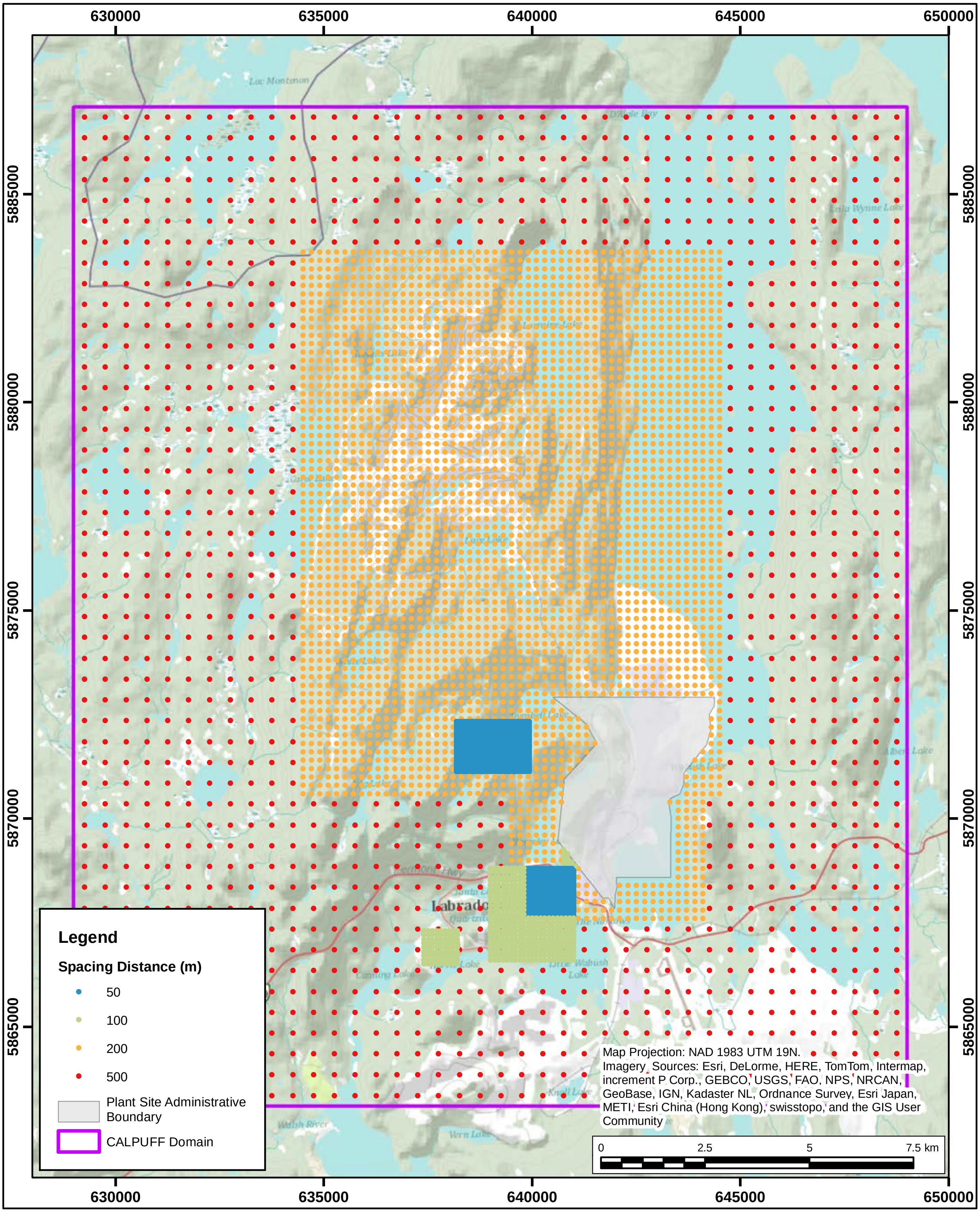
Date Revised:	Mar. 28, 2014	



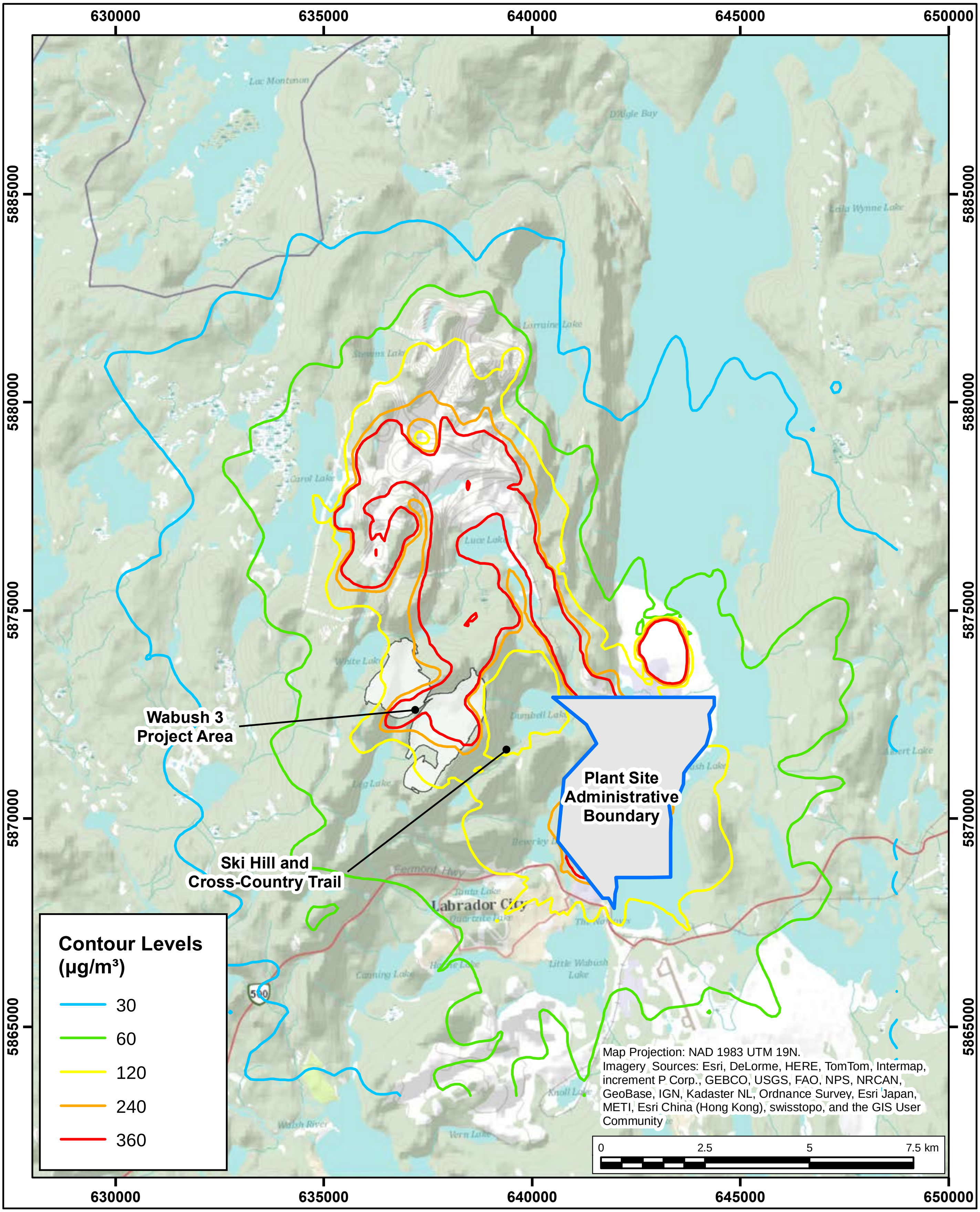
CALPUFF Domain and Receptors

True North

Drawn by: NBN	Figure: 10
Approx. Scale:	1:125,000
Date Revised:	May 9, 2014

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

Project #1400675



TSP - 24 Hour Averaging Period

Future Build Scenario

POI Limit = 120 µg/m³

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by:	NBN	Figure:	11
Approx. Scale:			1:125,000
Date Revised:			Apr. 28, 2014

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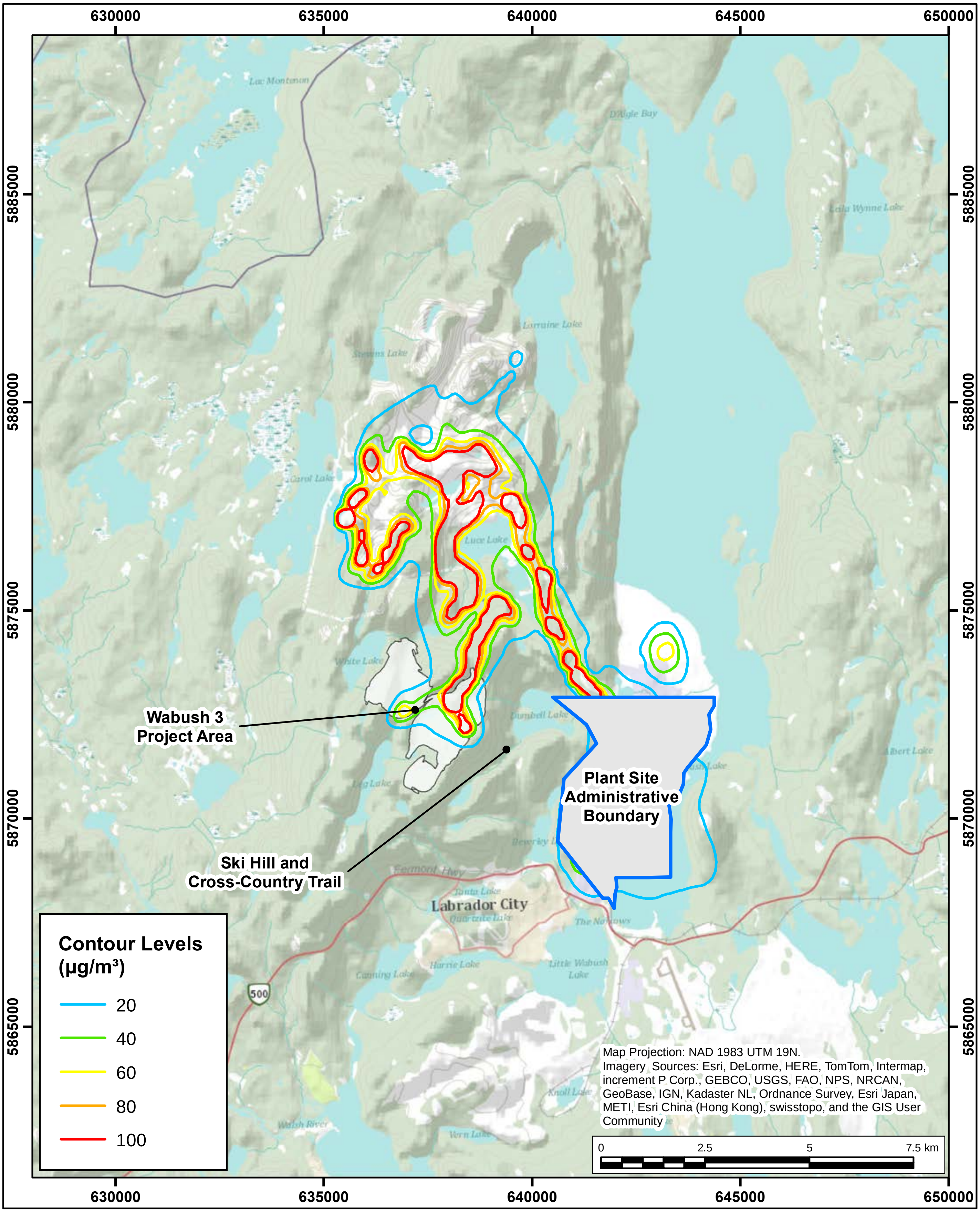

TSP - Arithmetic Annual Averaging

Future Build Scenario

POI Limit = 60 µg/m³

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

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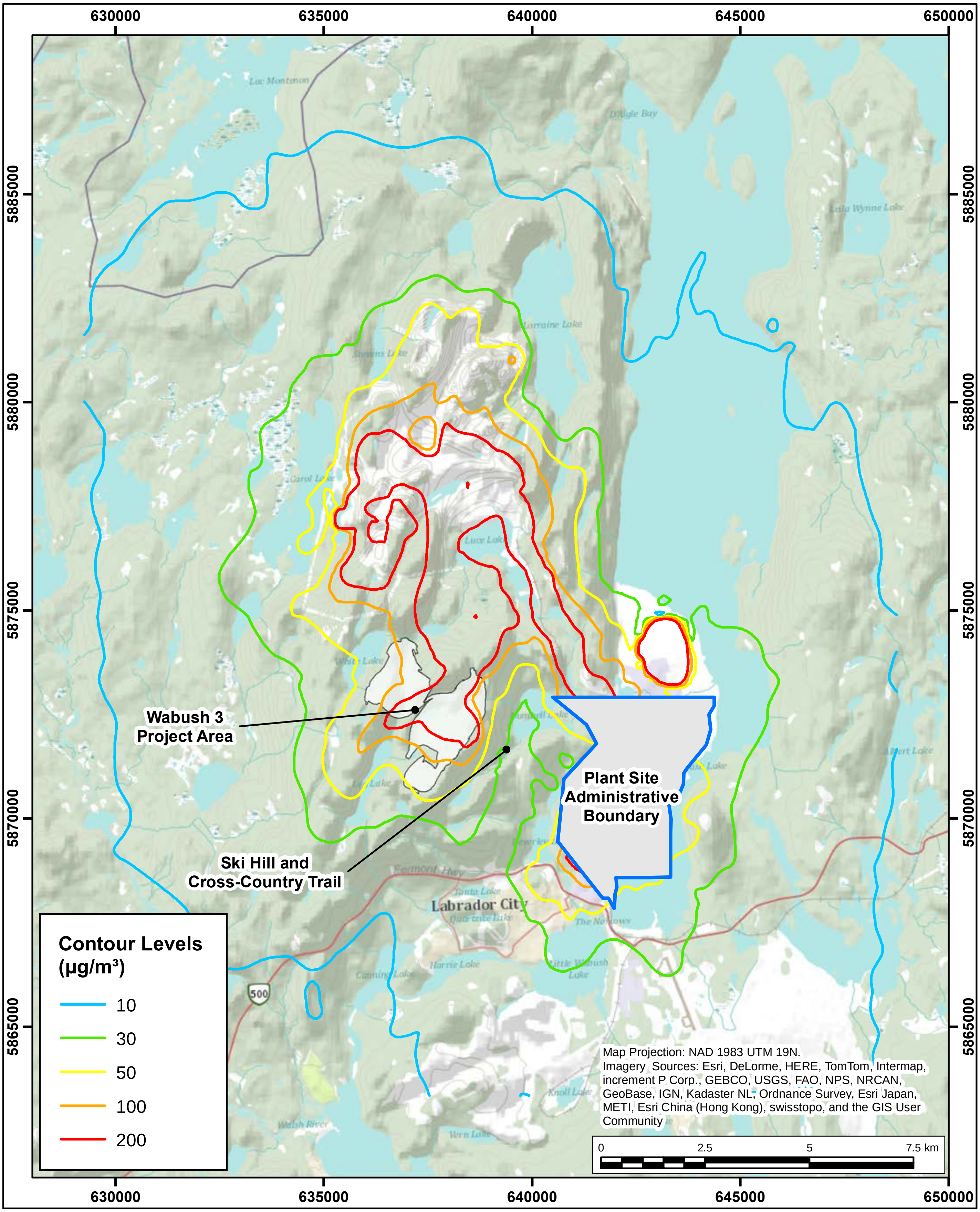
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

RWDI



PM_{10} - 24 Hour Averaging Period

Future Build Scenario

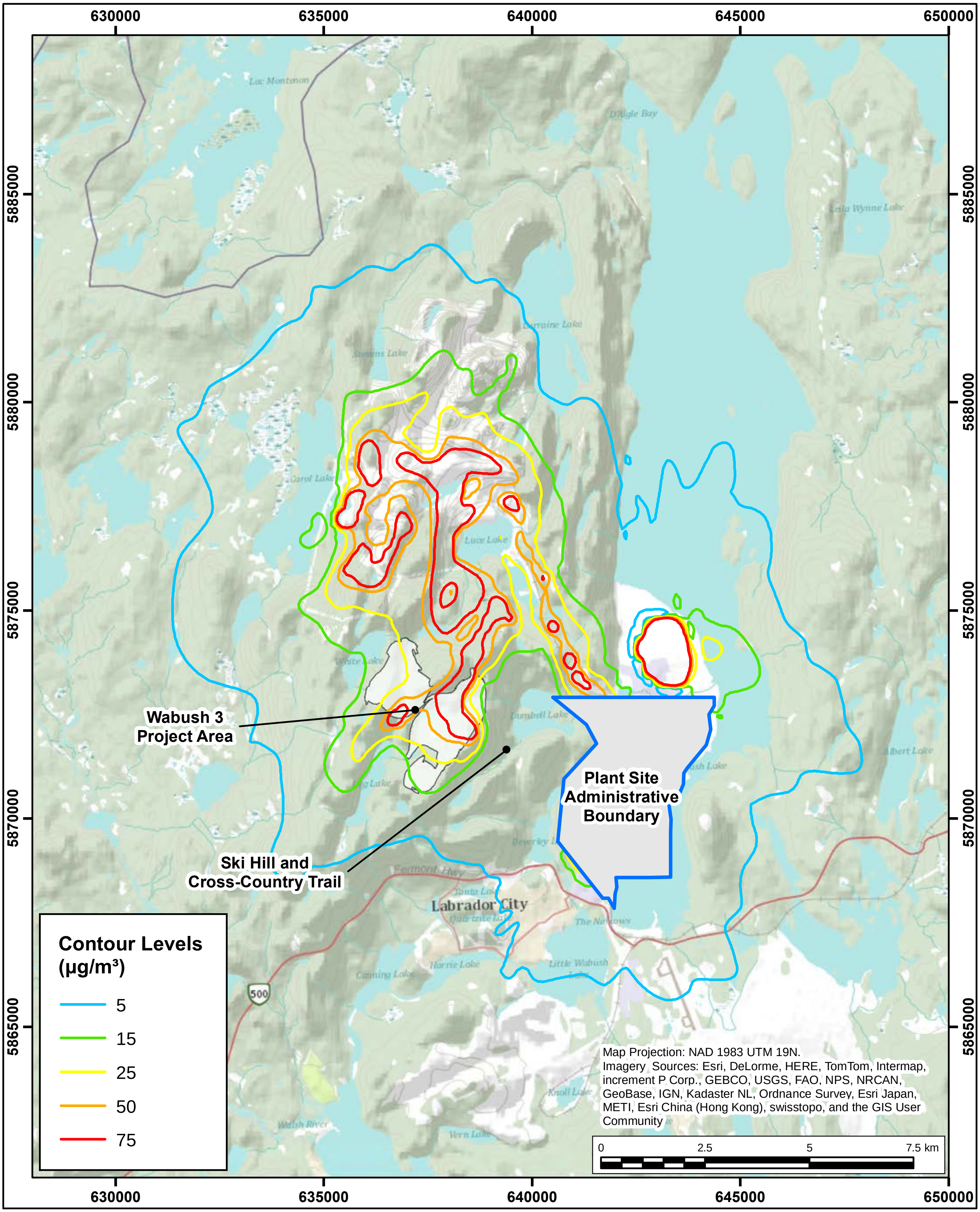
POI Limit = 50 µg/m³

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 13	RWDI
Approx. Scale:	1:125,000	
Date Revised:	Apr. 28, 2014	



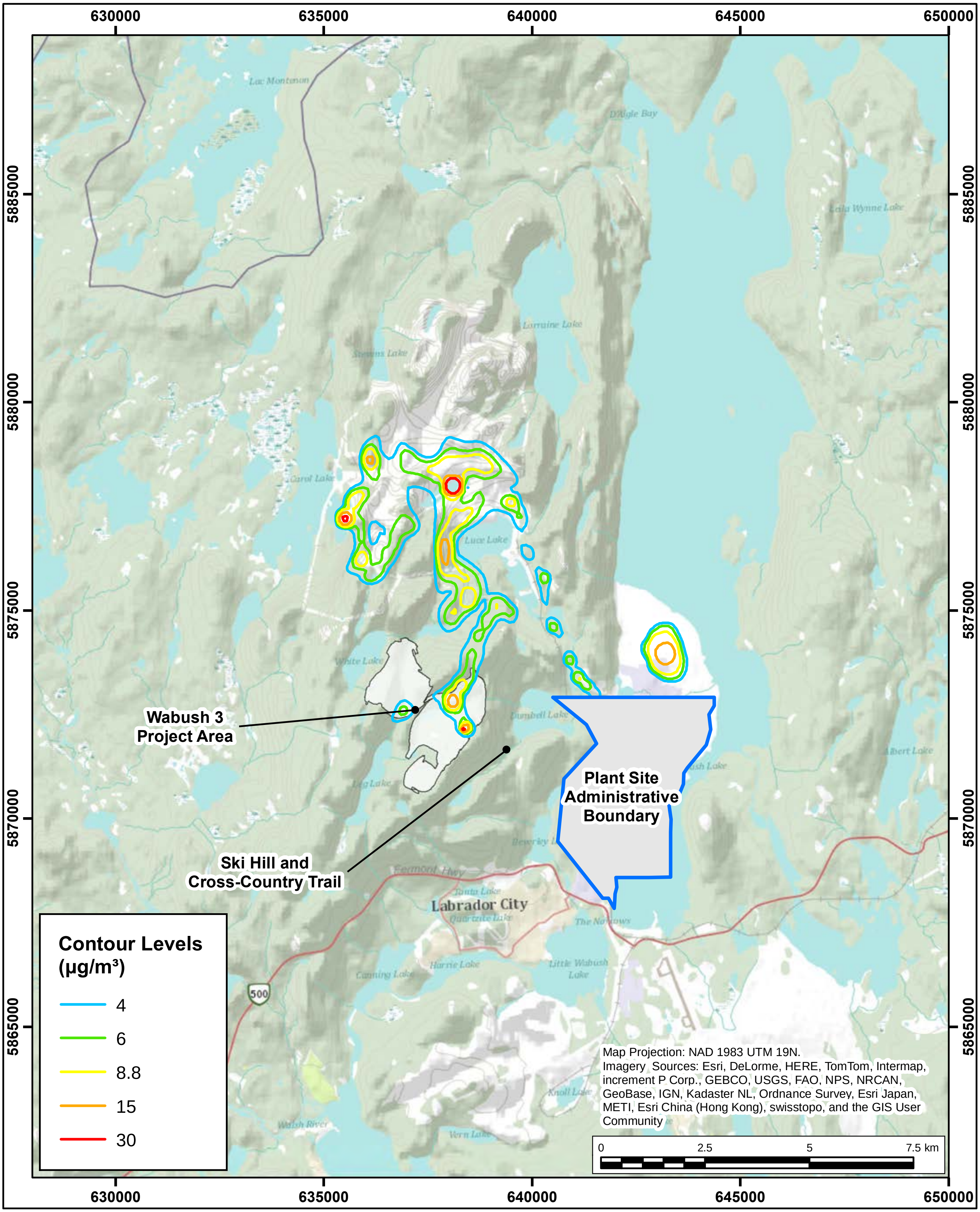
$PM_{2.5}$ - 24 Hour Averaging Period
Future Build Scenario
POI Limit = 25 µg/m³

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 14	RWDI
Approx. Scale:	1:125,000	
Date Revised:	Apr. 28, 2014	



PM$_{2.5}$ - Annual Averaging Period

Future Build Scenario

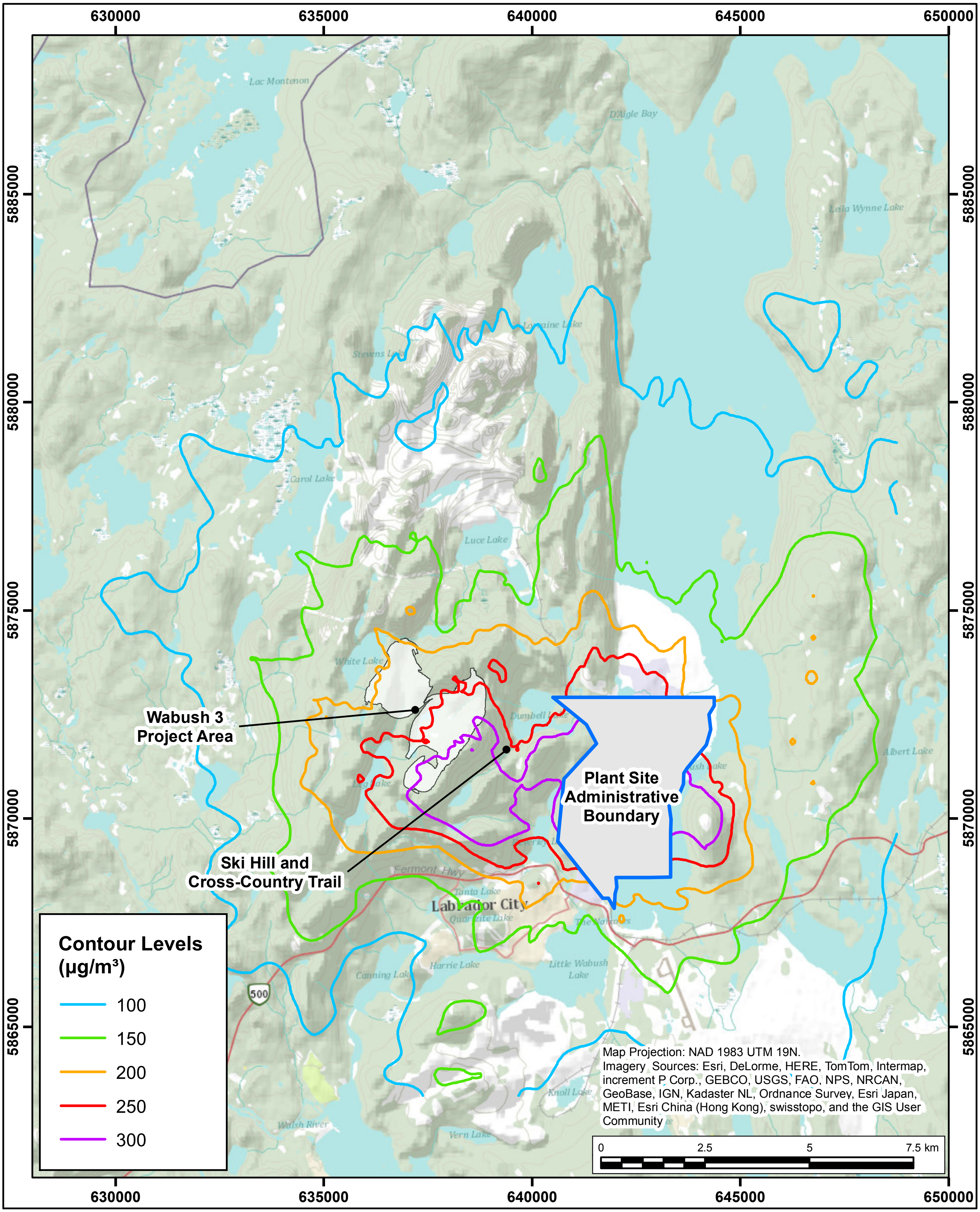
POI Limit = 8.8 µg/m³

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 15	RWDI
Approx. Scale:	1:125,000	
Date Revised:	Apr. 28, 2014	



Sulphur Dioxide - 1 Hour Averaging Period

Future Build Scenario

POI Limit = 900 µg/m³

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

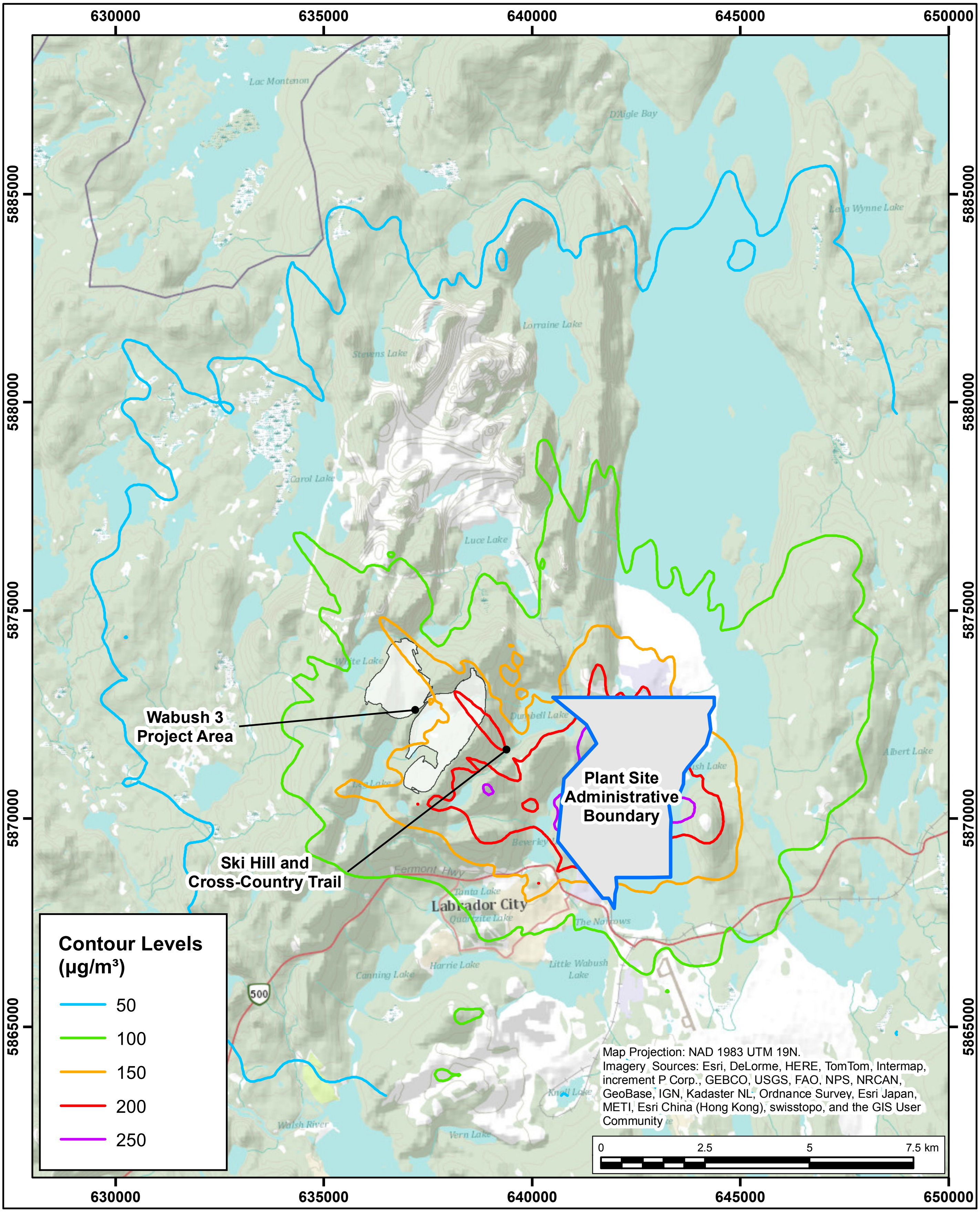
Drawn by: NBN

Figure: 16

Approx. Scale: 1:125,000

Date Revised: Apr. 28, 2014

RWDI



Sulphur Dioxide - 3 Hour Averaging Period

Future Build Scenario

POI Limit = 600 µg/m³

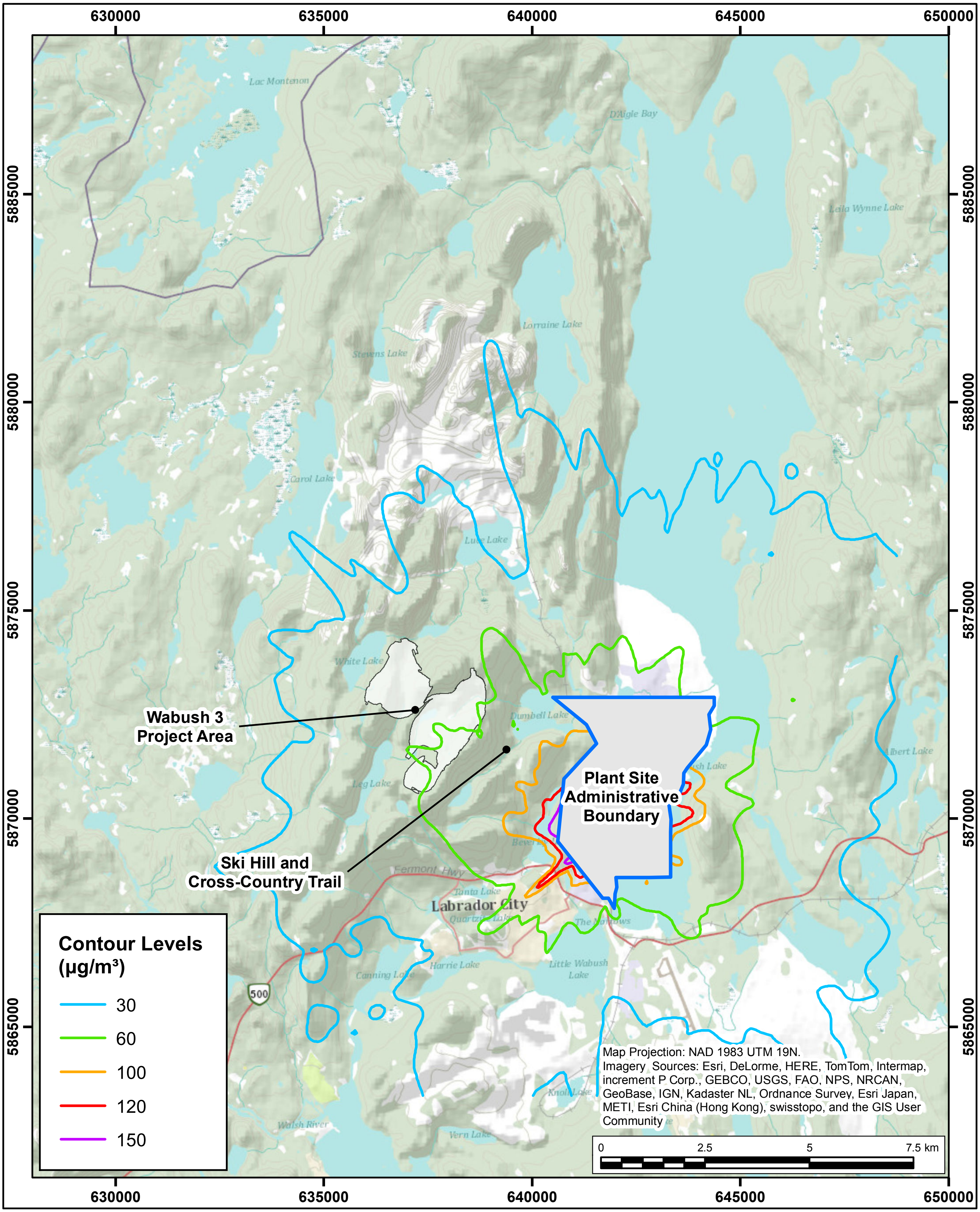
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 17
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

RWDI



Sulphur Dioxide - 24 Hour Averaging Period

Future Build Scenario

POI Limit = 300 µg/m³

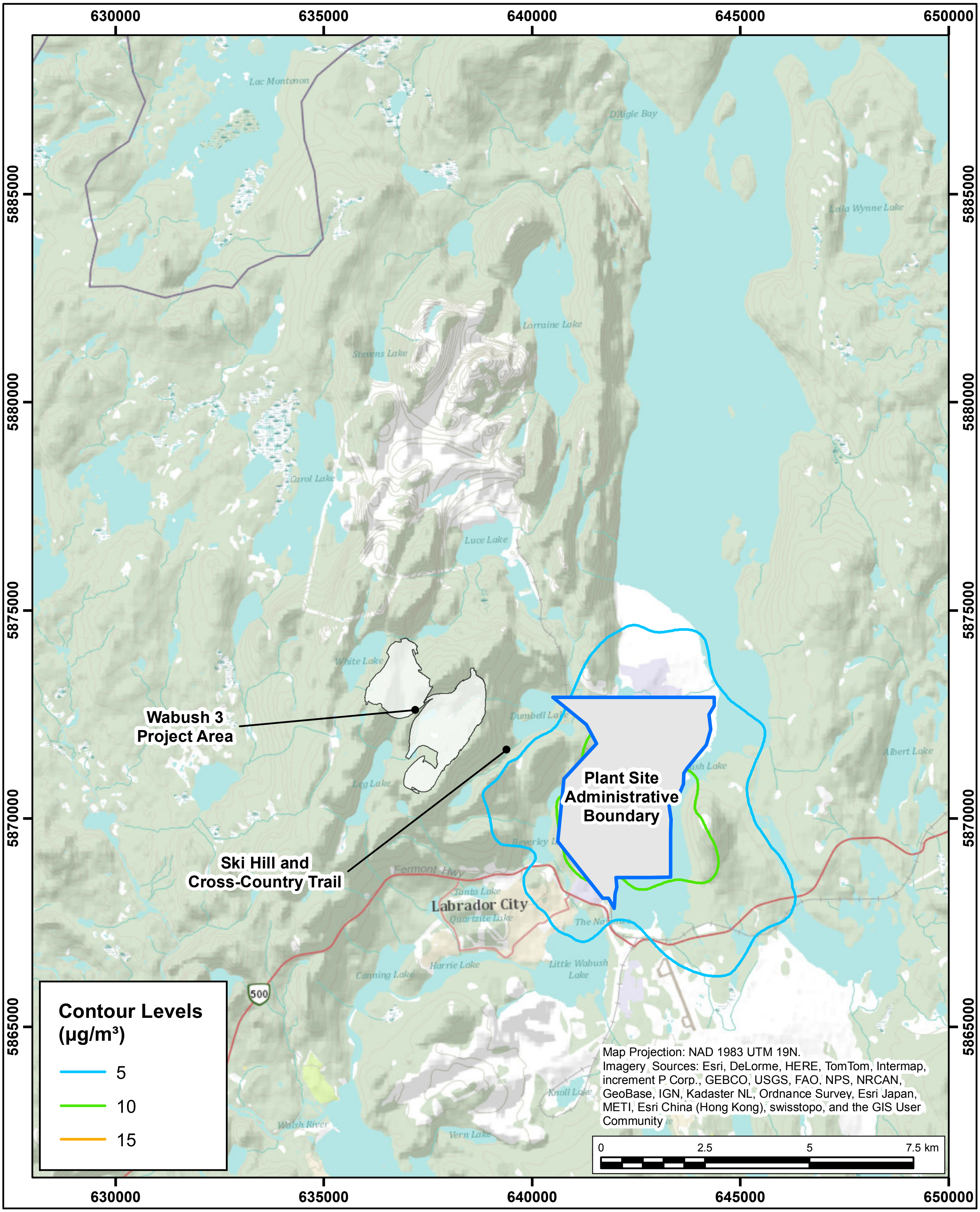
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 18
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

RWDI



Sulphur Dioxide - Arithmetic Annual Averaging

Future Build Scenario

POI Limit = 60 μg/m³

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 19	RWDI
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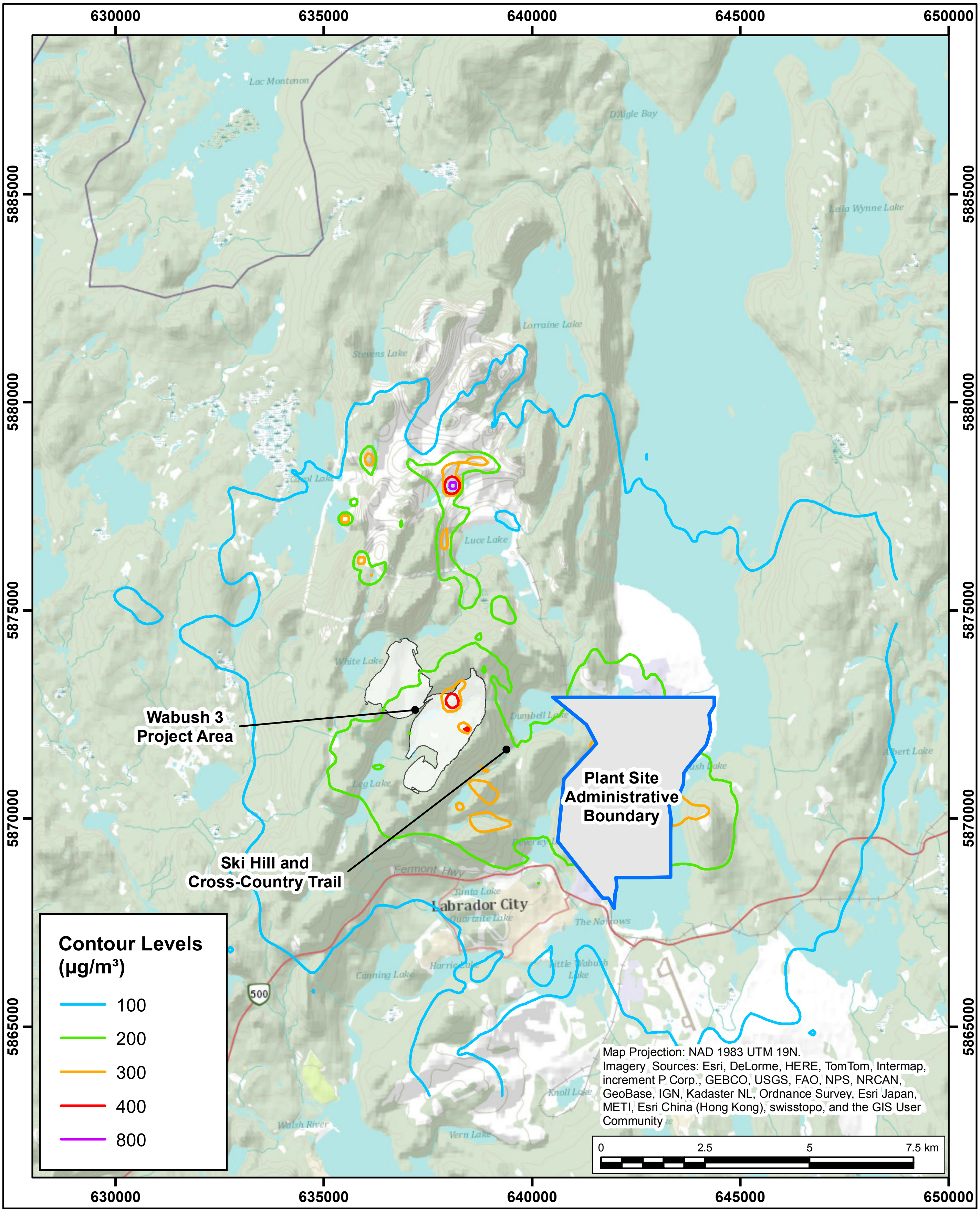


Carbon Monoxide - 1 Hour Averaging Period

Future Build Scenario

POI Limit = 35,000 µg/m³

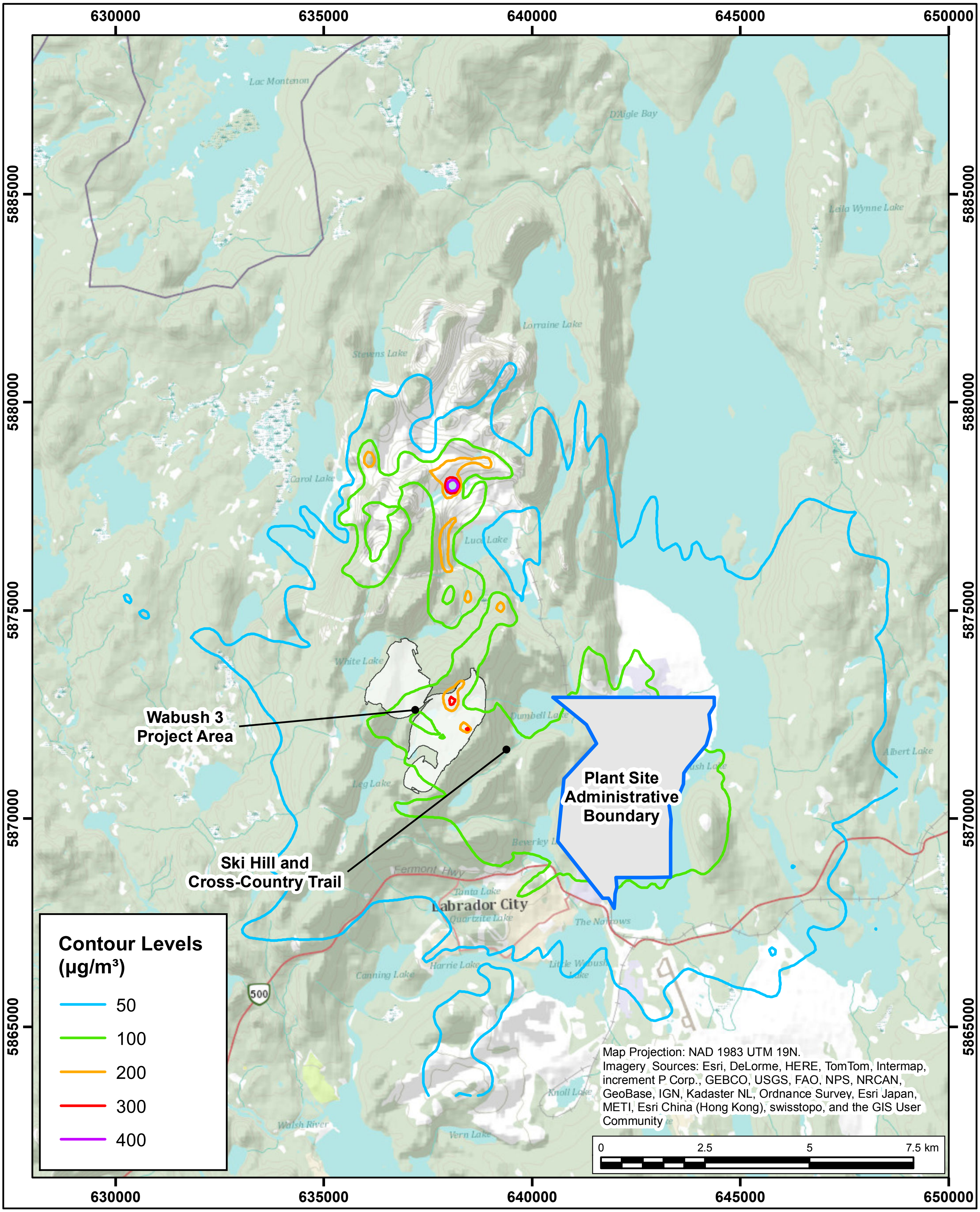
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 20
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

RWDI



Carbon Monoxide - 8 Hour Averaging Period

Future Build Scenario

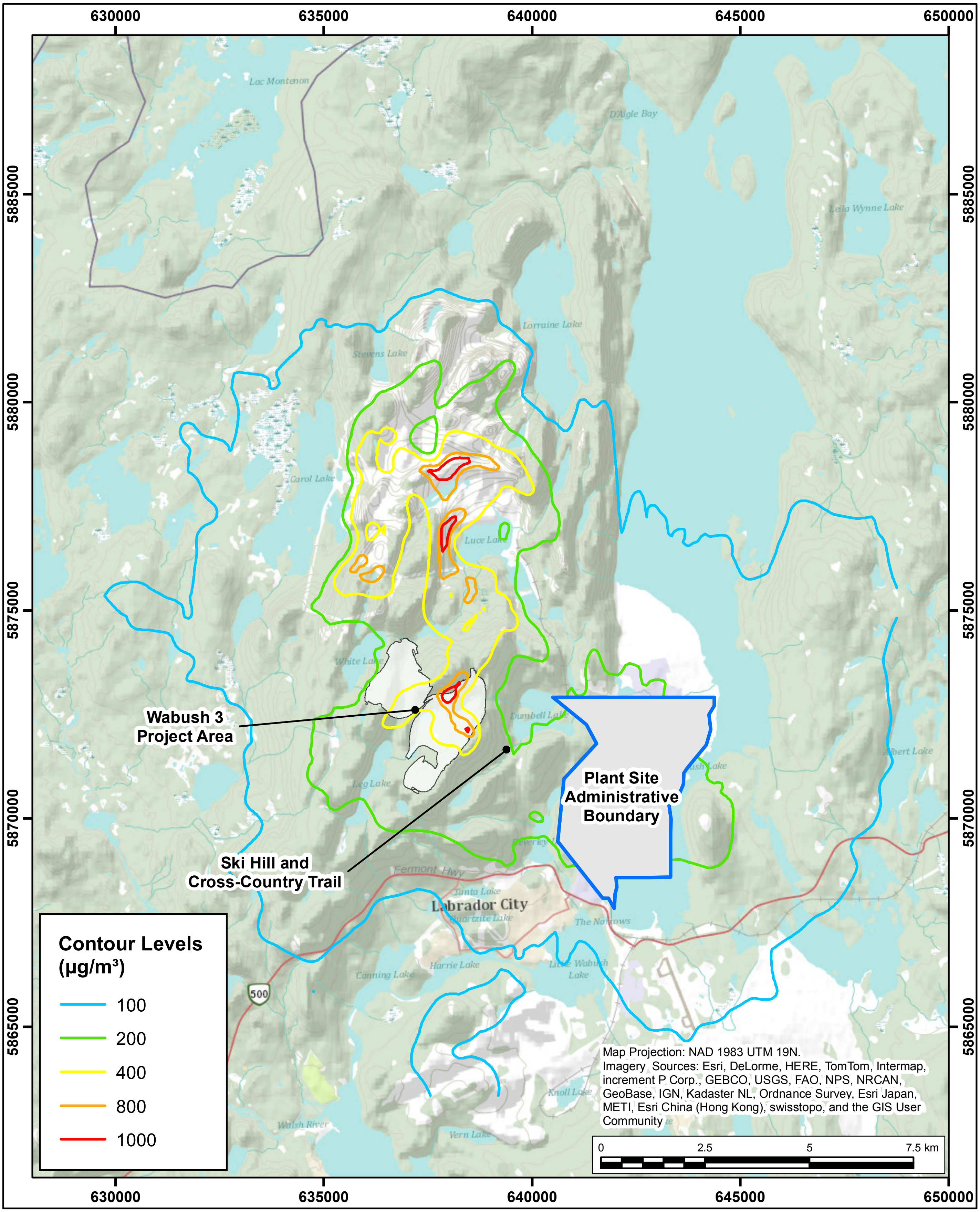
POI Limit = 15,000 μg/m³

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 21
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014



Nitrogen Dioxide - 1 Hour Averaging Period

Future Build Scenario

POI Limit = 400 µg/m³

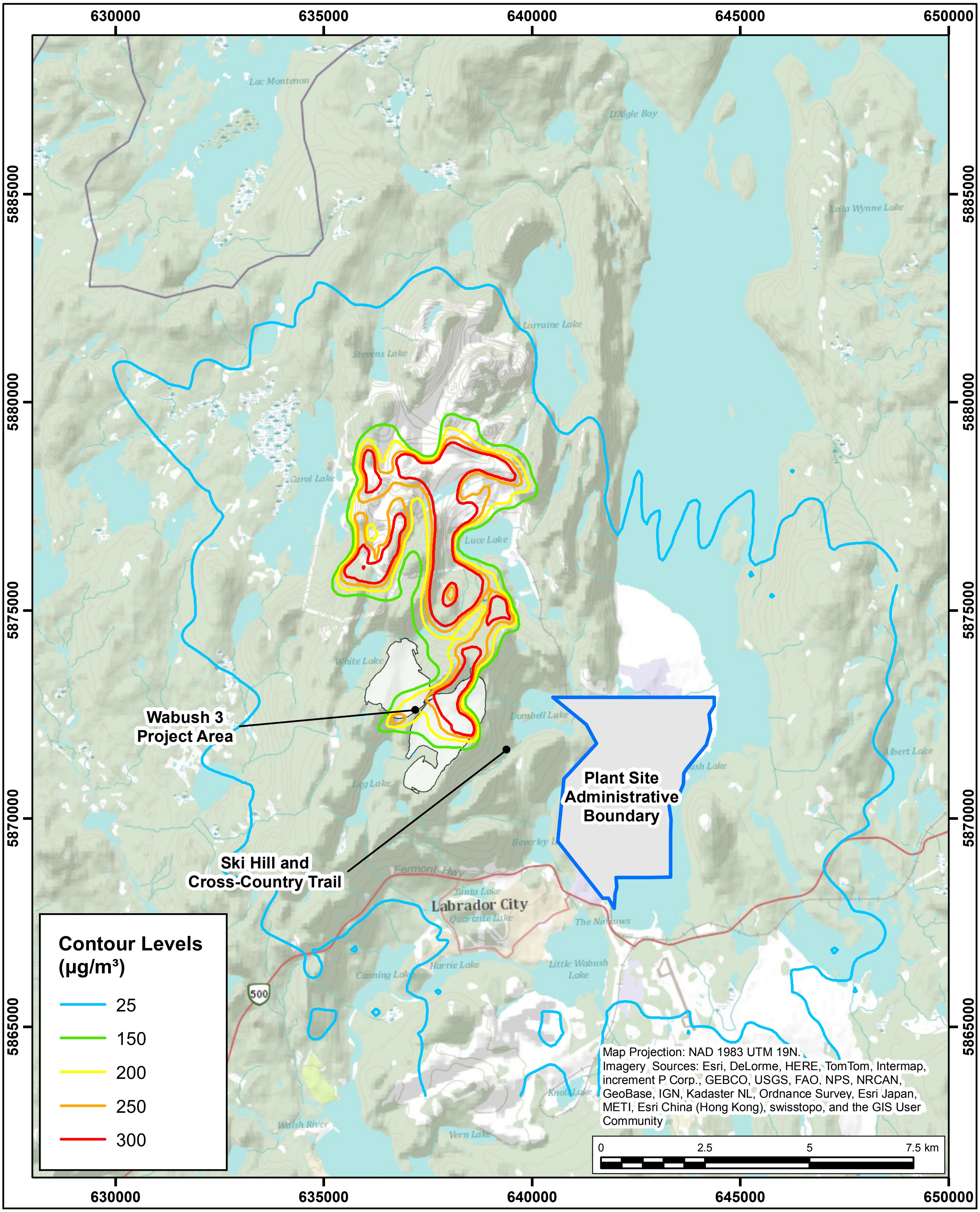
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 22
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

RWDI



Nitrogen Dioxide - 24 Hour Averaging Period

Future Build Scenario

POI Limit = 200 µg/m³

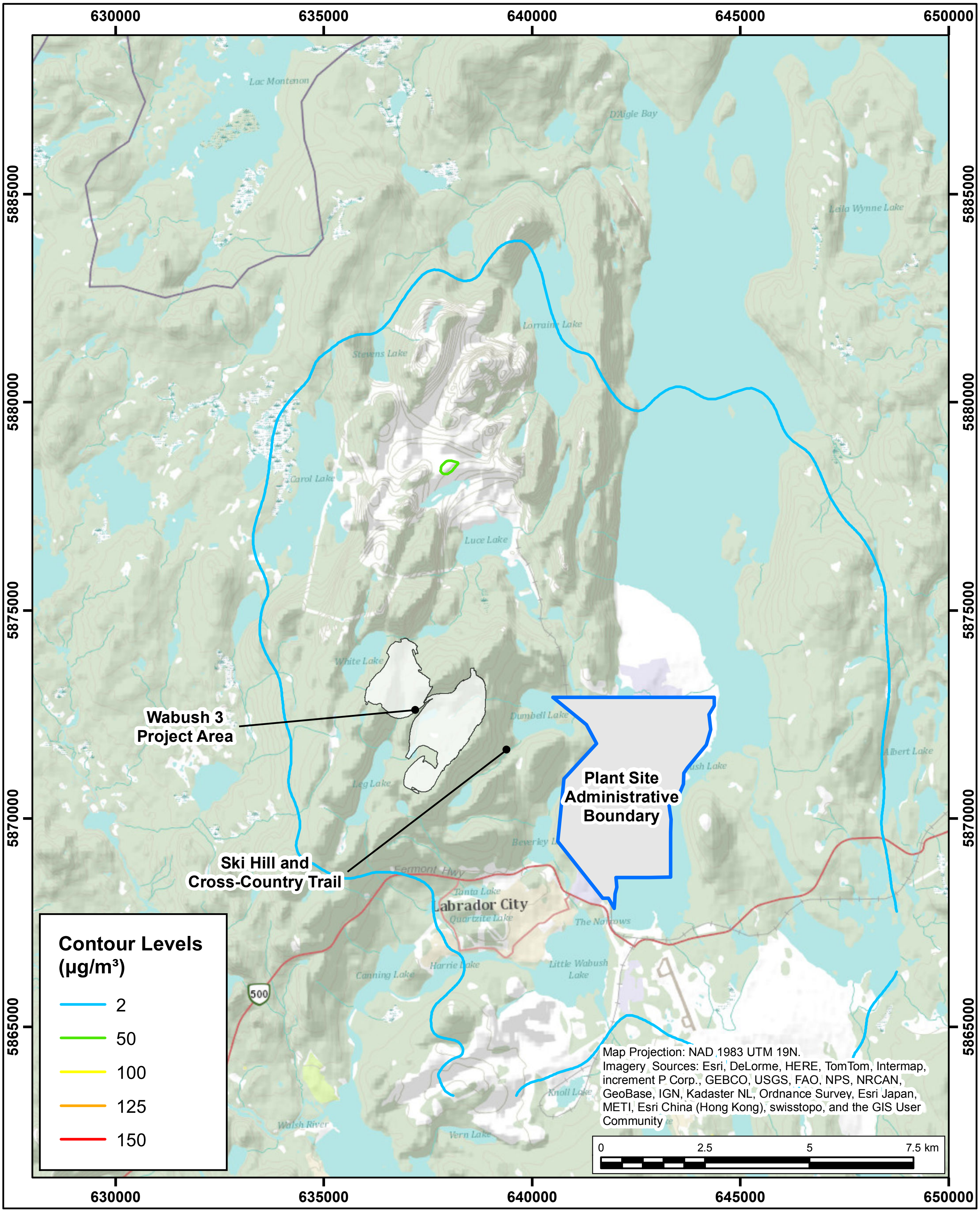
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 23
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

RWDI



Nitrogen Dioxide - Arithmetic Annual Averaging

Future Build Scenario

POI Limit = 100 µg/m³

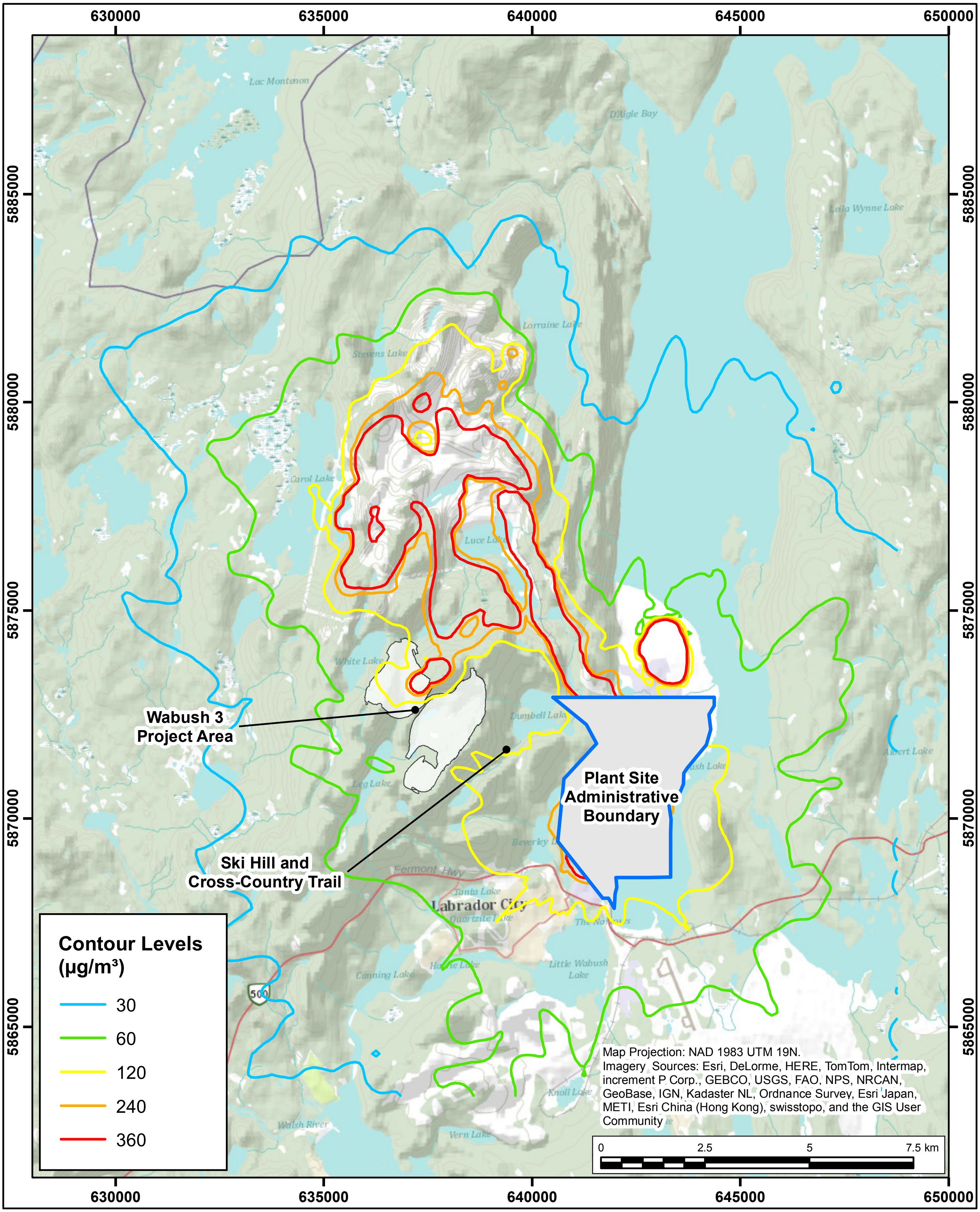
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 24
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

RWDI



TSP - 24 Hour Averaging Period

Future No Build Scenario

POI Limit = 120 µg/m³

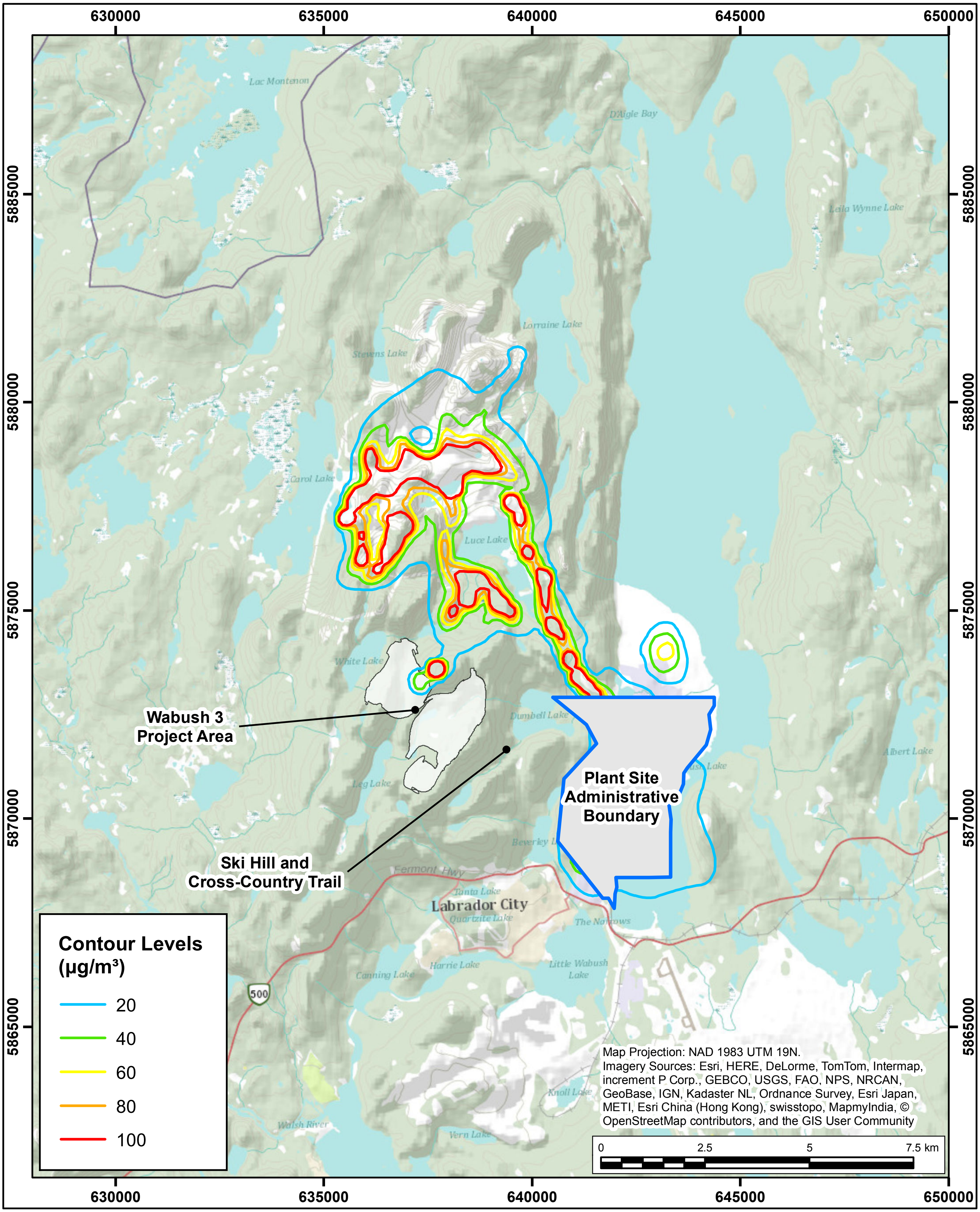
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

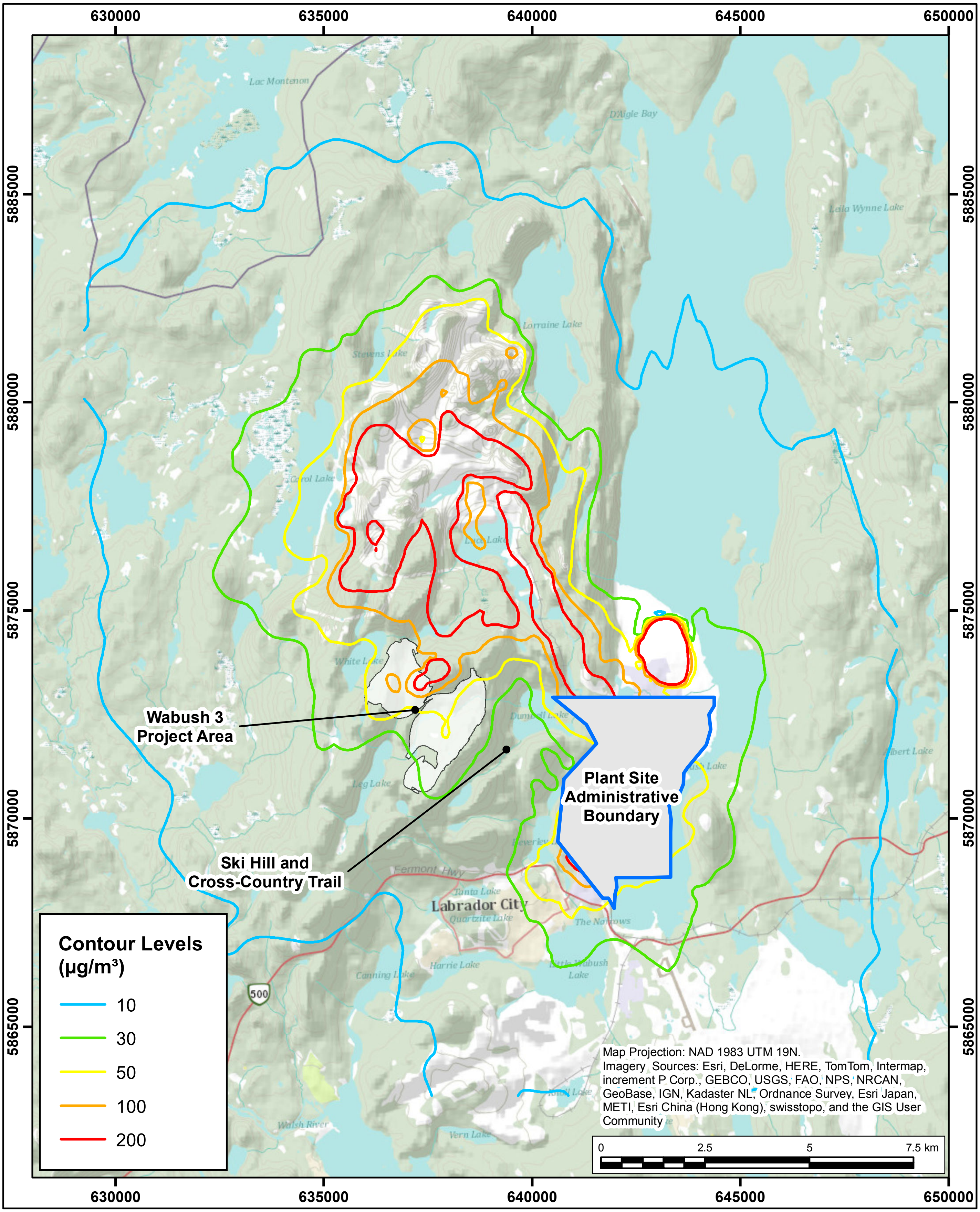
Drawn by:	NBN	Figure:	25
Approx. Scale:			1:125,000
Date Revised:			Apr. 28, 2014

RWDI



TSP - Arithmetic Annual Averaging Future No Build Scenario POI Limit = 60 µg/m³	True North	Drawn by: NBN	Figure: 26
		Approx. Scale:	1:125,000
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador	Project #1400675	Date Revised:	May 13, 2014

RWDI



PM$_{10}$ - 24 Hour Averaging Period

Future No Build Scenario

POI Limit = 50 μg/m³

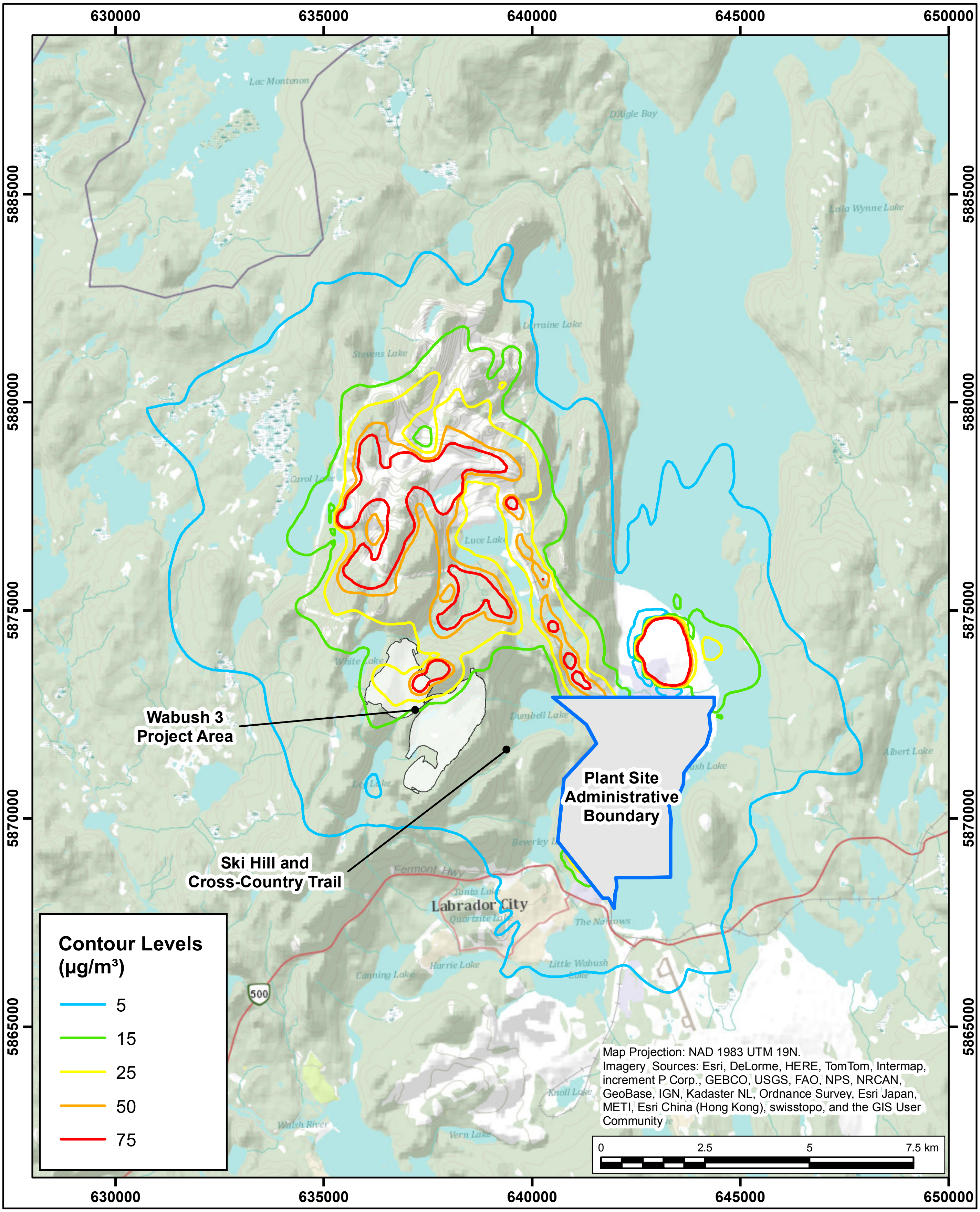
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 27
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

RWDI



$PM_{2.5}$ - 24 Hour Averaging Period

Future No Build Scenario

POI Limit = 25 µg/m³

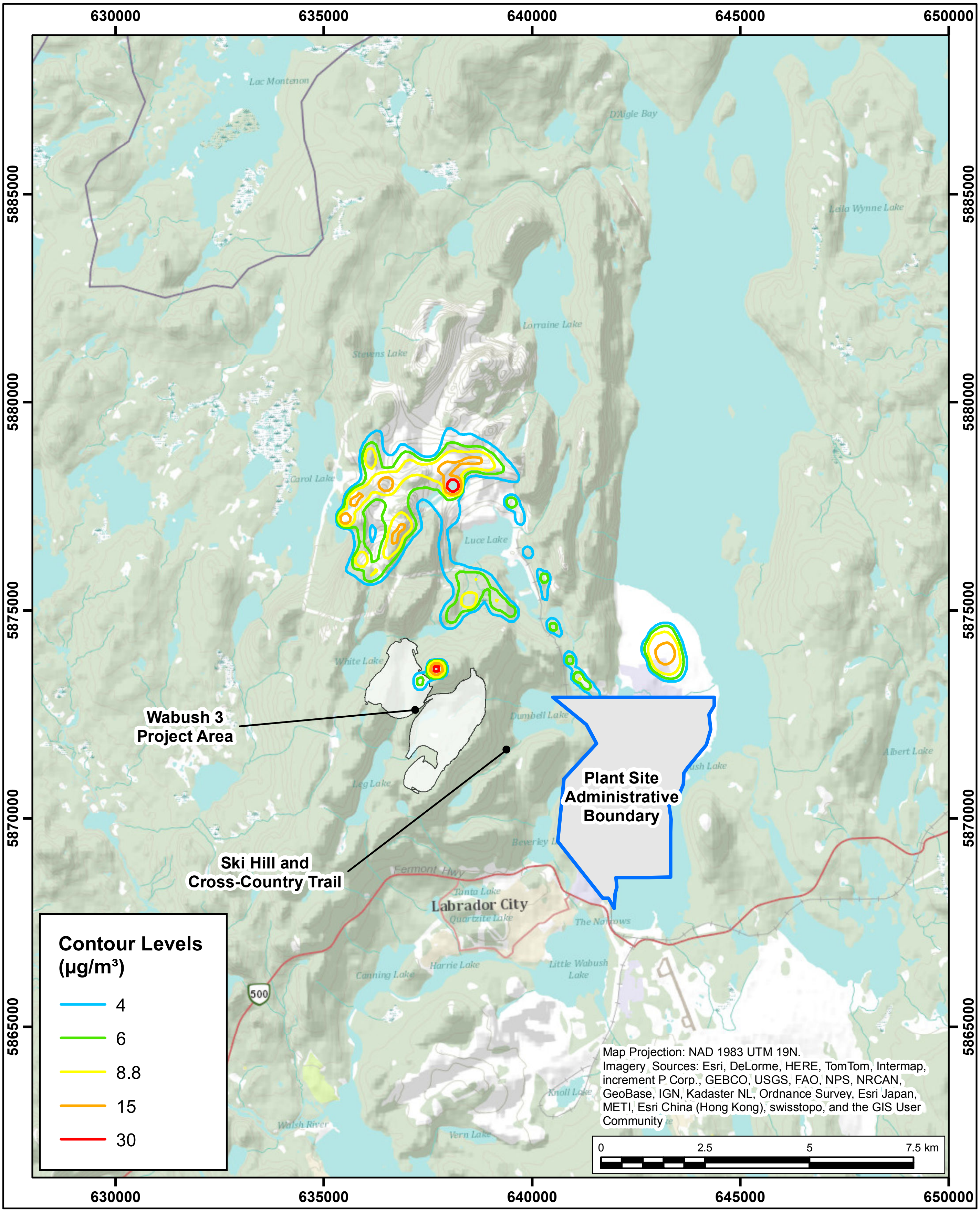
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 28
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

RWDI



$PM_{2.5}$ - Annual Averaging Period

Future No Build Scenario

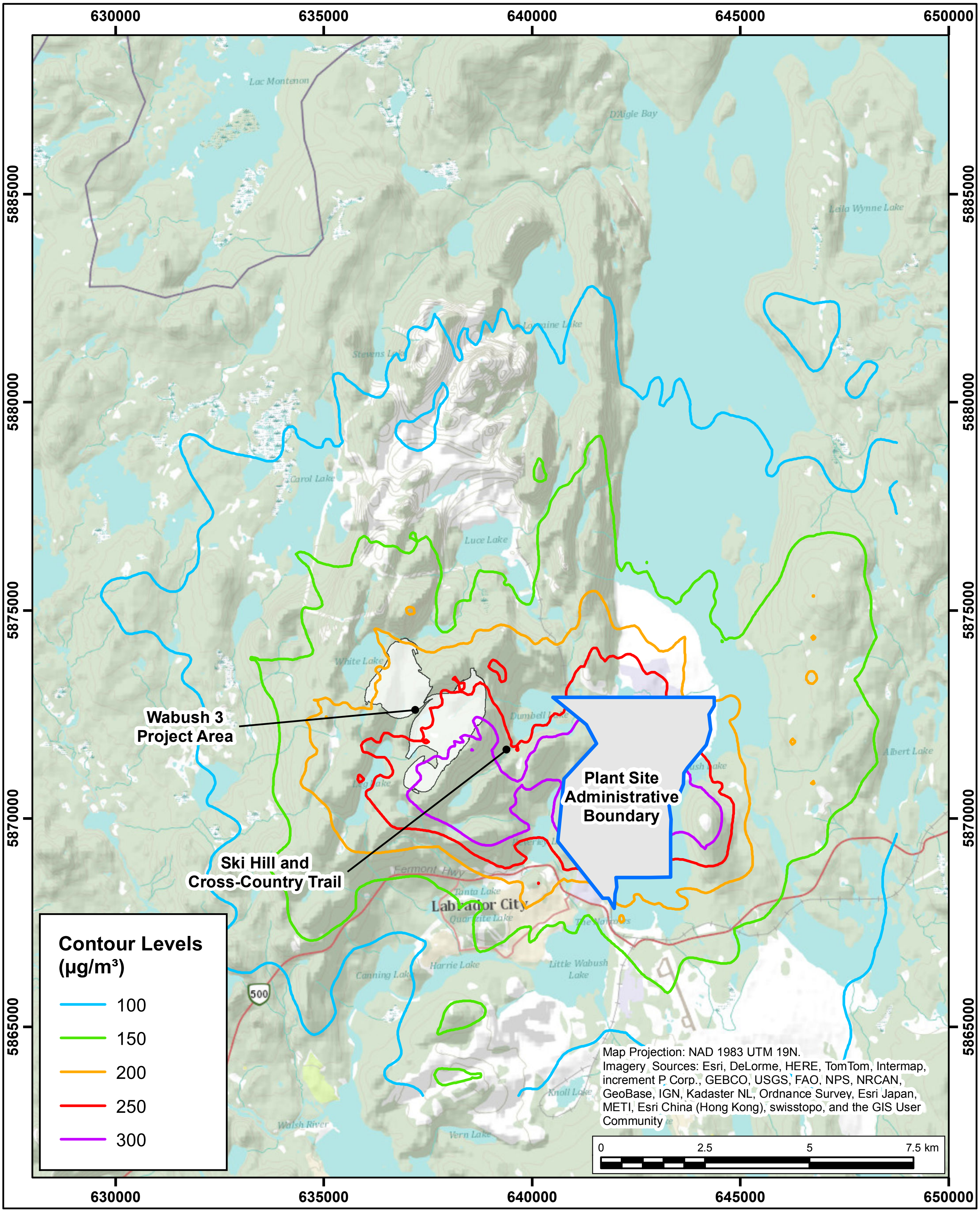
POI Limit = 8.8 µg/m³

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 29	RWDI
Approx. Scale:	1:125,000	
Date Revised:	Apr. 28, 2014	



Sulphur Dioxide - 1 Hour Averaging Period

Future No Build Scenario

POI Limit = 900 µg/m³

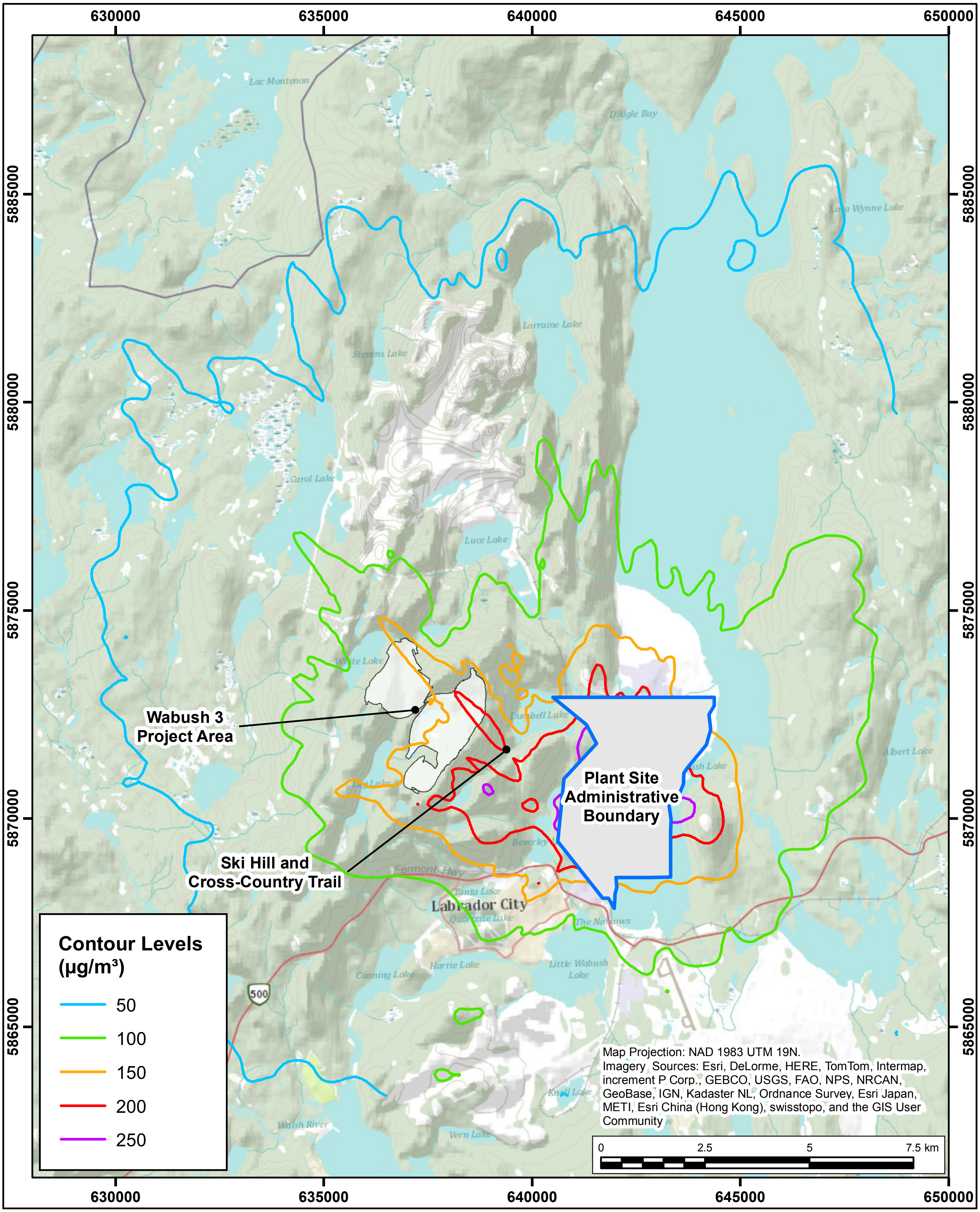
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 30
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

RWDI



Sulphur Dioxide - 3 Hour Averaging Period

Future No Build Scenario

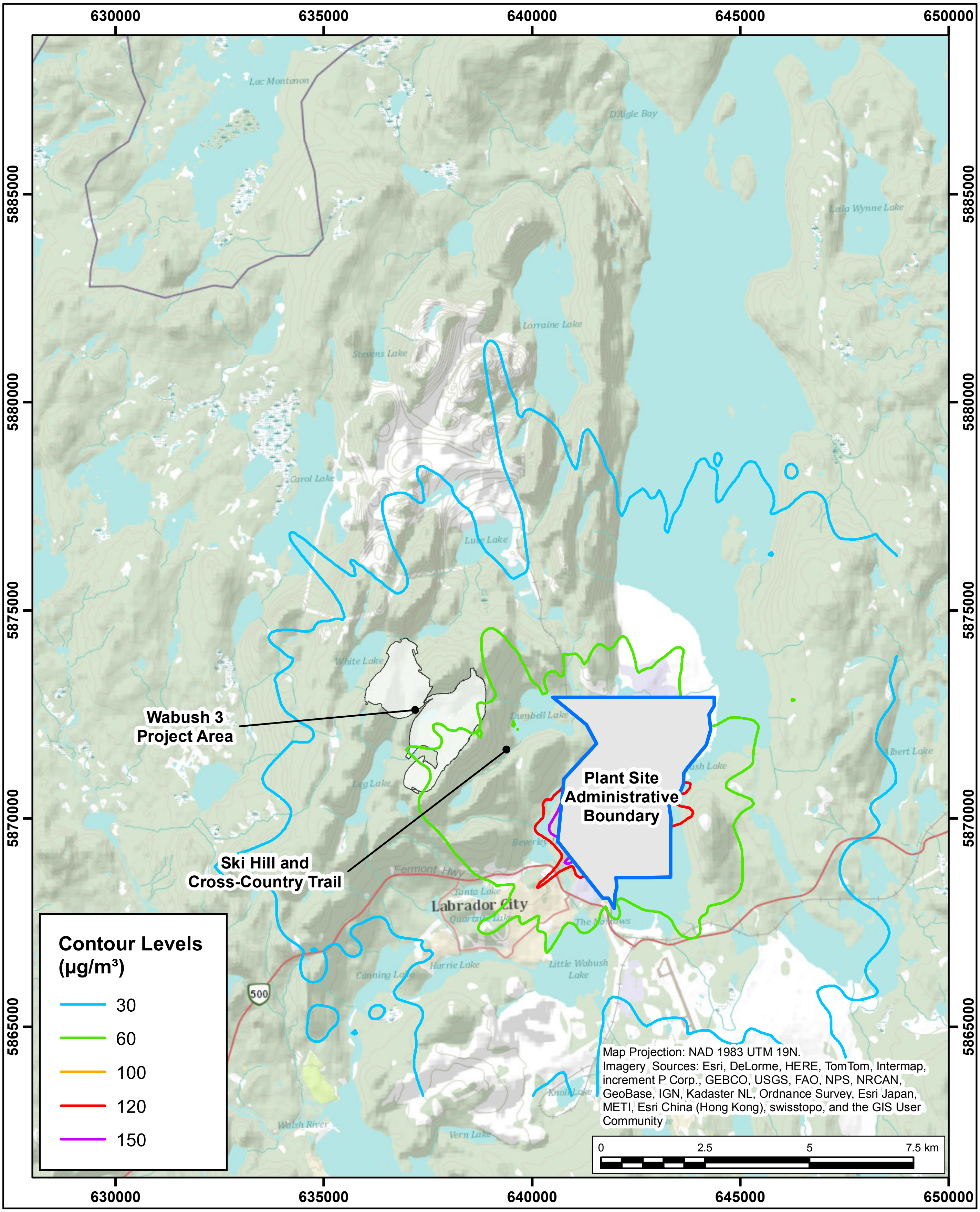
POI Limit = 600 µg/m³

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 31
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014



Sulphur Dioxide - 24 Hour Averaging Period

Future No Build Scenario

POI Limit = 300 µg/m³

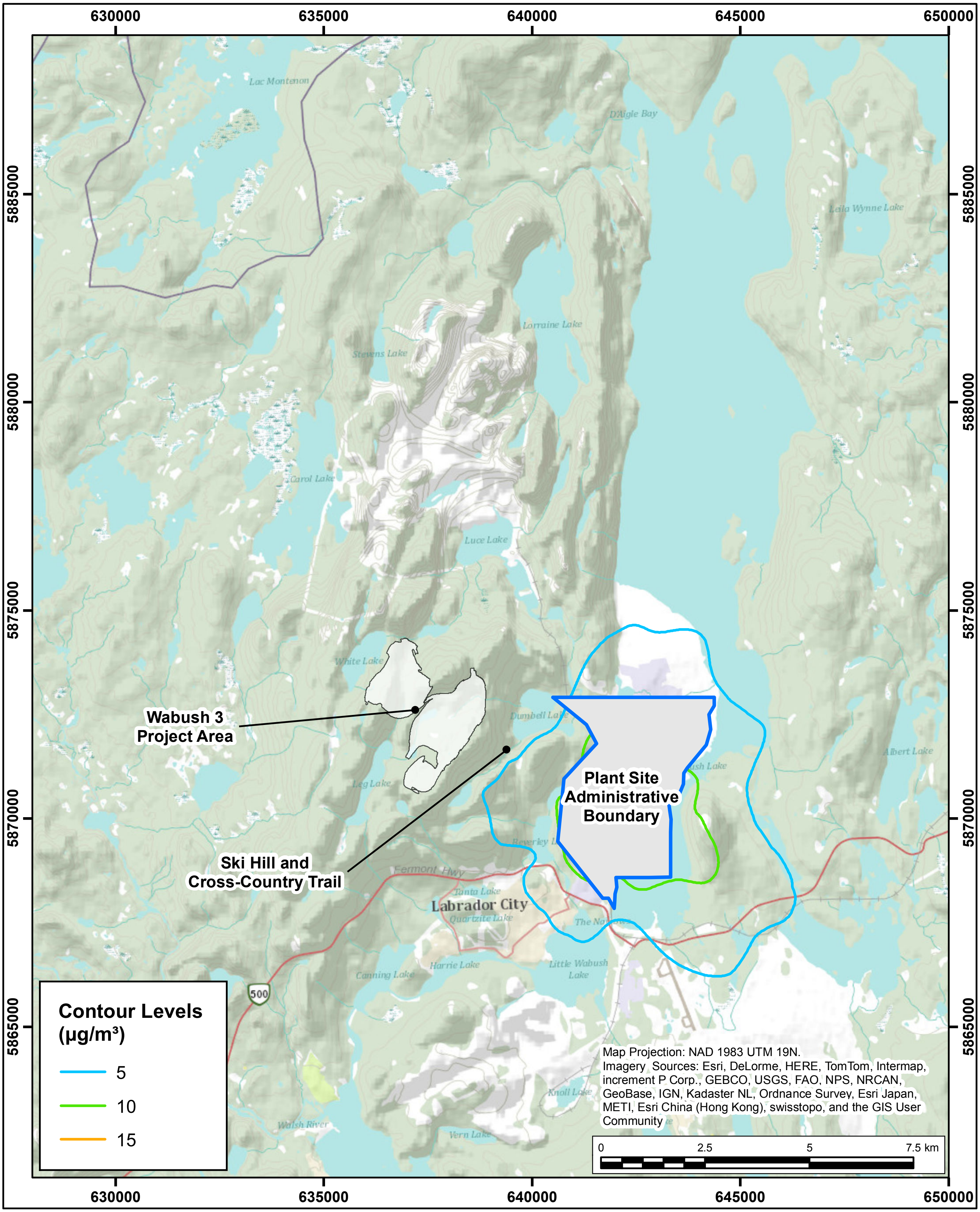
Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by:	NBN	Figure:	32
Approx. Scale:			1:125,000
Date Revised:			Apr. 28, 2014

RWDI



Sulphur Dioxide - Arithmetic Annual Averaging

Future No Build Scenario

POI Limit = 60 µg/m³

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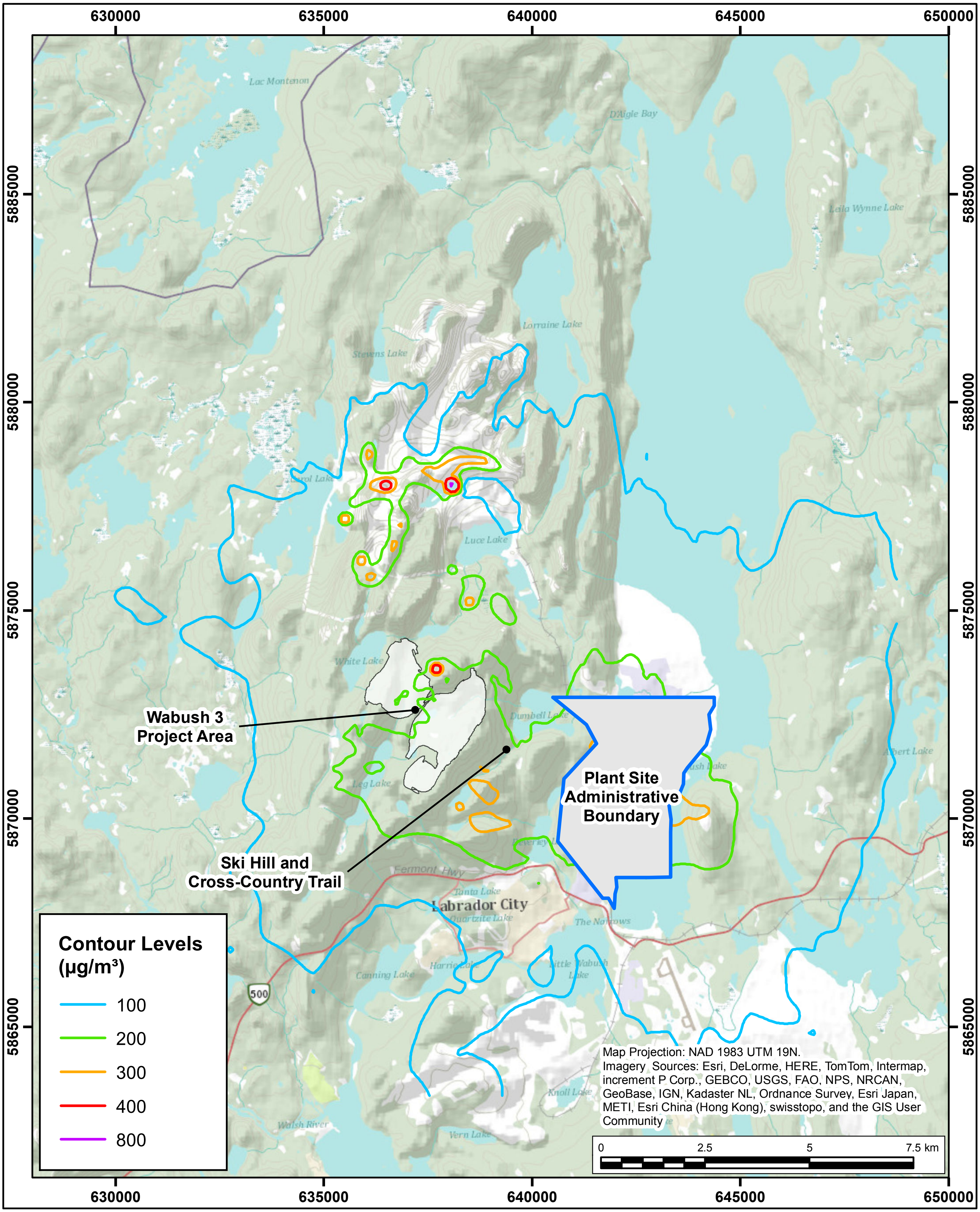
Project #1400675

Drawn by: NBN	Figure: 33
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

RWDI



Carbon Monoxide - 1 Hour Averaging Period

Future No Build Scenario

POI Limit = 35,000 µg/m³

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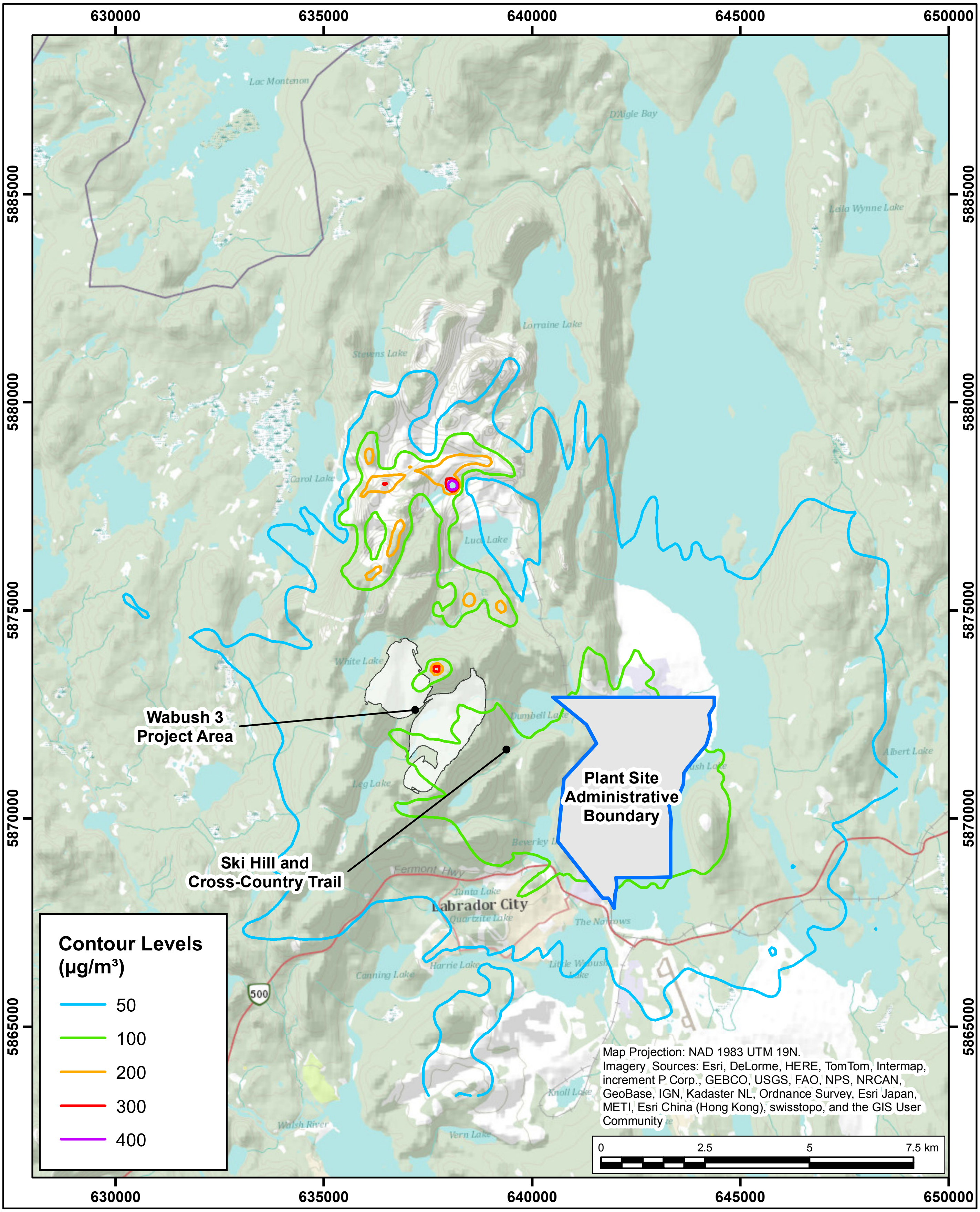
Project #1400675

Drawn by: NBN	Figure: 34
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

RWDI



Carbon Monoxide - 8 Hour Averaging Period

Future No Build Scenario

POI Limit = 15,000 µg/m³

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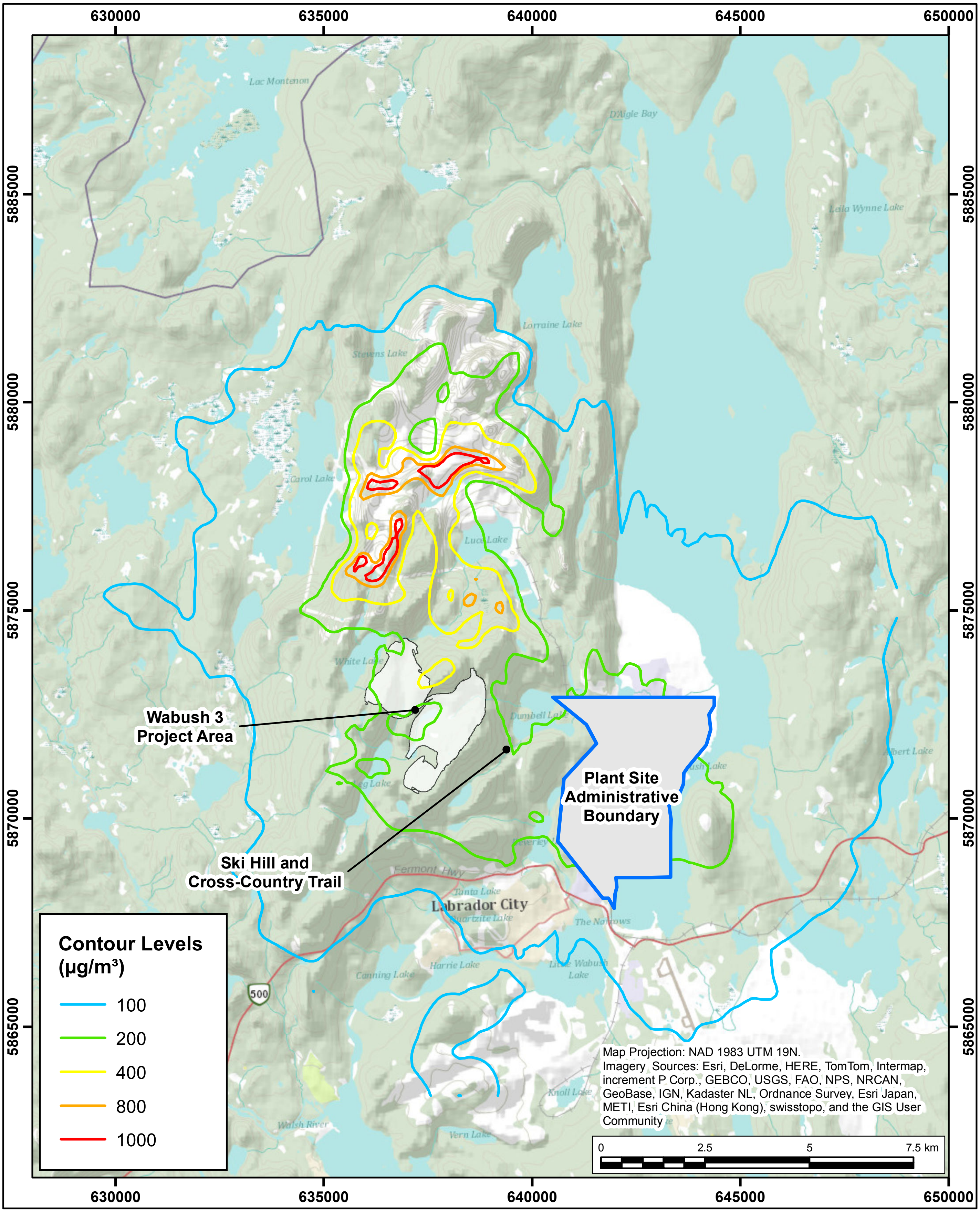
True North

Project #1400675

Drawn by: NBN	Figure: 35
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

RWDI



Nitrogen Dioxide - 1 Hour Averaging Period

Future No Build Scenario

POI Limit = 400 µg/m³

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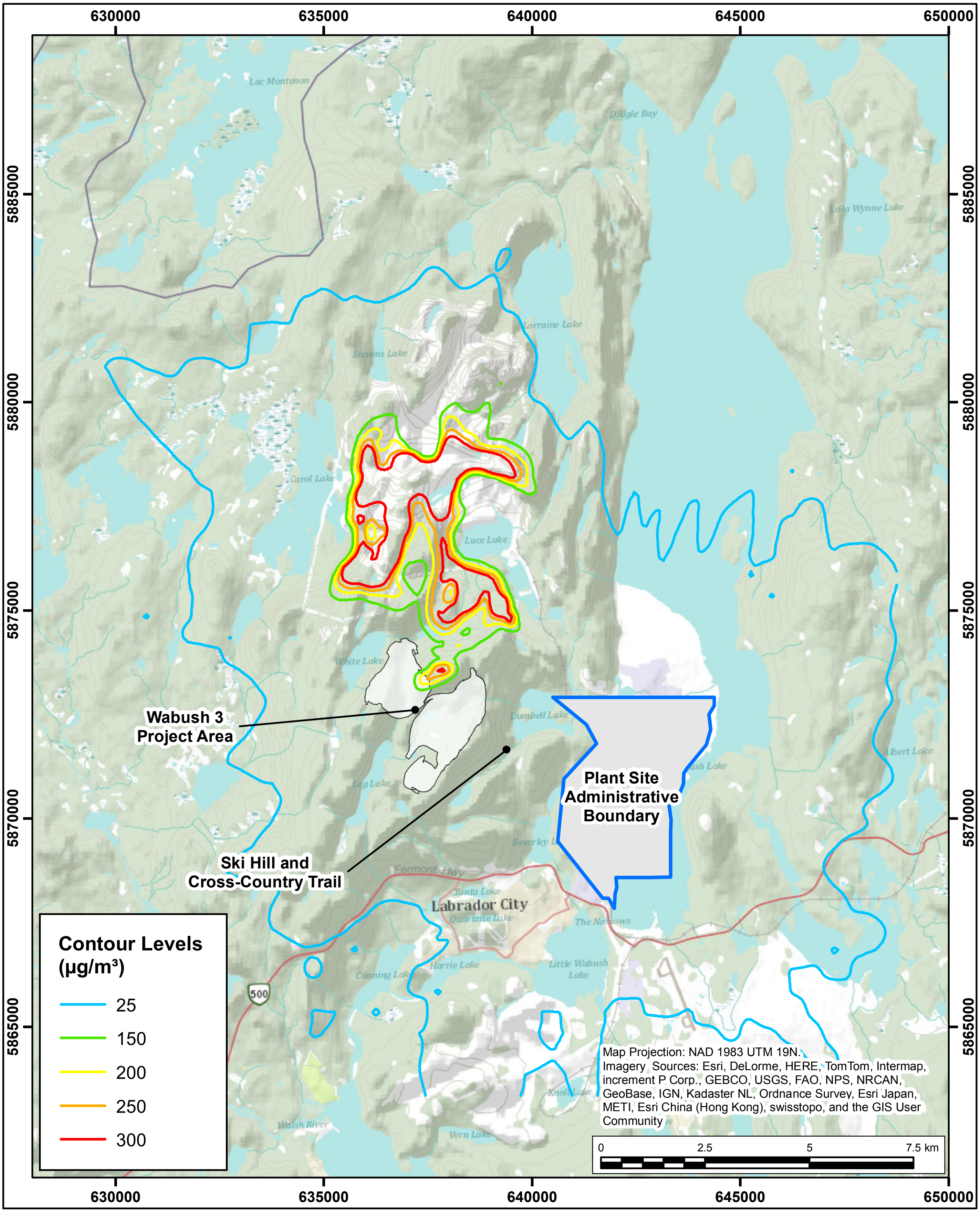
True North

Project #1400675

Drawn by: NBN	Figure: 36
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

RWDI



Nitrogen Dioxide - 24 Hour Averaging Period

Future No Build Scenario

POI Limit = 200 µg/m³

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True North

Project #1400675

Drawn by: NBN	Figure: 37
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

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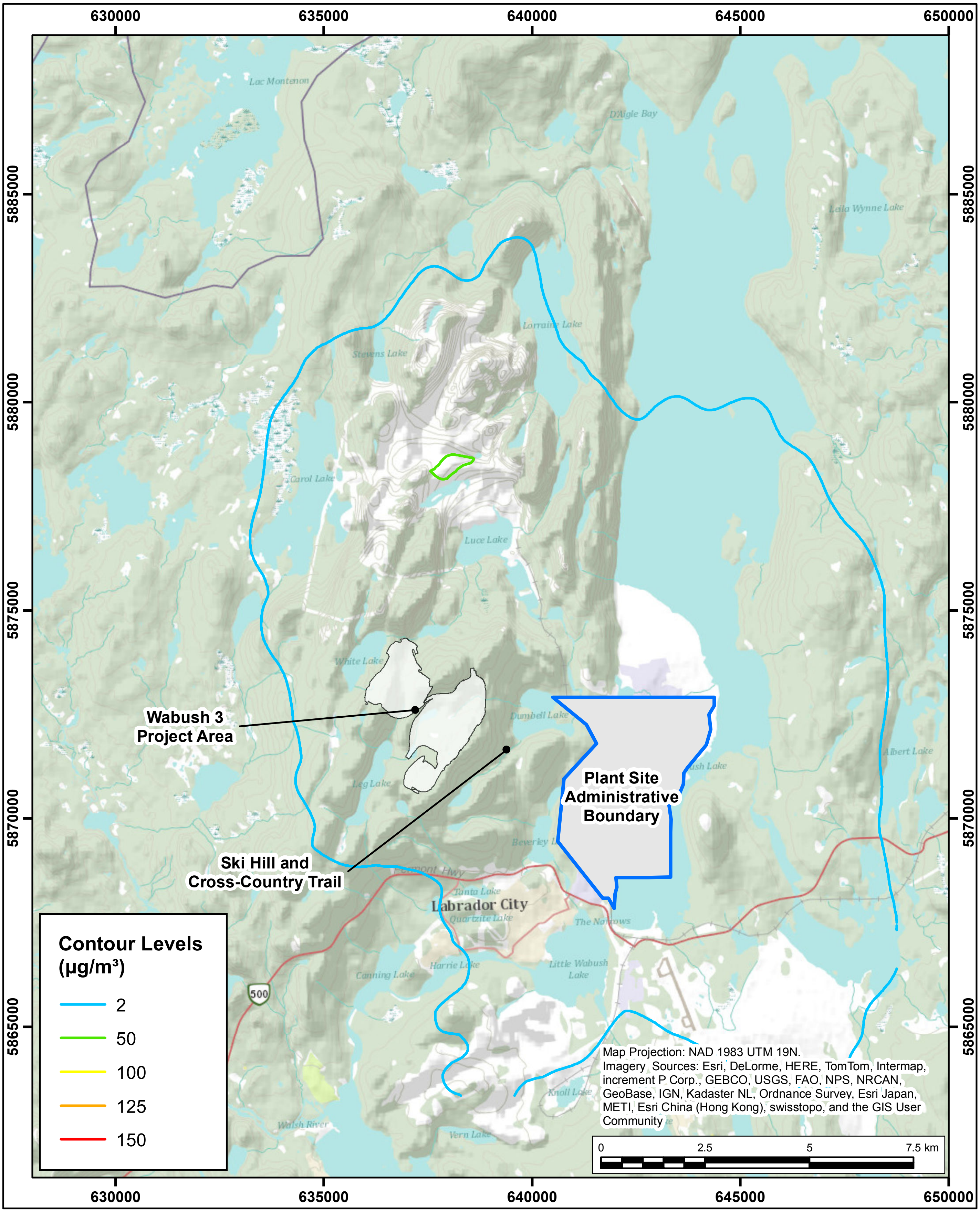

Nitrogen Dioxide - Arithmetic Annual Averaging

Future No Build Scenario

POI Limit = 100 μg/m³

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True North

Project #1400675

Drawn by: NBN	Figure: 38
Approx. Scale:	1:125,000
Date Revised:	Apr. 28, 2014

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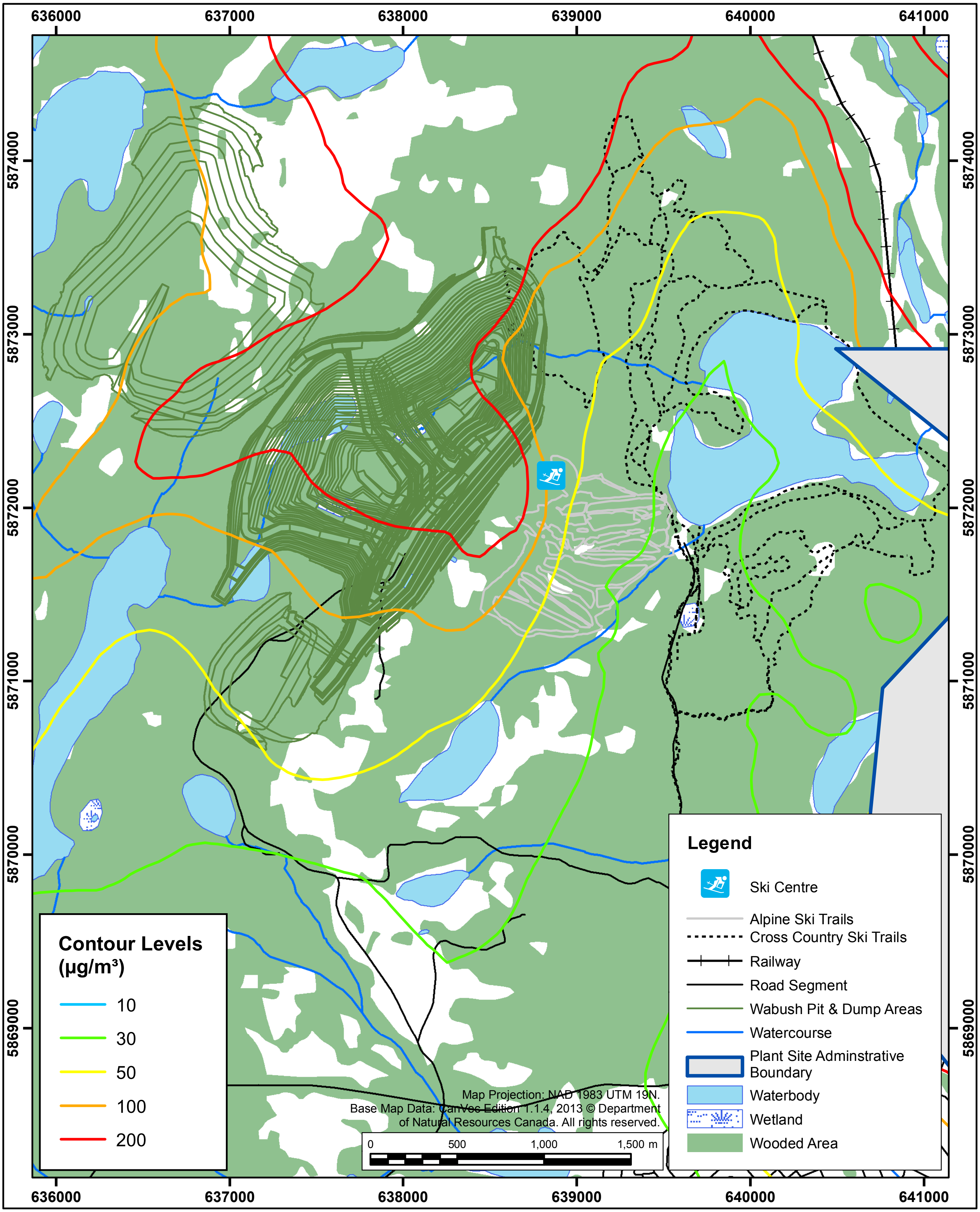

PM10 - 24 Hour Averaging Period
Future Build Scenario
POI Limit = 50 µg/m³

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

True North

Project #1400675

Drawn by: NBN	Figure: 39
Approx. Scale:	1:30,000
Date Revised:	Apr. 29, 2014

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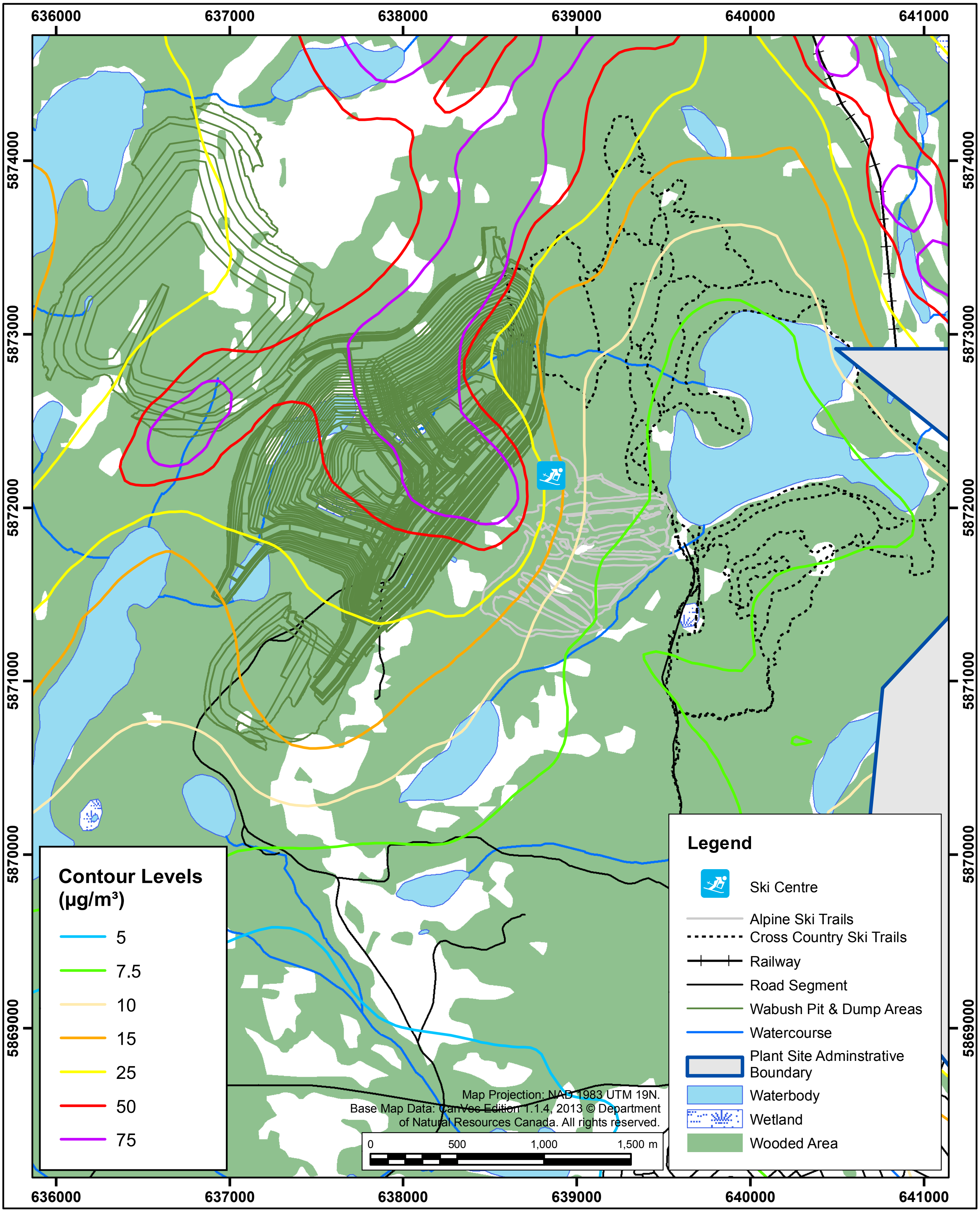

PM2.5 - 24 Hour Averaging Period

Future Build Scenario

POI Limit = 25 µg/m³

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True North

Project #1400675

Drawn by: NBN	Figure: 40
Approx. Scale:	1:30,000
Date Revised:	Apr. 29, 2014

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APPENDIX A

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CONSULTING ENGINEERS & SCIENTISTS

CANADA'S BEST MANAGED COMPANIES

Iron Ore Company
Labrador City, NL

Report

Air Quality Assessment Blasting Emissions
RWDI # 1400675
May 13, 2014

SUBMITTED TO
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TABLE OF CONTENTS

Tables

Figures

1. INTRODUCTION

Blasting occurs only approximately once per week, and was not included as part of the day-to-day mining operations in the dispersion modelling assessment. It is addressed separately here.

Blasting does not lend itself well to dispersion modelling. While numerical dispersion models are designed primarily for continuous emission sources, blasts are brief, transient events. The emissions are variable, depending on the configuration of the blast and the characteristics of the rock being blasted, and reliable published emissions data are scarce. As a result of these issues, dispersion modelling of emissions from blasts was not attempted. As an alternative, IOC has undertaken air quality monitoring downwind of blasts and provided RWDI with data for 2013 and 2014. The monitoring data were used to compare the air quality impact of blasts to Newfoundland and Labrador Ambient Air Quality Standards and to the predicted impacts of the various other emission sources at the mine.

2. MONITORING METHODOLOGY

The sampled parameters were PM_{10} (2014 only), carbon monoxide (CO), oxides of nitrogen (NO_X), hydrogen sulphide (H_2S), sulphur dioxide (SO_2) and total hydrocarbons (THC, as C_4H_8). PM_{10} was sampled using a DustTrak Aerosol Monitor, Model 8520, manufactured by TSI. The PM_{10} sampling relied on the factory calibration, which is based on a standard mineral dust. The other parameters were sampled using an iBrid Mx6 multigas analyzer, manufactured by Industrial Scientific Corporation. The Ibrid Mx6 was calibrated monthly, using calibration gas standards provided by Industrial Scientific.

A blast occurs approximately once per week. During each event, the intent was to position the instruments directly downwind of the blast location, at an approximate distance of 500m. This was done to the extent possible within the limitations of the rugged terrain of the mine site. In a few cases, the monitors ended up not downwind of the blast, due to a wind shift. These events have been excluded from the data presented here. Figure 1 shows an example of a typical monitoring location relative to a blast, with the concentric rings representing 500m intervals.

3. MONITORING RESULTS

Figures 2 through 8 show examples of instantaneous concentrations plotted over a 1-hour period encompassing a blast. The typical pattern consists of a brief spike in concentration, lasting on the order of one to two minutes. In the examples for SO_2 and H_2S (Figures 6 and 7), the concentrations are reported as negative values, due to the instruments being calibrated so that a positive concentration yields a negative voltage. The H_2S sensor sometimes experienced a very brief positive spike just prior to the blast for unknown reasons. In the case of SO_2, the upper end of the instrument range was 2 ppm (represented as -2 ppm in the graph), and any instantaneous concentrations above that level during a blast were recorded as 2 ppm. As a result, the sensor underestimates the instantaneous peak SO_2 levels.

Tables 1 and 2 summarize the instantaneous peak and 1-hour average concentrations measured downwind of blasts from March through September, 2013, and January through March of 2014. During some of the events, the CO and THC experienced zero drift, which could have an impact on the reported 1-hour averages. As a result, some reported 1-hour averages in the data set are negative. For the most recent data (2014), the zero drift was corrected by calculating the baseline average concentration prior to the blast and after the blast fumes had dissipated. If significantly different from zero, the baseline average concentration was subtracted from the overall 1-hour average concentration.

Due to the brief nature of the events, the average concentrations over the 1-hour periods encompassing the blast are significantly lower in magnitude than the instantaneous peaks. The 1-hour averaged concentrations of gaseous contaminants are well correlated to each other. For example, Figure 9 shows the correlation between CO and NO. The correlation coefficient is relatively high (R^2 = 0.74). There is also a correlation between PM_{10} measurements and gaseous pollutants, as shown in Figure 10, but it is weaker. PM_{10} was measured only during 2014 and, consequently, the number of samples is relatively small. Although the correlation is weaker (R^2 = 0.39), the regression was used to make an approximate estimate of PM_{10} levels during the 2013 measurement campaign, when PM_{10} was not directly measured. Those estimates are included in Tables 1 and 2.

4. WORST-CASE 1-HOUR CONCENTRATIONS OF GASES

Some of the contaminants measured during the monitoring program have short-term (1-hour) ambient air standards within Newfoundland and Labrador Regulation 39/04. Table 3a compares the measured 1-hour averaged concentrations to those standards. The concentrations of all contaminants vary widely from one event to another, due to the many factors that come into play (wind speed, atmospheric stability, topography around the blast location, siting of the instruments, variations in the blast pattern, etc.). Table 3 shows both the average and maximum value of the 1-hour concentrations from among the various blast events.

The maximum 1-hr concentrations of CO, and SO_2 easily complied with the standards, but both the average and maximum values of the 1-hr NO_2 and H_2S concentrations exceeded the standard. Note that this was occurring at locations within the mine site, at approximately 500m away from the blast.

The plume of contaminants from a blast spreads laterally and vertically as it travels downwind and, as a result, the concentrations decrease with distance. Making the approximate assumption that the concentrations are related to the square of the distance from the source, then concentrations can be estimated at farther distances than 500m. Table 3b shows estimated concentrations at a distance of 1200m, which corresponds approximately to the clearance zone that IOC maintains for explosion safety reasons during blasts. During the average event, the 1-hr concentrations of all contaminants, including NO2 and H2S are well below the standards at this distance. During the worst-case event, the 1-hour NO_2 concentration is close to meeting the standard, while the 1-hour H2S concentration remains well above the standard. The worst-case 1-hour H_2S concentration was estimated to meet at a downwind distance of approximately 2700m. These are approximate estimates that will be affected by topography and possibly other factors.

Note that blasts are brief events that occur infrequently. Within the proposed Wabush 3 mining area, the anticipated frequency of blasts is only approximately 2 per month. In some of these cases, the wind direction will be such that emissions are directed away from the nearby downhill ski and cross-country recreation areas. In addition, only approximately 6% and 15% of the monitoring events shown in Table 2 had downwind NO_2 and H_2S concentrations estimated to be above the NL standard outside the 1200m clearance zone. Taking these factors into consideration, it is concluded that the worst-case scenario of 1-hr NO_2 and H_2S concentrations exceeding the NL standard outside the safety clearance zone in the recreational areas will be very infrequent.

5. WORST-CASE 24-HOUR CONCENTRATIONS OF GASES AND PM_{10}

Since the blasts are brief events, with no more than one blast occurring on a single day, their contribution to 24-hour concentrations is generally small and has little implication for compliance with 24-hour standards. Table 4 summarizes the data on the 24-hour contributions, and shows that the contributions were small compared to the applicable standards, with the exception of the maximum 24-hour H_2S.

In the case of H_2S, the average value across all events was well below the 24-hour standard, but the maximum value was above it. Recall that the measurements took place at an approximate distance of 500m from the blast. Assuming once again that the concentration decreased in relation to the square of the distance from the source, the 24-hour H_2S concentration in the worst-case event fell within the standard at a distance of approximately 900m from the source. This distance is within the 1200m safety clearance zone maintained by IOC on blast days.

6. IMPLICATIONS FOR DUST DEPOSITION

The impact of the blasts on dust deposition (*i.e.,* dustfall) in the surrounding area can be inferred from the monitoring results for inhalable airborne particulate matter, PM_{10}. Table 4 shows that the contribution of the blasts to 24-hour concentrations of PM_{10} is small compared to the predicted contribution from other emission sources that operate at the active face (less than 10%). The predicted contribution from the other sources shown in Table 4 is based on the contour plots of maximum 24-hour PM_{10}, as predicted by the CALPUFF dispersion model (shown previously).

Similarly, it is expected that the blast contributions to total suspended particulate matter (TSP) and dustfall are also small in relation to the contribution from the other sources. Together with the fact that blasts occur only approximately once per week in total, and only about twice per month in the Wabush 3 mining area, this means that blasting has only minor implications for dustfall levels.

7. CONCLUSION

The air monitoring data suggest that 1-hr contaminant concentrations associated with blasts will not exceed the applicable 1-hr and 24-hr NL standards outside the 1200m safety clearance zone that IOC maintains on blast days. Therefore, the safety clearance zone adequately addresses short-term pollutant levels during blasts. A key exception is 1-hr H_2S during a worst-case blasting event, when the NL standard is estimated to be exceeded to a distance of 2700m from the blast. The maximum 1-hr NO_2 concentration during a worst-case blast event also exceeds the NL standard beyond the 1200m clearance zone, but only slightly. Blasts are expected to occur only approximately twice per month in the proposed Wabush 3 mining area, and the majority of the blasts experience much lower H_2S and NO_2 levels than the worst-case event. Therefore, the potential for the 1-hr H2S standard to be exceeded outside the clearance zone in the downhill ski and cross-country ski recreational area is low.

Blasts also contribute along with other emission sources (trucks, loaders, dozers, etc.) to 24-hour average concentrations of some contaminants (CO, NO_2, PM). The data indicate that the contribution is small compared to that of the other sources, and generally not significant.

The blasts will also contribute to long-term dust deposition off site, but since the blasts make only a small contribution to 24-hour airborne dust levels compared to other emissions sources that operate at the active face, and since they occur infrequently, they make only a small contribution to overall dust deposition (dustfall) and can be ignored.

APPENDIX A TABLES

Table 1: Instantaneous Peak Concentrations during a Selection of Blasts from 2013 and 2014

Date	Peak PM_{10}* (mg/m^3)	Peak CO (ppm)	Peak NO (ppm)	Peak NO_2 (ppm)	Peak SO_2 (ppm)	Peak H_2S (ppm)	Peak THC as C_4H_8 (ppm)
08/03/2013	1.3	13	8	0.7	0.6	0	0.3
28/03/2013	0.8	7	5	0.5	0.4	0.4	0.9
01/04/2013	8.4	101	51	14	2	0.8	11
05/04/2013	18.3	156	111	73	2	10	23
25/04/2013	4.3	56	26	4	2	0.5	6.2
28/04/2013	36.0	214	219	71	2	10	40
10/05/2013	1.0	9	6	0.3	0.3	0	1
14/05/2013	1.0	5	6	1.5	1.4	0	0.7
26/05/2013	9.9	73	60	28	2	4.1	12
11/06/2013	2.5	36	15	2.4	2	0	2.2
21/06/2013	1.5	19	9	0.3	0.3	0	0.8
24/06/2013	28.1	261	171	120	2	10	28
05/07/2013	7.1	71	43	13	2	1.6	6.9
08/07/2013	11.8	43	72	8.7	2	0	9.3
19/07/2013	2.3	19	14	1.7	1.2	0	1.4
22/07/2013	6.3	78	38	7.6	2	0.6	8.1
24/07/2013	7.4	104	45	7.3	2	0.8	8.9
17/08/2013	3.0	24	18	2.2	2	0.6	1.8
23/08/2013	4.4	36	27	2.6	2	0.5	4.8
02/09/2013	3.6	28	22	2.2	1.9	0	3.5
05/09/2013	15.1	94	92	20	2	1.6	17
10/09/2013	8.6	94	52	12	2	1	11
19/09/2013	1.8	13	11	4.1	2	0.5	1.9
26/09/2013	4.4	66	27	1.4	1.2	0.8	5.1
28/09/2013	10.4	96	63	19	2	1.7	12
28/01/2014	11.3	117	160	36	2	1.8	26
03/02/2014	0.7	6	7	1.9	1.9	0	0.7
24/02/2014	0.092	5	4	0.8	0.8	0	0.4
28/02/2014	20	120	74	21	2	1.5	18
04/03/2014	1.4	3	2	0.5	0.5	0	0.9
07/03/2014	8.1	52	35	14.7	2	2.1	6.6
23/03/2014	0.98	89	48	19	2	2.4	11

* During 2013, PM_{10} was not recorded, but was estimated using PM_{10}-NO correlation from 2014 data

Table 2: 1-hour Average Concentrations During Blasts in 2013 and 2014

Date	1-hr PM_{10}* (mg/m^3)	1-hr CO (ppm)	1-hr NO (ppm)	1-hr NO_2 (ppm)	1-hr SO_2 (ppm)	1-hr H_2S (ppm)	1-hr THC as C_4H_8 (ppm)
08/03/2013	0.073	1.2	0.69	0.039	0.03	0	0.00025
28/03/2013	0.018	0.32	0.17	0.015	0.013	0.0005	0.18
01/04/2013	0.148	2.8	1.4	0.24	0.083	0.082	0.39
05/04/2013	0.275	3.1	2.6	1.3	0.26	0.32	0.91
25/04/2013	0.059	0.84	0.56	0.071	0.058	0.0016	0.77
28/04/2013	0.243	2.4	2.3	0.71	0.07	0.12	0.52
10/05/2013	0.007	0.14	0.069	0.003	0.0028	0	0.18
14/05/2013	0.057	0.47	0.54	0.16	0.15	0	0.094
26/05/2013	0.158	1.45	1.5	0.58	0.075	0.11	1.08
11/06/2013	0.048	0.77	0.45	0.061	0.048	0	0.023
21/06/2013	0.023	0.47	0.22	0.0082	0.0019	0	0.0082
24/06/2013	0.243	3.7	2.3	1.25	0.097	0.18	0.0092
05/07/2013	0.086	0.98	0.81	0.21	0.057	0.021	-0.97
08/07/2013	0.027	-1.6	0.26	0.14	0.0122	0	-0.53
19/07/2013	0.048	-0.84	0.45	0.1	0.022	0	-0.58
22/07/2013	0.090	0.9	0.85	0.12	0.055	0.00345	0.15
24/07/2013	0.137	2.2	1.3	0.2	0.1	0.012	0.47
17/08/2013	0.060	0.71	0.57	0.45	0.037	0.0042	-0.54
23/08/2013	0.048	0.57	0.45	0.037	-0.031	0.00076	0.072
02/09/2013	0.056	0.75	0.53	0.052	0.043	0	0.048
05/09/2013	0.148	1.8	1.4	0.23	0.065	0.016	0.73
10/09/2013	0.232	3.3	2.2	0.38	0.14	0.032	0.38
19/09/2013	0.084	0.88	0.8	0.21	0.17	0.0024	0.26
26/09/2013	0.275	4.4	2.6	0.19	0.17	0.0093	0.62
28/09/2013	0.137	1.6	1.3	0.25	0.06	0.018	0.17
28/01/2014	0.092	1.6	1.3	0.25	0.044	0.029	0.32
03/02/2014	0.019	0.19	0.11	0.036	0.032	0.00082	0.0064
24/02/2014	0.008	0.1	0.079	0.019	0.02	0	0.0022
28/02/2014	0.15	1.7	1.5	0.34	0.043	0.00011	0.51
04/03/2014	0.023	0.044	0.03	0.0072	0.008	0	0.0067
07/03/2014	0.13	0.8	0.72	0.23	0.069	0.034	0.091
23/03/2014	0.021	1.9	1.2	0.33	0.12	0.034	0.2

* During 2013, PM_{10} was not recorded, but was estimated using PM_{10}-NO correlation from 2014 data

Table 3a: Comparison of 1-hour Concentrations to NL Standards at ~500m from blast

	PM_{10} (mg/m^3)	CO (ppm)	NO (ppm)	NO_2 (ppm)	SO_2 (ppm)	H_2S (ppm)	THC as C_4H_8 (ppm)
Average	0.10	1.24	0.98	0.26	0.066	0.032	0.17
Maximum	0.27	4.40	2.60	1.30	0.26	0.32	1.08
1-hr Ambient Standard	n/a	31	n/a	0.21	0.35	0.011	n/a

Table 3b: Comparison of Estimated 1-hour Concentrations to NL Standards at 1200m from blast

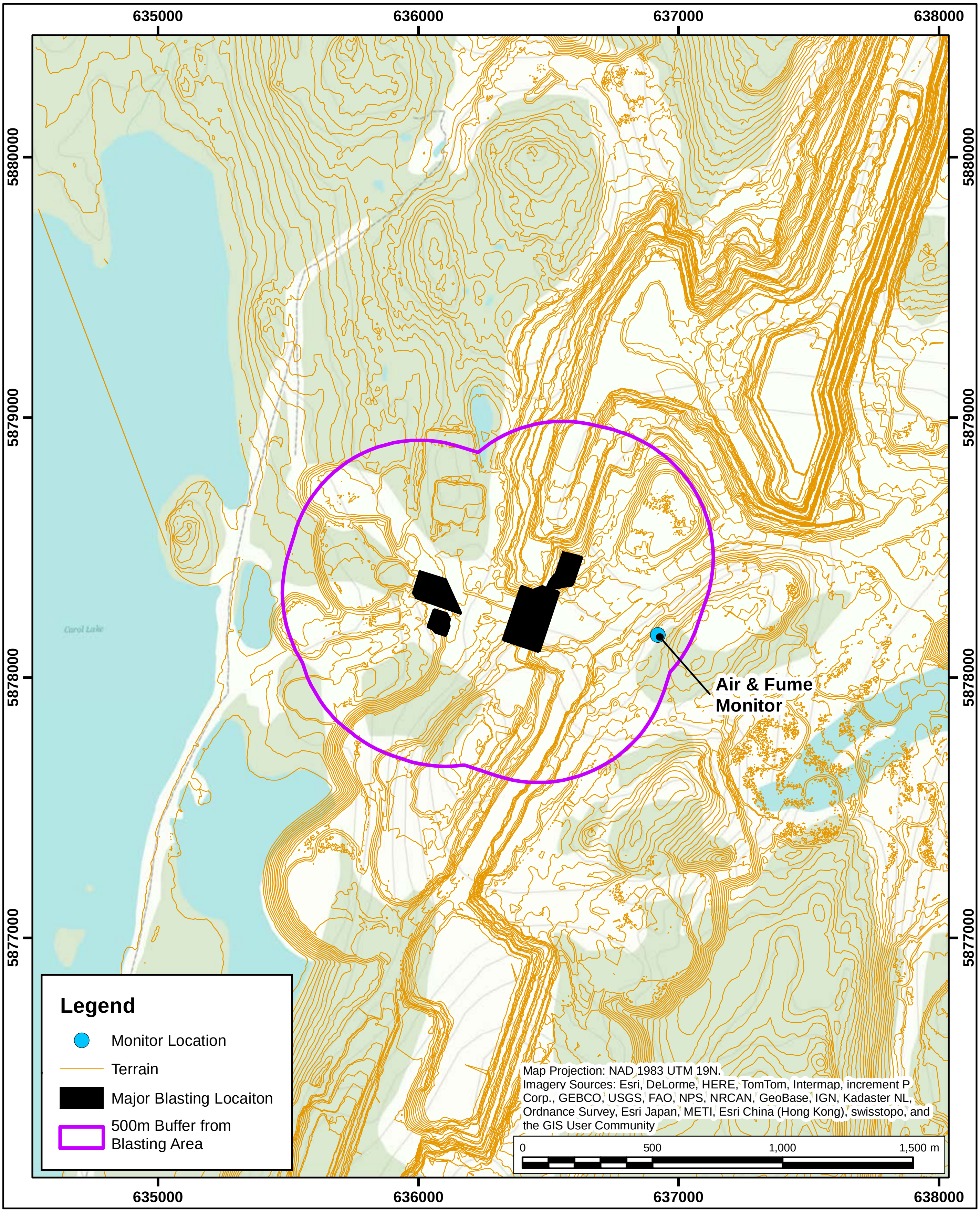
	PM_{10} (mg/m^3)	CO (ppm)	NO (ppm)	NO_2 (ppm)	SO_2 (ppm)	H_2S (ppm)	THC as C_4H_8 (ppm)
Average	0.017	0.215	0.17	0.045	0.012	0.006	0.03
Maximum	0.048	0.764	0.45	0.23	0.045	0.056	0.19
1-hr Ambient Standard	n/a	31	n/a	0.21	0.35	0.011	n/a

Table 4: Comparison of 24-hour Concentrations to NL Standards at ~500m from Blast

	PM_{10} (mg/m^3)	CO (ppm)	NO (ppm)	NO_2 (ppm)	SO_2 (ppm)	H_2S (ppm)	C_4H_8 (ppm)
Max Contribution: Other Sources*	~ 0.15	n/a	n/a	~ 0.1	n/a	n/a	n/a
Average Blast Contribution	0.004	0.052	0.041	0.011	0.003	0.001	0.007
Max Blast Contribution	0.011	0.183	0.108	0.054	0.011	0.013	0.045
24-hr Ambient Standard	0.05	n/a	n/a	0.1	0.12	0.004	n/a

*Contribution from other sources is based on contour plots of maximum 24-hr PM_{10}, derived from CALPUFF modelling, and shown elsewhere in this report

APPENDIX A FIGURES



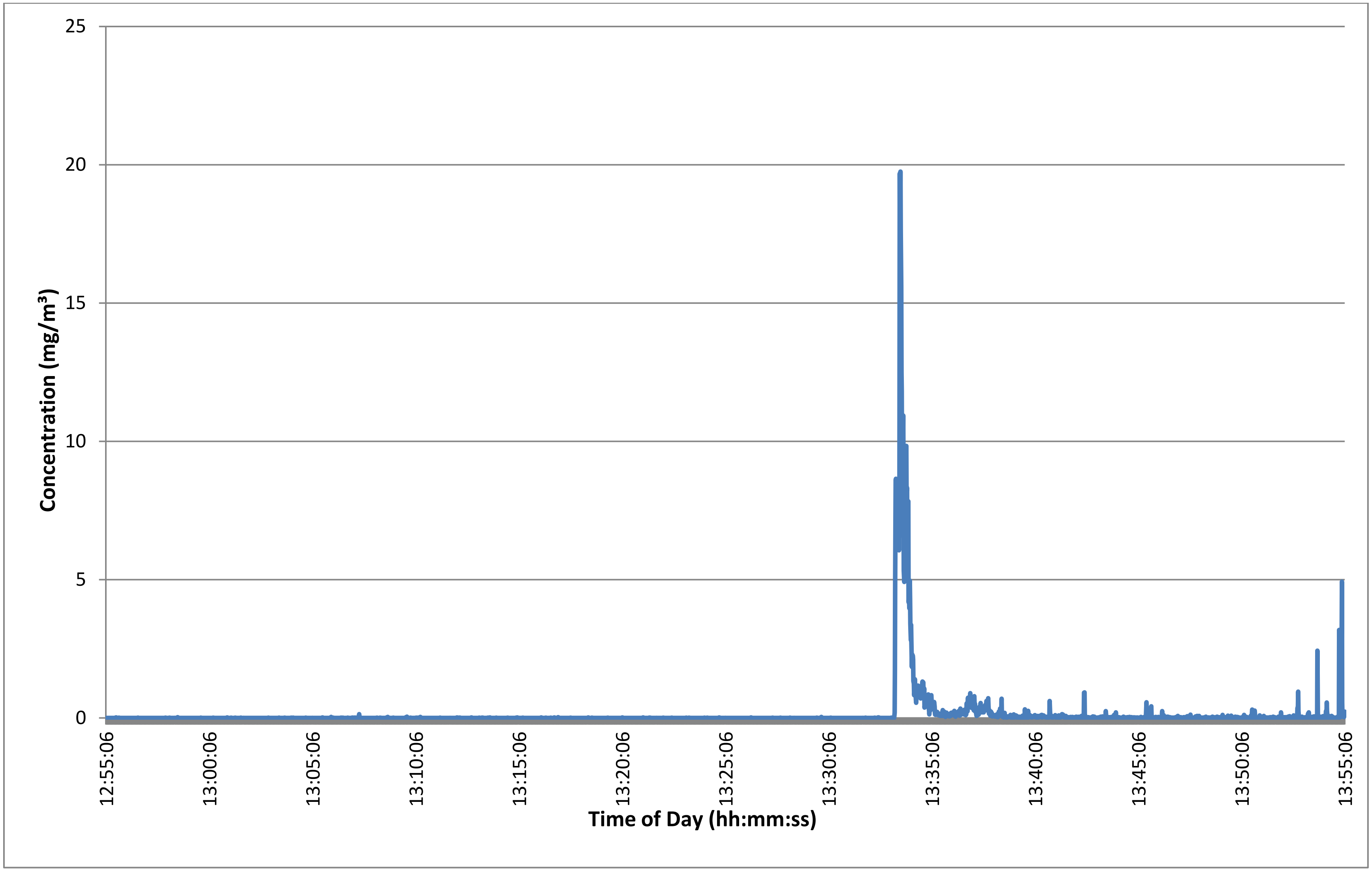
Location of Blast and Air Monitors at Sherwood Pit on Feb. 28, 2014

Iron Ore Company of Canada - Labrador City, Newfoundland and Labrador

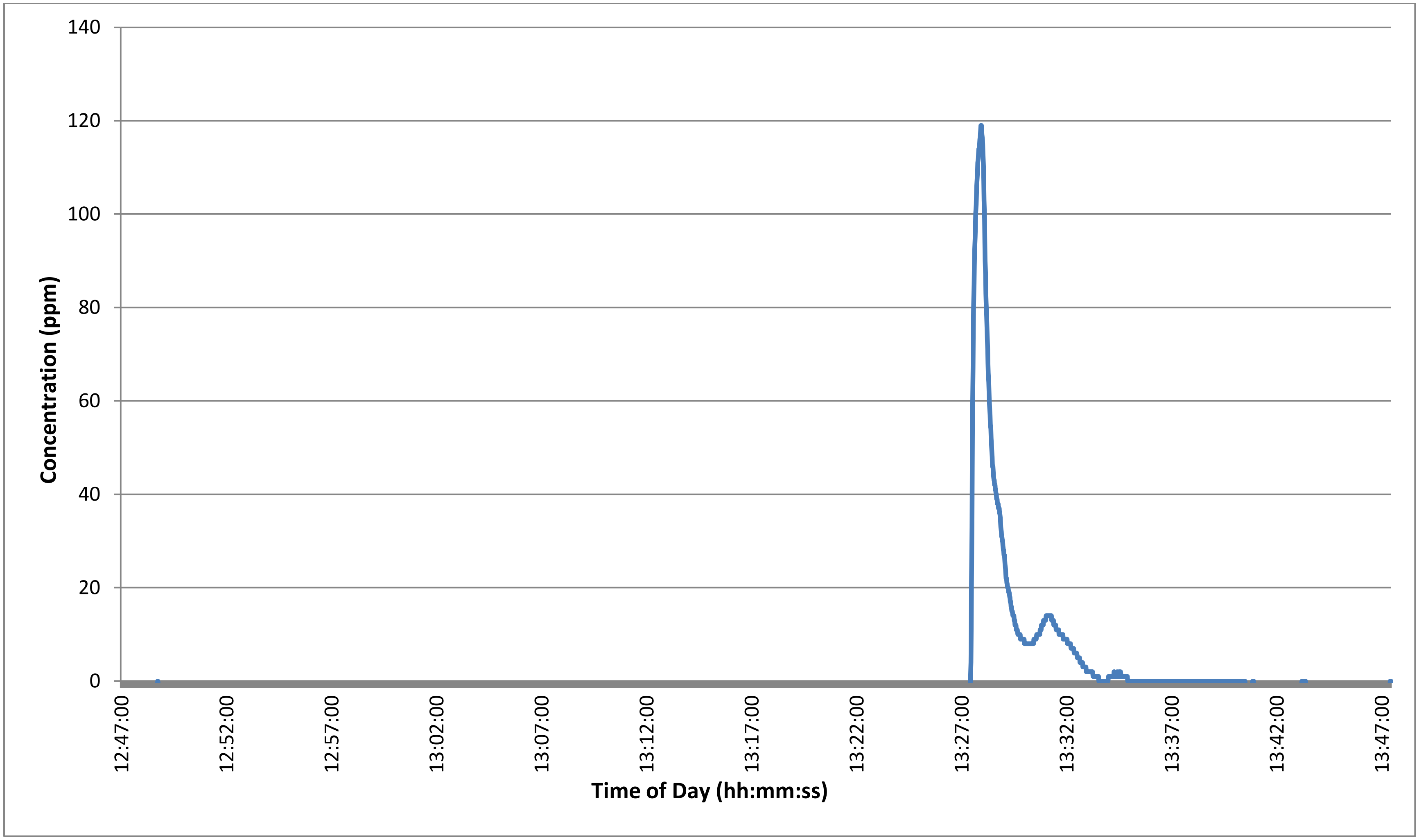
Project #1400675

Drawn by: NBN	Figure: A1
Approx. Scale:	1:20,000
Date Revised:	Apr. 3, 2014

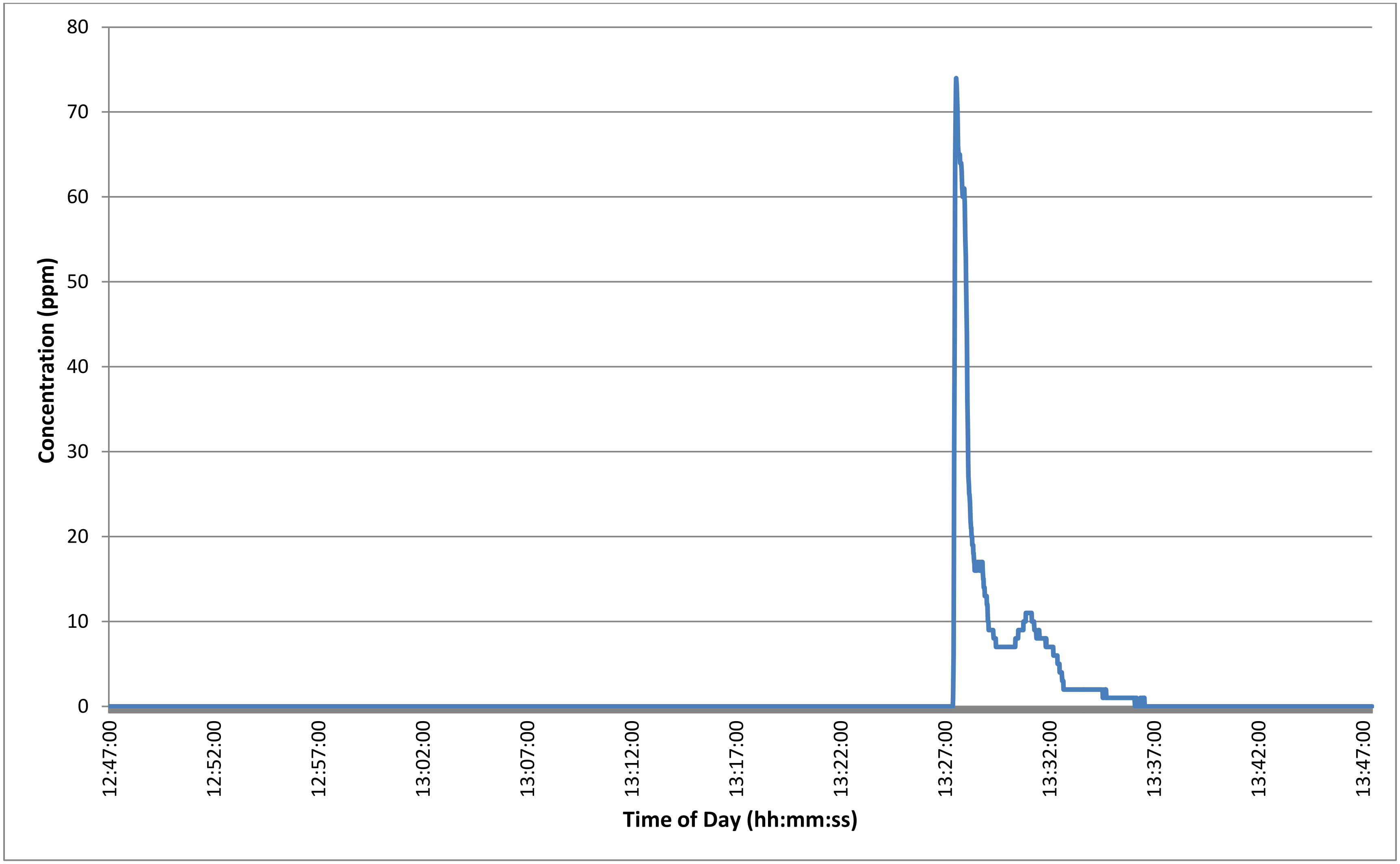
RWDI



PM_{10} (mg/m^3) on February 28, 2014	Figure No: A2	RWDI
IOC Wabush 3 Project # 1400675	Date: April 14, 2014	

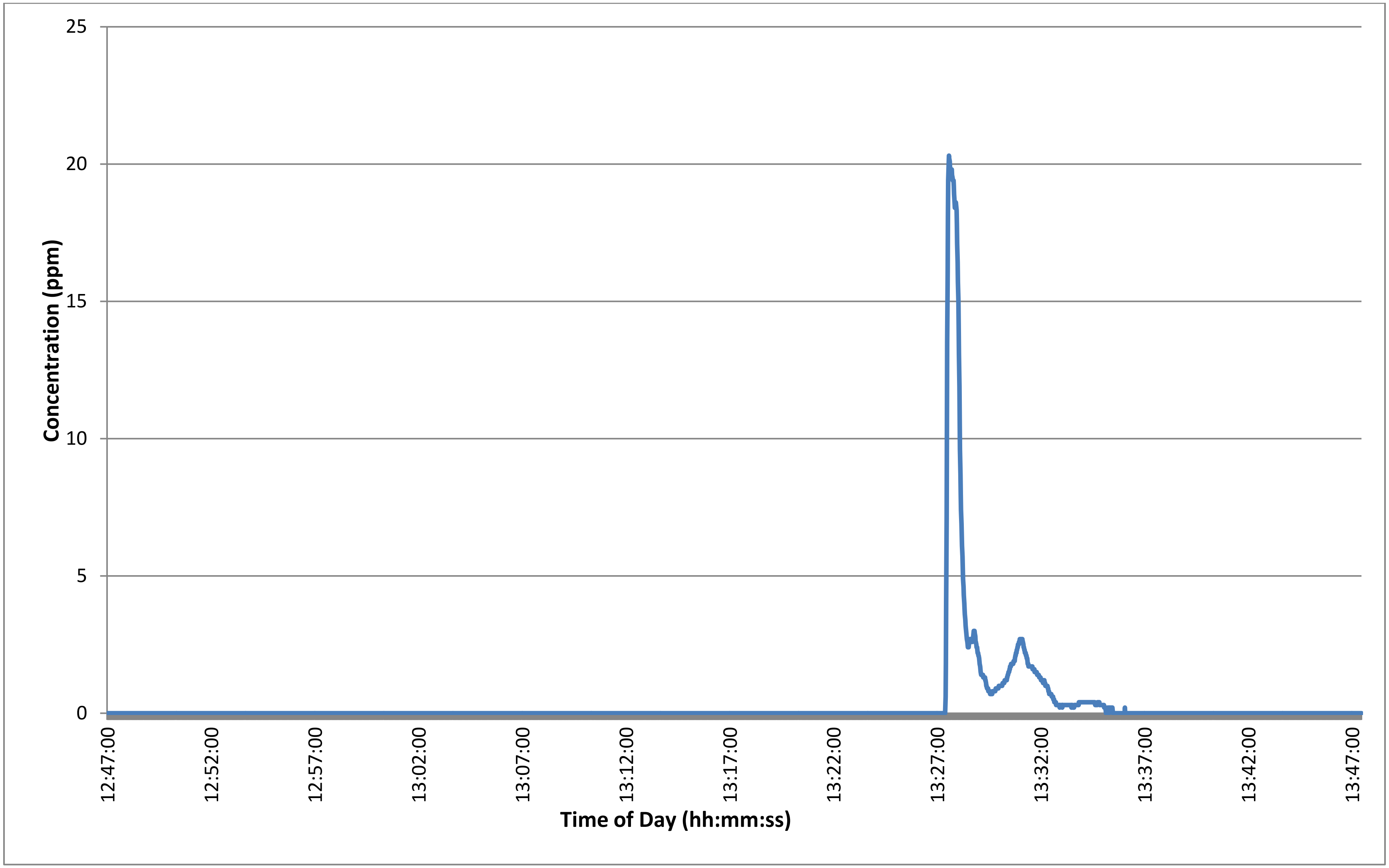


CO (ppm) on February 28, 2014		Figure No: A3	RWDI
IOC Wabush 3	Project # 1400675	Date: April 14, 2014	



NO (ppm) on February 28, 2014		Figure No: A4
IOC Wabush 3	Project # 1400675	Date: April 14, 2014

RWDI



NO_2 (ppm) on February 28, 2014

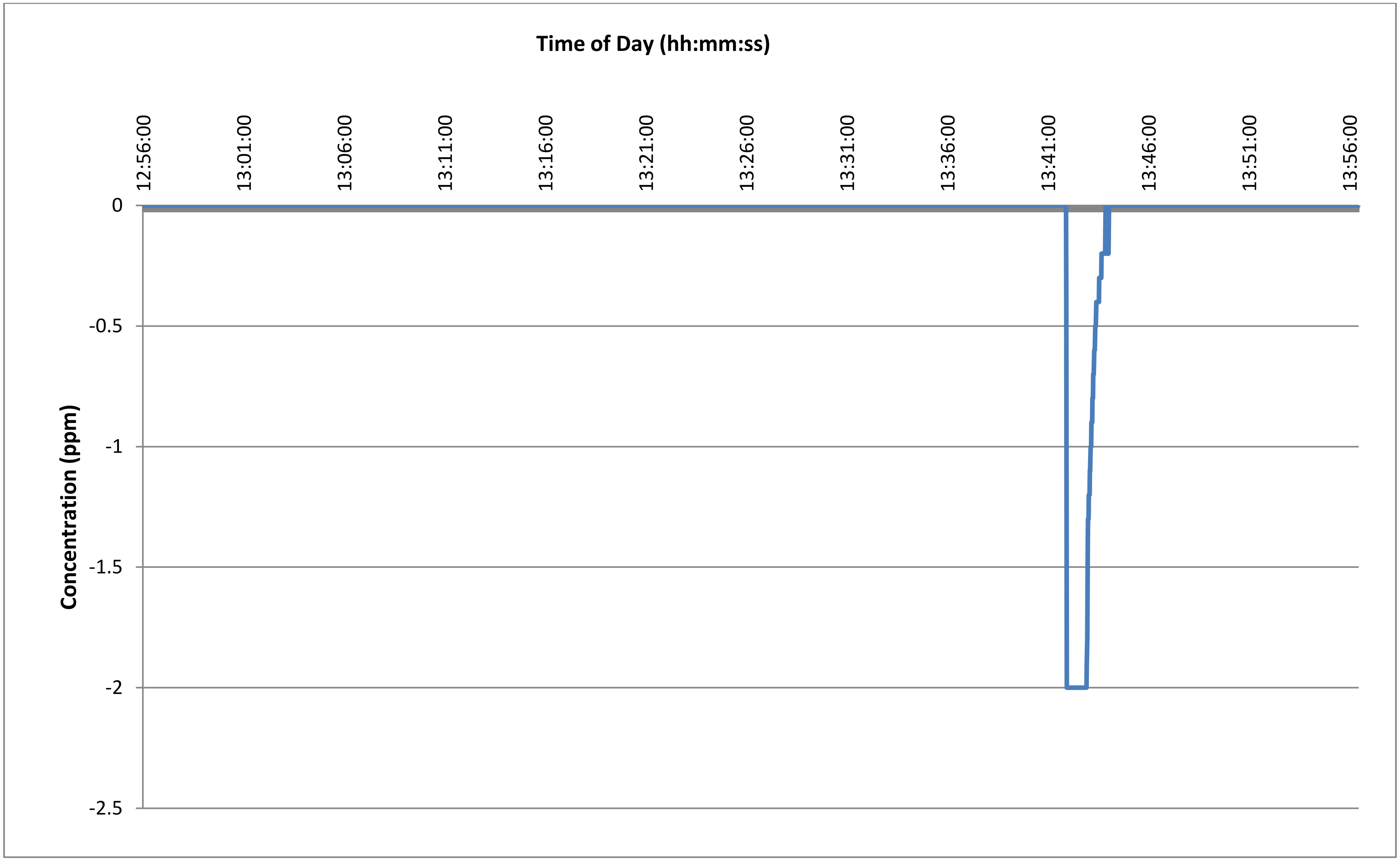
IOC Wabush 3

Project # 1400675

Figure No: A5

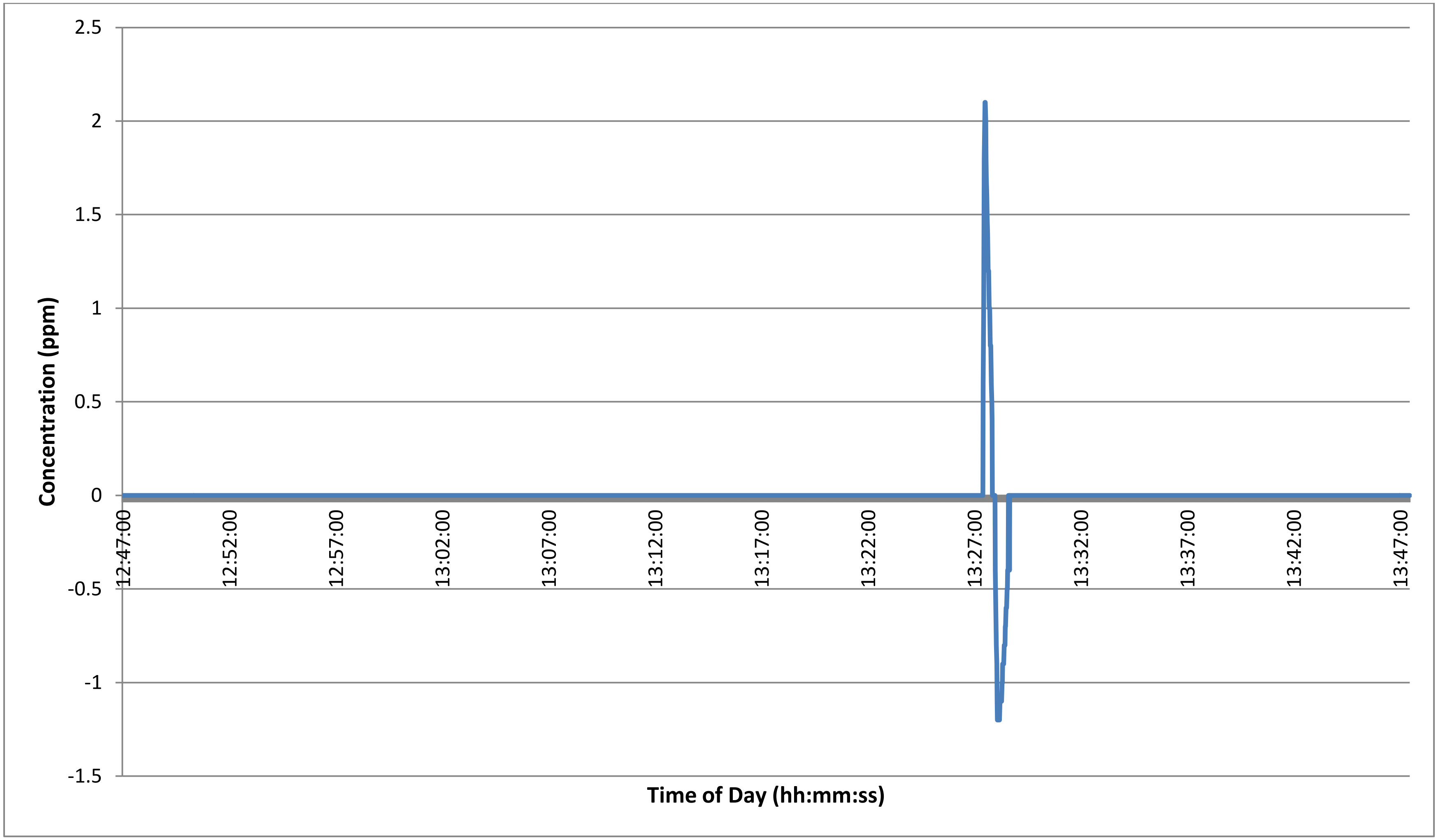
Date: April 14, 2014

RWDI

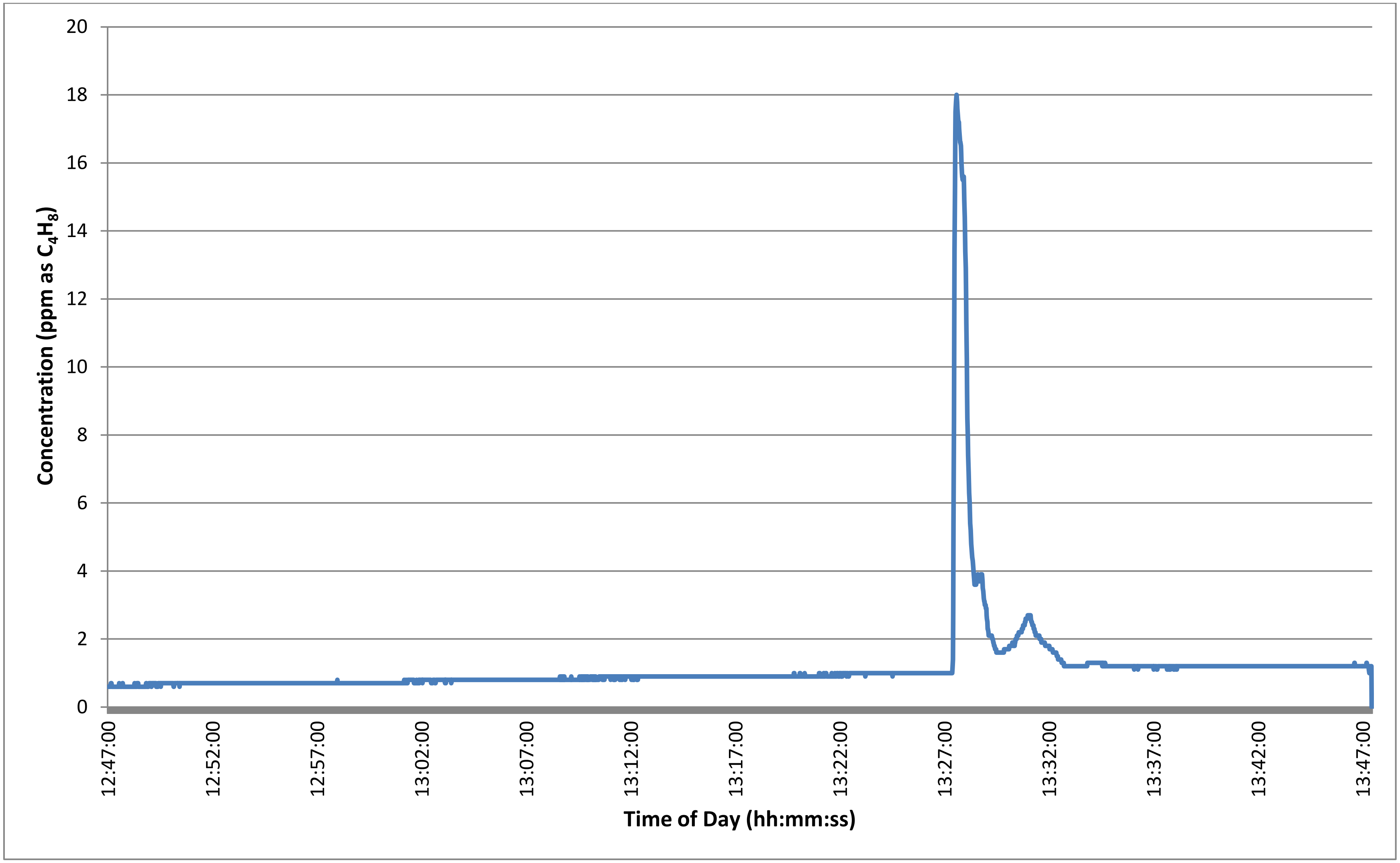


SO_2 (ppm) on February 28, 2014		Figure No: A6
IOC Wabush 3	Project # 1400675	Date: April 14, 2014

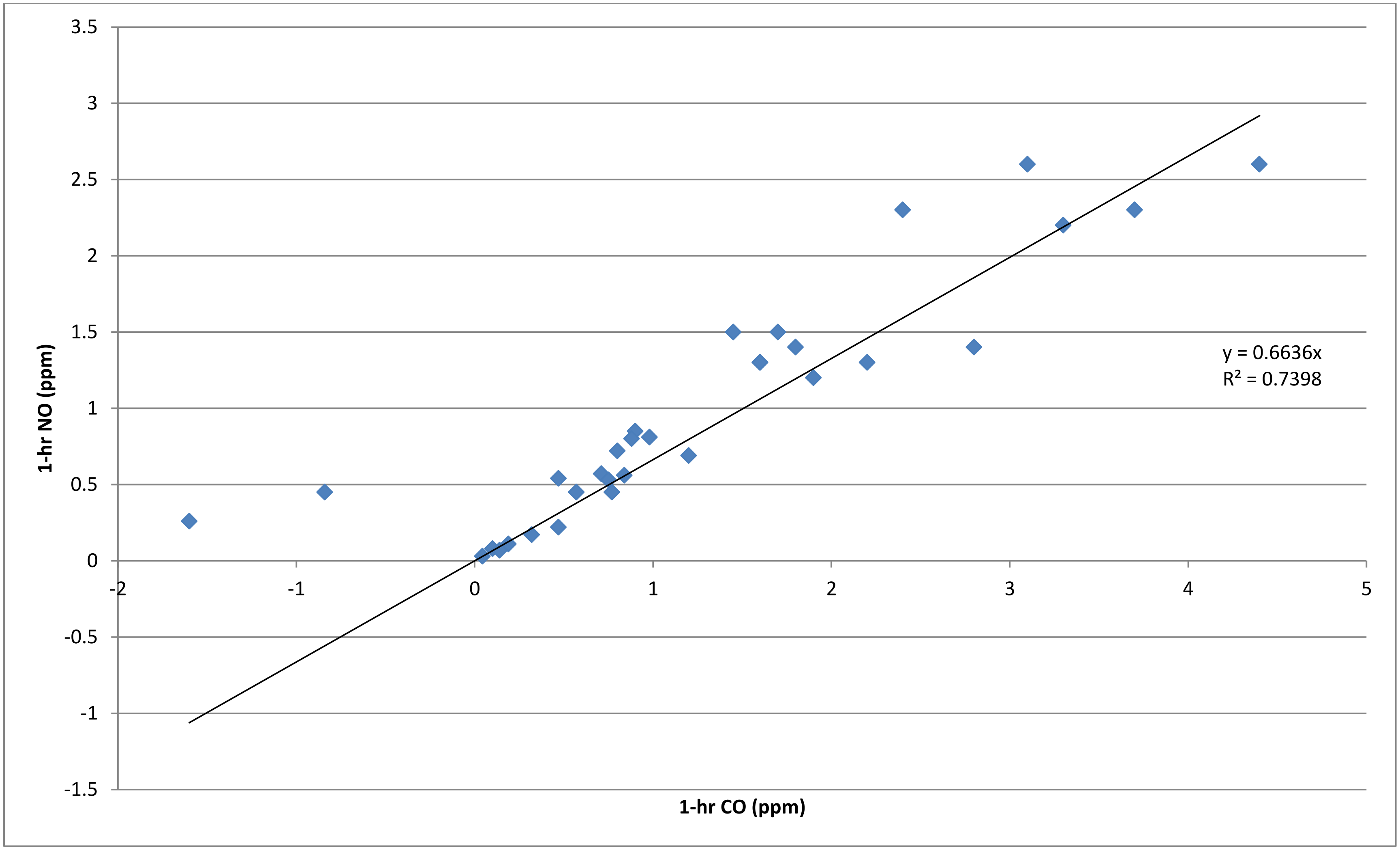
RWDI



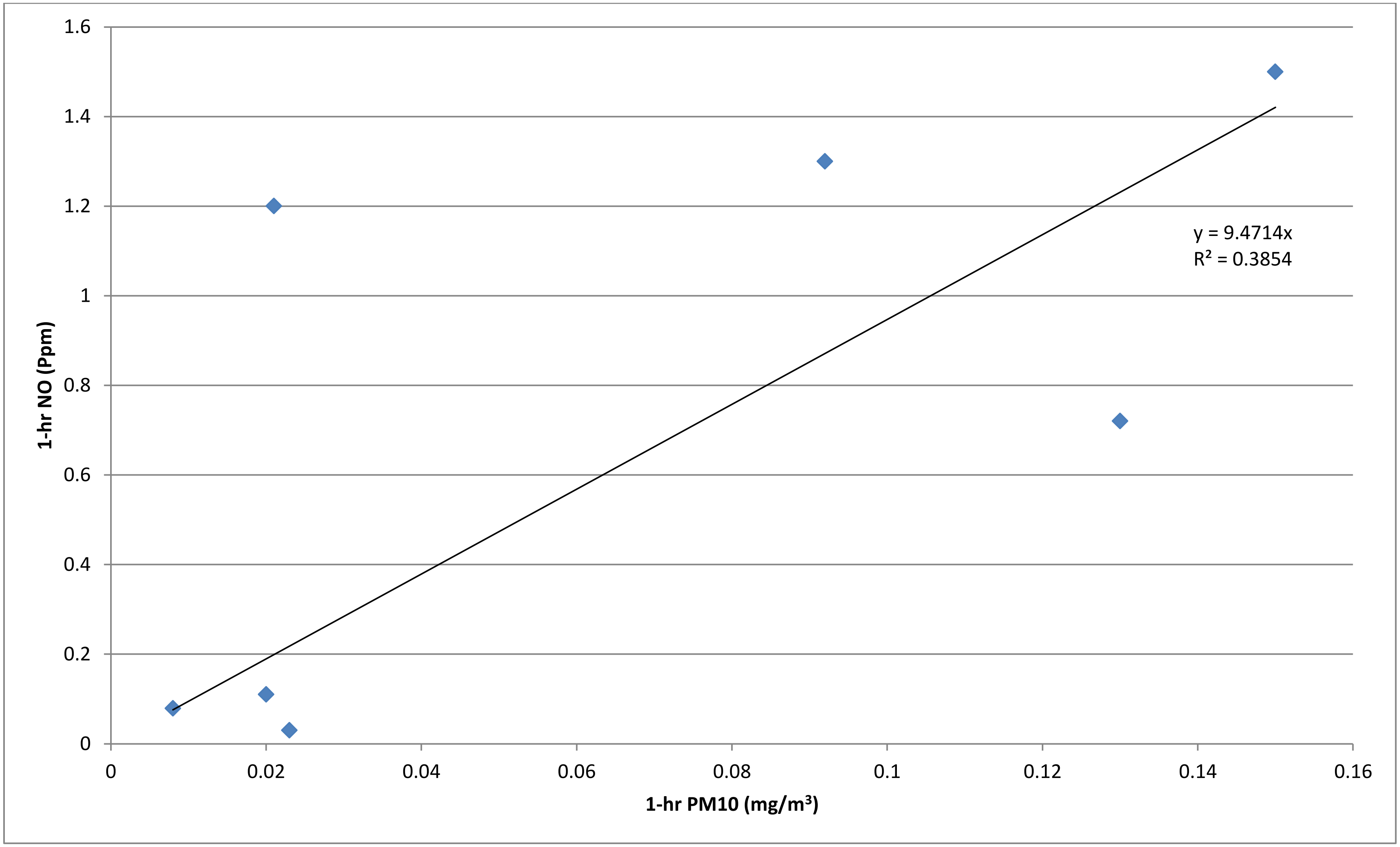
H_2S (ppm) on February 28, 2014 IOC Wabush 3 Project # 1400675	Figure No: A7 Date: April 14, 2014	RWDI



THC (ppm as C_4H_8) on February 28, 2014		Figure No: A8	RWDI
IOC Wabush 3	Project # 1400675	Date: April 14, 2014	



Correlation between NO and CO Levels during Blasts	Figure No: A9	RWDI
IOC Wabush 3 — Project # 1400675	Date: April 14, 2014	



Correlation between NO and PM_{10} Levels during Blasts	Figure No: A10	RWDI
IOC Wabush 3 — Project # 1400675	Date: April 14, 2014	

APPENDIX B

Appendix B1
Non Road Engine Compression Ignition
Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling - Compresion Ignition
US EPA 2004, Report No. NR-009c

SCENARIO:	IOC - Future Build Scenario (Haul Trucks)
Model Year:	2018

Equipment	Location	Number of Equipment	Rated Max HP [1]	Load Factor	Model Year [2]	Model Year For Emissions	Predicted Use by 2018 Hrs	Expected Lifespan Hrs	Fraction of Useful Life Expended [3]	Transient Adjustment Factors [4]					Fuel Sulfur (%) [5]	Conversion Total HC to TOG [6]
										BSFC	HC	CO	NOX	PM		
Komatsu 830E	Haul Road	1	2500	85%	2001	2001	69522	75000	93%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2005	2005	65913	75000	88%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2005	2005	65806	75000	88%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2005	2005	63351	75000	84%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2006	2006	58318	75000	78%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2006	2006	59084	75000	79%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2006	2006	52881	75000	71%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2006	2006	53620	75000	71%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2006	2006	49246	75000	66%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2006	2006	47962	75000	64%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2009	2009	44922	75000	60%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2009	2009	45241	75000	60%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2009	2009	45749	75000	61%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2010	2010	41006	75000	55%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2012	2012	42682	75000	57%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2012	2012	36417	75000	49%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2012	2012	37069	75000	49%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	35074	75000	47%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	33179	75000	44%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	34716	75000	46%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	31560	75000	42%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	32547	75000	43%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	31076	75000	41%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	30821	75000	41%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	31346	75000	42%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	28661	75000	38%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	27876	75000	37%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	27516	75000	37%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	26383	75000	35%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	26295	75000	35%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	25780	75000	34%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	23359	75000	31%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2014	2014	22886	75000	31%	1.00	1.00	1.00	1.00	1.00	0.002%	2.070
Komatsu 930E	Haul Road	1	2700	85%	2015	2015	17165	75000	23%	1.00	1.00	1.00	1.00	1.00	0.002%	3.070
Komatsu 930E	Haul Road	1	2700	85%	2016	2015	11443	75000	15%	1.00	1.00	1.00	1.00	1.00	0.002%	4.070
Komatsu 930E	Haul Road	1	2700	85%	2016	2015	15734	75000	21%	1.00	1.00	1.00	1.00	1.00	0.002%	5.070
Komatsu 930E	Haul Road	1	2700	85%	2016	2015	15734	75000	21%	1.00	1.00	1.00	1.00	1.00	0.002%	6.070
Komatsu 930E	Haul Road	1	2700	85%	2016	2015	12874	75000	17%	1.00	1.00	1.00	1.00	1.00	0.002%	7.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	11443	75000	15%	1.00	1.00	1.00	1.00	1.00	0.002%	8.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	10013	75000	13%	1.00	1.00	1.00	1.00	1.00	0.002%	9.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	10013	75000	13%	1.00	1.00	1.00	1.00	1.00	0.002%	10.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	14304	75000	19%	1.00	1.00	1.00	1.00	1.00	0.002%	11.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	12874	75000	17%	1.00	1.00	1.00	1.00	1.00	0.002%	12.070
Komatsu 930E	Haul Road	1	2700	85%	2018	2015	5722	75000	8%	1.00	1.00	1.00	1.00	1.00	0.002%	13.070
Komatsu 930E	Haul Road	1	2700	85%	2018	2015	4291	75000	6%	1.00	1.00	1.00	1.00	1.00	0.002%	14.070
Komatsu 930E	Haul Road	1	2700	85%	2018	2015	4291	75000	6%	1.00	1.00	1.00	1.00	1.00	0.002%	15.070

Notes:
1.Rated HP taken from equipment manufacturers spec sheets
2. Model year must be entered as four digits (i.e., 1996). Model year based on year equipment was fiirst put to use.
3. The Fractional Useful Life Expended is calculated as Predicted Use by 2018 (hours) / Expected Lifespan of equipment (hours).
4. The transient adjustment factor (TAF) accounts for varying emissions due to transient engine loads and speeds. TAFs are provided in Table A3.
5. Fuel Sulfur for nonroad diesel will likely follow US legislation (i.e., pre 2007- 5000 ppm, 2007 500 ppm, 2010 15 ppm)
6. Conversion of Total HC to TOG is provided for diesel nonroad equipment in US EPA's Conversion Factors for Hydrocarbon Emission Components.
7. Greenhouse gases CH_4 and N_2O are calculated from emission factors from the Environment Canada GHG Inventory, 2006. Assumes diesel density of 850 g/L.

Appendix B2

Non Road Engine Compression Ignition Spreadsheet
Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling - Compresion Ignition
US EPA 2004, Report No. NR-009c

SCENARIO:	IOC - Future No-Build Scenario (Haul Trucks
Model Year:	2018

Equipment	Location	Number of Equipment	Rated Max HP [1]	Load Factor	Model Year [2]	Model Year For Emissions	Predicted Use by 2018 Hrs	Expected Lifespan Hrs	Fraction of Useful Life Expended [3]	Transient Adjustment Factors[4] BSFC	HC	CO	NOX	PM	Fuel Sulfur (%) [5]	Conversion Total HC to TOG [6]
Komatsu 830E	Haul Road	1	2500	85%	2001	2001	69522	75000	93%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2005	2005	65913	75000	88%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2005	2005	65806	75000	88%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2005	2005	63351	75000	84%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2006	2006	58318	75000	78%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2006	2006	59084	75000	79%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2006	2006	52881	75000	71%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2006	2006	53620	75000	71%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2006	2006	49246	75000	66%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 830E	Haul Road	1	2500	85%	2006	2006	47962	75000	64%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2009	2009	44922	75000	60%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2009	2009	45241	75000	60%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2009	2009	45749	75000	61%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2010	2010	41006	75000	55%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2012	2012	42682	75000	57%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2012	2012	36417	75000	49%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2012	2012	37069	75000	49%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	35074	75000	47%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	33179	75000	44%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	34716	75000	46%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	31560	75000	42%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	32547	75000	43%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	31076	75000	41%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	30821	75000	41%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	31346	75000	42%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	28661	75000	38%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	27876	75000	37%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	27516	75000	37%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	26383	75000	35%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	26295	75000	35%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	25780	75000	34%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2013	2013	23359	75000	31%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2014	2014	22886	75000	31%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2015	2015	17165	75000	23%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2016	2015	11443	75000	15%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2016	2015	15734	75000	21%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2016	2015	15734	75000	21%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2016	2015	12874	75000	17%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	11443	75000	15%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	10013	75000	13%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	10013	75000	13%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	14304	75000	19%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	12874	75000	17%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2018	2015	5722	75000	8%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2018	2015	4291	75000	6%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2018	2015	4291	75000	6%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2016	2015	12874	75000	17%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	11443	75000	15%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	10013	75000	13%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	10013	75000	13%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	14304	75000	19%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Komatsu 930E	Haul Road	1	2700	85%	2017	2015	12874	75000	17%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070

Notes:

1.Rated HP taken from equipment manufacturers spec sheets
2. Model year must be entered as four digits (i.e., 1996). Model year based on year equipment was fiirst put to use.
3. The Fractional Useful Life Expended is calculated as Predicted Use by 2018 (hours) / Expected Lifespan of equipment (hours).
4. The transient adjustment factor (TAF) accounts for varying emissions due to transient engine loads and speeds. TAFs are provided in Table A3.
5. Fuel Sulfur for nonroad diesel will likely follow US legislation (i.e., pre 2007- 5000 ppm, 2007 500 ppm, 2010 15 ppm)
6. Conversion of Total HC to TOG is provided for diesel nonroad equipment in US EPA's Conversion Factors for Hydrocarbon Emission Components.
7. Greenhouse gases CH_4 and N_2O are calculated from emission factors from the Environment Canada GHG Inventory, 2006. Assumes diesel density of 850 g/L.

Appendix B3

Non Road Engine Compression Ignition Spreadsheet

Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling - Compresion Ignition

US EPA 2004, Report No. NR-009c

SCENARIO:	**IOC - Future Build Scenario (loaders and shovels)**
Model Year:	2018

Equipment	Location	Number of Equipment	Rated Max HP [1]	Load Factor	Model Year [2]	Model Year For Emissions	Predicted Use by 2018 Hrs	Expected Lifespan Hrs	Fraction of Useful Life Expended [3]	Transient Adjustment Factors [4] BSFC	HC	CO	NOX	PM	Fuel Sulfur (%) [5]	Conversion Total HC to TOG [6]
LeTourneau L1850	Stockpile	1	2000	50%	2005	2005	47999	45000	100%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
LeTourneau L1850	Stockpile	1	2000	50%	2007	2007	41425	45000	92%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
P&H 2800XPB	Mine Pit	1	Electric													
P&H 2800XPB	Mine Pit	1	Electric													
P&H 2800XPB	Mine Pit	1	Electric													
P&H 2800XPB	Mine Pit	1	Electric													
P&H 2800XPB	Mine Pit	1	Electric													
Komatsu PC5500	Mine Pit	1	2520	54%	2015	2015	17450	90000	19%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
P&H 2800XPB	Mine Pit	1	Electric													
P&H 2800XPB	Mine Pit	1	Electric													

Notes:

1.Rated HP taken from equipment manufacturers spec sheets

2. Model year must be entered as four digits (i.e., 1996). Model year based on year equipment was fiirst put to use.

3. The Fractional Useful Life Expended is calculated as Predicted Use by 2018 (hours) / Expected Lifespan of equipment (hours).

4. The transient adjustment factor (TAF) accounts for varying emissions due to transient engine loads and speeds. TAFs are provided in Table A3.

5. Fuel Sulfur for nonroad diesel will likely follow US legislation (i.e., pre 2007- 5000 ppm, 2007 500 ppm, 2010 15 ppm)

6. Conversion of Total HC to TOG is provided for diesel nonroad equipment in US EPA's Conversion Factors for Hydrocarbon Emission Components.

7. Greenhouse gases CH_4 and N_2O are calculated from emission factors from the Environment Canada GHG Inventory, 2006. Assumes diesel density of 850 g/L.

Appendix B4

Non Road Engine Compression Ignition Spreadsheet

Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling - Compresion Ignition

US EPA 2004, Report No. NR-009c

SCENARIO: **IOC - Future Build Scenario (loaders and shovels)**

Model Year: 2018

Equipment	Location	Number of Equipment	Rated Max HP [1]	Load Factor	Model Year [2]	Model Year For Emissions	Predicted Use by 2018 Hrs	Expected Lifespan Hrs	Fraction of Useful Life Expended [3]	Transient Adjustment Factors [4] BSFC	HC	CO	NOX	PM	Fuel Sulfur (%) [5]	Conversion Total HC to TOG [6]
LeTourneau L1850	Stockpile	1	2000	50%	2005	2005	47999	45000	100%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
LeTourneau L1850	Stockpile	1	2000	50%	2007	2007	41425	45000	92%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
P&H 2800XPB	Mine Pit	1	Electric													
P&H 2800XPB	Mine Pit	1	Electric													
P&H 2800XPB	Mine Pit	1	Electric													
P&H 2800XPB	Mine Pit	1	Electric													
P&H 2800XPB	Mine Pit	1	Electric													
Komatsu PC5500	Mine Pit	1	2520	54%	2015	2015	17450	90000	19%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
P&H 2800XPB	Mine Pit	1	Electric													
P&H 2800XPB	Mine Pit	1	Electric													
P&H 2800XPB	Mine Pit	1	Electric													

Notes:

1.Rated HP taken from equipment manufacturers spec sheets

2. Model year must be entered as four digits (i.e., 1996). Model year based on year equipment was fiirst put to use.

3. The Fractional Useful Life Expended is calculated as Predicted Use by 2018 (hours) / Expected Lifespan of equipment (hours).

4. The transient adjustment factor (TAF) accounts for varying emissions due to transient engine loads and speeds. TAFs are provided in Table A3.

5. Fuel Sulfur for nonroad diesel will likely follow US legislation (i.e., pre 2007- 5000 ppm, 2007 500 ppm, 2010 15 ppm)

6. Conversion of Total HC to TOG is provided for diesel nonroad equipment in US EPA's Conversion Factors for Hydrocarbon Emission Components.

7. Greenhouse gases CH_4 and N_2O are calculated from emission factors from the Environment Canada GHG Inventory, 2006. Assumes diesel density of 850 g/L.

Appendix B5
Non Road Engine Compression Ignition Spreadsheet
Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling - Compresion Ignition
US EPA 2004, Report No. NR-009c

SCENARIO: IOC - Dozers (Future Build and Future No Build)
Model Year: 2018

Equipment	Location	Number of Equipment	Rated Max HP [1]	Load Factor	Model Year [2]	Model Year For Emissions	Predicted Use by 2018 Hrs	Expected Lifespan Hrs	Fraction of Useful Life Expended [3]	Transient Adjustment Factors [4]					Fuel Sulfur (%) [5]	Conversion Total HC to TOG [6]
										BSFC	HC	CO	NOX	PM		
CAT 844H	Near shovels and waste dumps	1	687	75%	2009	2009	43562	45000	97%	1.01	1.05	1.53	1.04	1.47	0.002%	1.070
CAT 844H	Near shovels and waste dumps	1	687	75%	2009	2009	43440	45000	97%	1.01	1.05	1.53	1.04	1.47	0.002%	1.070
CAT 844H	Near shovels and waste dumps	1	687	75%	2012	2012	27120	45000	60%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
CAT 844H	Near shovels and waste dumps	1	687	75%	2012	2012	27120	45000	60%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
CAT 844H	Near shovels and waste dumps	1	687	75%	2016	2015	7884	45000	18%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
CAT D11R	Near shovels and waste dumps	1	915	75%	2009	2009	47616	55000	87%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
CAT D11T	Near shovels and waste dumps	1	935	75%	2009	2009	46183	55000	84%	1.01	1.05	1.53	0.95	1.23	0.002%	1.070
CAT D10T	Near shovels and waste dumps	1	646	75%	2011	2011	34373	55000	62%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
CAT D10T	Near shovels and waste dumps	1	646	75%	2012	2012	29421	55000	53%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
CAT D10T	Near shovels and waste dumps	1	646	75%	2012	2012	28354	55000	52%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
CAT D10T	Near shovels and waste dumps	1	646	75%	2013	2013	22883	55000	42%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
CAT D10T	Near shovels and waste dumps	1	646	75%	2014	2014	18396	55000	33%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
CAT D10T	Near shovels and waste dumps	1	646	75%	2014	2014	18396	55000	33%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
CAT D10T	Near shovels and waste dumps	1	646	75%	2015	2015	13140	55000	24%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070

Notes:
1.Rated HP taken from equipment manufacturers spec sheets
2. Model year must be entered as four digits (i.e., 1996). Model year based on year equipment was fiirst put to use.
3. The Fractional Useful Life Expended is calculated as Predicted Use by 2018 (hours) / Expected Lifespan of equipment (hours).
4. The transient adjustment factor (TAF) accounts for varying emissions due to transient engine loads and speeds. TAFs are provided in Table A3.
5. Fuel Sulfur for nonroad diesel will likely follow US legislation (i.e., pre 2007- 5000 ppm, 2007 500 ppm, 2010 15 ppm)
6. Conversion of Total HC to TOG is provided for diesel nonroad equipment in US EPA's Conversion Factors for Hydrocarbon Emission Components.
7. Greenhouse gases CH_4 and N_2O are calculated from emission factors from the Environment Canada GHG Inventory, 2006. Assumes diesel density of 850 g/L.

Appendix B6
Non Road Engine Compression Ignition Spreadsheet
Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling - Compresion Ignition
US EPA 2004, Report No. NR-009c

SCENARIO:	IOC - Drills (Future Build and Future No Build)
Model Year:	2018

Equipment	Location	Number of Equipment	Rated Max HP [1]	Load Factor	Model Year [2]	Model Year For Emissions	Predicted Use by 2018 Hrs	Expected Lifespan Hrs	Fraction of Useful Life Expended [3]	Transient Adjustment Factors [4] BSFC	HC	CO	NOX	PM	Fuel Sulfur (%) [5]	Conversion Total HC to TOG [6]
P&H 120A	Mining Area	1	Electric													
P&H 320XPC	Mining Area	1	Electric													
P&H 320XPC	Mining Area	1	Electric													
P&H 320XPC	Mining Area	1	Electric													
P&H 320XPC	Mining Area	1	Electric													
P&H 320XPC	Mining Area	1	Electric													
P&H 320XPC	Mining Area	1	Electric													
P&H 320XPC	Mining Area	1	Electric													
P&H 320XPC	Mining Area	1	Electric													
P&H 320XPC	Mining Area	1	Electric													
Atlas Copco PV271	Mining Area	1	755	75%	2014	2014	22629	30000	75%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Atlas Copco PV272	Mining Area	1	755	75%	2014	2014	18103	30000	60%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Atlas Copco PV273	Mining Area	1	755	75%	2015	2015	16595	30000	55%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Atlas Copco PV273	Mining Area	1	755	75%	2016	2015	10560	30000	35%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Atlas Copco PV273	Mining Area	1	755	75%	2016	2015	13577	30000	45%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
Atlas Copco PV273	Mining Area	1	755	75%	2017	2015	4526	30000	15%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
P&H 320XPC	Mining Area	1	Electric													

Notes:
1.Rated HP taken from equipment manufacturers spec sheets
2. Model year must be entered as four digits (i.e., 1996). Model year based on year equipment was fiirst put to use and are assumed to be new equipment.
3. The Fractional Useful Life Expended is calculated as Predicted Use by 2018 (hours) / Expected Lifespan of equipment (hours).
4. The transient adjustment factor (TAF) accounts for varying emissions due to transient engine loads and speeds. TAFs are provided in Table A3.
5. Fuel Sulfur for nonroad diesel will likely follow US legislation (i.e., pre 2007- 5000 ppm, 2007 500 ppm, 2010 15 ppm)
6. Conversion of Total HC to TOG is provided for diesel nonroad equipment in US EPA's Conversion Factors for Hydrocarbon Emission Components.
7. Greenhouse gases CH_4 and N_2O are calculated from emission factors from the Environment Canada GHG Inventory, 2006. Assumes diesel density of 850 g/L.

Appendix B7
Non Road Engine Compression Ignition Spreadsheet
Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling - Compresion Ignition
US EPA 2004, Report No. NR-009c

SCENARIO: **IOC - Graders (Future Build and Future No Build)**
Model Year: 2018

Equipment	Location	Number of Equipment	Rated Max HP [1]	Load Factor	Model Year [2]	Model Year For Emissions	Predicted Use by 2018 Hrs	Expected Lifespan Hrs	Fraction of Useful Life Expended [3]	Transient Adjustment Factors [4] BSFC	HC	CO	NOX	PM	Fuel Sulfur (%) [5]	Conversion Total HC to TOG [6]
CAT 16M	Haul Road	1	312	80%	2009	2009	49871	60000	83%	1.01	1.05	1.53	1.04	1.47	0.002%	1.070
CAT 16M	Haul Road	1	312	80%	2009	2009	49520	60000	83%	1.01	1.05	1.53	1.04	1.47	0.002%	1.070
CAT 16M	Haul Road	1	312	80%	2009	2009	48850	60000	81%	1.01	1.05	1.53	1.04	1.47	0.002%	1.070
CAT 16M	Haul Road	1	312	80%	2009	2009	48850	60000	81%	1.01	1.05	1.53	1.04	1.47	0.002%	1.070
CAT 16M	Haul Road	1	312	80%	2011	2011	35561	60000	59%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
CAT 16H	Haul Road	1	285	80%	2006	2006	65597	60000	100%	1.01	1.05	1.53	1.04	1.47	0.002%	1.070
CAT 16M	Haul Road	1	312	80%	2013	2013	23828	60000	40%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
CAT 16M	Haul Road	1	312	80%	2016	2015	8410	60000	14%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070
CAT 16M	Haul Road	1	312	80%	2017	2015	4205	60000	7%	1.00	1.00	1.00	1.00	1.00	0.002%	1.070

Notes:
1.Rated HP taken from equipment manufacturers spec sheets
2. Model year must be entered as four digits (i.e., 1996). Model year based on year equipment was fiirst put to use.
3. The Fractional Useful Life Expended is calculated as Predicted Use by 2018 (hours) / Expected Lifespan of equipment (hours).
4. The transient adjustment factor (TAF) accounts for varying emissions due to transient engine loads and speeds. TAFs are provided in Table A3.
5. Fuel Sulfur for nonroad diesel will likely follow US legislation (i.e., pre 2007- 5000 ppm, 2007 500 ppm, 2010 15 ppm)
6. Conversion of Total HC to TOG is provided for diesel nonroad equipment in US EPA's Conversion Factors for Hydrocarbon Emission Components.
7. Greenhouse gases CH_4 and N_2O are calculated from emission factors from the Environment Canada GHG Inventory, 2006. Assumes diesel density of 850 g/L.